Proceedings of the Fifth ENIGMA Meeting

Neubrandenburg, Germany - June 13-17, 2005

The 5th ENIGMA meeting was organized by Heidelberg team of Stefan Wagner

The European Network for the Investigation of Galactic nuclei through Multifrequency Analysis (ENIGMA) is a Research Training Network funded within the FP5 program of the European Community

Network Coordinator: Stefan J. Wagner

5th ENIGMA MEETING

13-17th June, 2005 – Bornmuehle (Germany)

Final program

MONDAY, 13th June	
Time	**Activity**
14:00-14:10	Welcome by J. Heidt (OC)
14:10-14:15	Welcome by S. Wagner
14:15-14:35	Discussion: Meetings and schools structuring
14:35-16:35	Workshop 1: OJ 287 (S. Ciprini)
16:35-17:05	***Coffee break***
17:05-19:05	Workshop 2: Time Series analysis (D. Emmanoulopoulos)

TUESDAY, 14th June		
Time *	**Speaker**	**Talk**
9:15 – 9:30	S. Wagner	Scientific program
9:30 – 9:40	A. Papageorgiou	Introduction to task 1 *(Task 1)*
9:40 – 10:05	E. Angelakis	Elimination of foreground sources in the CBI fields: status report *(Task 2)*
10:05 – 10:30	D. Emmanoulopoulos	Time series analysis of MKN 421 *(Task 2,4)*
10:30 – 10:50	L. Takalo	Introduction of task 3 *(Task 3)*
10:50 – 11:20		***Coffee break***
11:20 – 11:45	S. Wagner	Blazar astrophysics with H.E.S.S. *(Task 3)*
11:45 – 12:10	E. Ferrero	X-ray properties of GPS/CSS sources *(Task 3)*
12:10 – 12:35	M. Tröller	Host galaxies of CSS radio sources *(Task 2,4)*
12:35 – 14:00		***Lunch break***
14:00 – 14:25	L. Fuhrmann	Multi-frequency study of SWIFT blazars *(Task 3)*
14:25 – 14:50	L. Ostorero	INTEGRAL-multifrequency observations of S5 0716+714: first results of the core campaign *(Task 3)*
14:50 – 15:15	T. Krichbaum	Revised analysis of Effelsberg data on 0716 during November *(Task 4)*
15:15 – 15:40	I. Agudo	Polarimetric cm to mm behaviour of 0716+714 during the core campaign: VLBA and IRAM 30 m results *(Task 4,2)*
15:40 – 16:10		***Coffee break***
16:10 – 16:30	J. Heidt	OJ 287 - not variability related data
16:30 – 16:50	K. Nilsson	The next outburst of OJ 287 *(Task 4)*
16:50 – 17:15	S. Ciprini	Optical observations of PKS 0735+178, PKS 2155-304 and OJ 287 *(Task 4)*
17:15 – 17:40	A. Papageorgiou	Global VLBI polarization observations of radio-intermediate galaxies *(Task 4)*
17:40 – 18:05	V. Bezrukovs	High-frequency, multi-wavelength VLBI observations of BL Lac objects *(Task 4)*

* Time includes 5 min. for questions

WEDNESDAY, 15th June		
Time *	**Speaker**	**Talk**
9:30 – 9:55	J. Gracia	Modelling the jet of M87 *(Task 5)*
9:55 – 10:20	K. Katarzynski	Particle acceleration and synchrotron self-Compton radiation in Tev blazars *(Task 6)*
10:20 – 10:45	B. Sbarufatti	BL Lac spectroscopy with ESO-VLT 2: the complete sample and redshift lower limits
10:45 – 11:15		***Coffee break***
11:15 – 11:40	J. Heidt	Radio-silent blazars
11:40 – 14:00		***Lunch break***
14:00 – 18:00	Team leaders and young researchers sessions (in parallel)	

* Time includes 5 min. for questions

THURSDAY, 16th June	
Time	**Activity**
8:30-10:30	Workshop 3: TeV results
10:30-11:00	***Coffee break***
11:00-11:45	Workshop 4: S5 0716+714
12:00-19:00	*Lunch and excursion to the Tokamak facility in Greifswald*
19:00-20:00	Workshop 4: S5 0716+714 *(cont.)*

FRIDAY, 17th June	
Time	
8:00 – 13:00	*Excursion to BESSY:* *Berlin electron storage ring company* *for synchrotron radiation* *http://www.bessy.de*

Emmanouil Angelakis
Under the supervision of A. Kraus

Elimination of Foreground Sources in the Cosmic Background Imager fields and more …

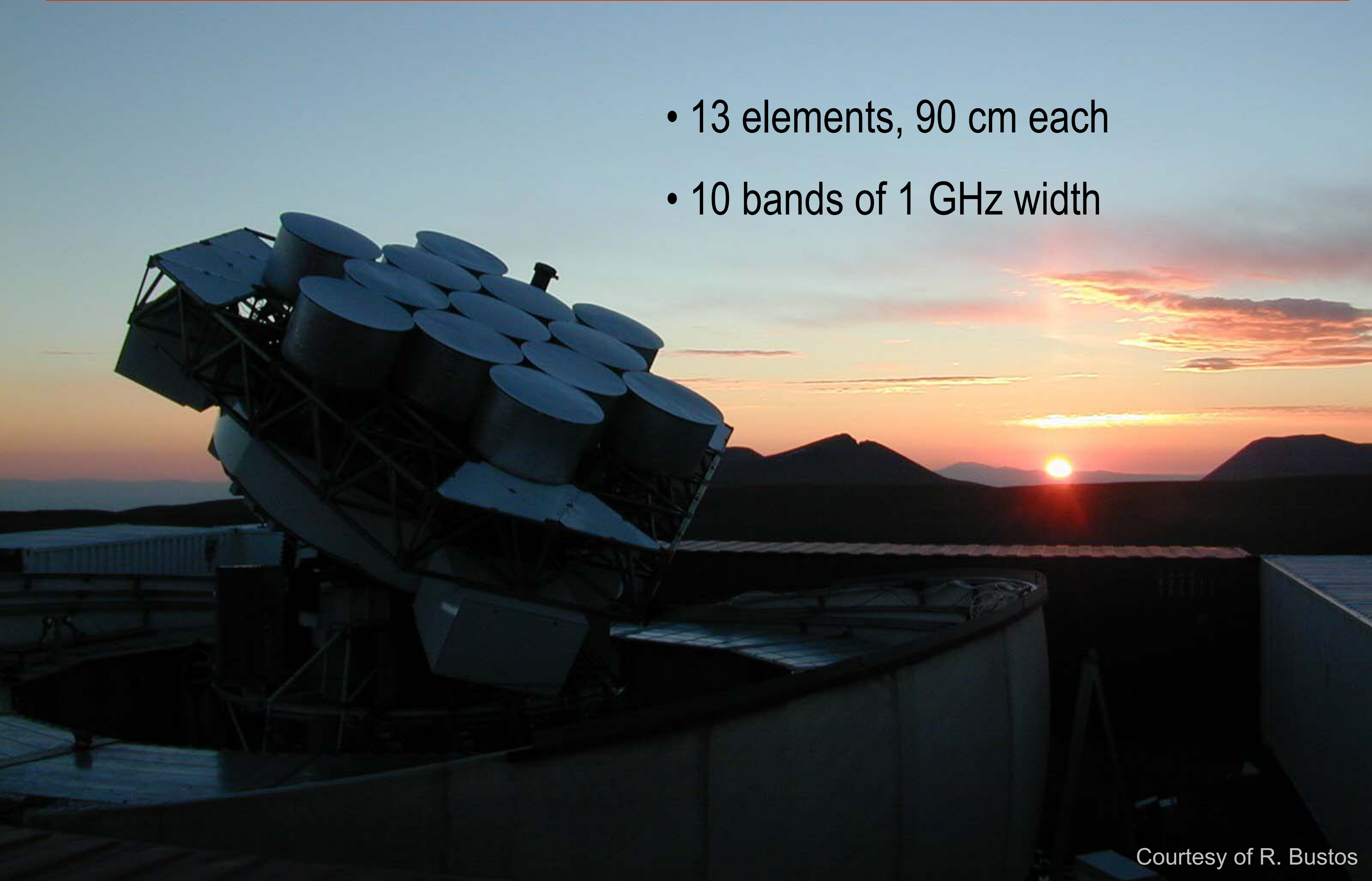
In collaboration with:
MPIfR: A. Kraus , T. Krichbaum, A. Witzel, A. Zensus
CALTECH: A. Readhead, T. Pearson, R. Bustos, R. Reeves

Max-Planck-Institut für Radioastronomie

ENIGMA RTN

Cosmic Background Imager

- 13 elements, 90 cm each
- 10 bands of 1 GHz width



Courtesy of R. Bustos

Cosmic Background Imager

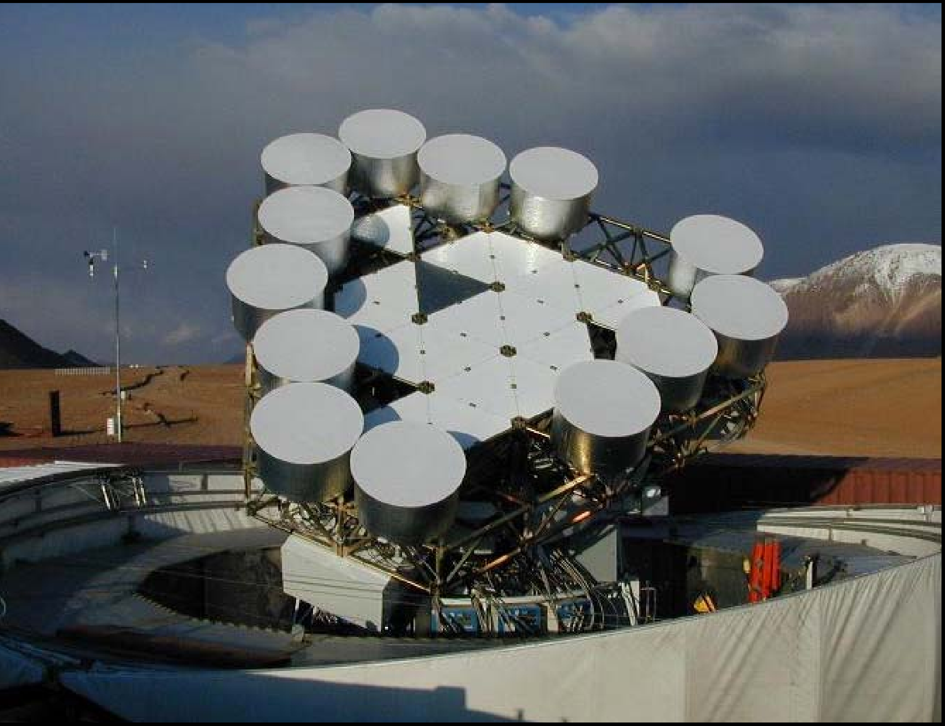
Courtesy of R. Bustos

Located in the Atacama desert at an altitude of 5080 m

Cosmic Background Imager

Open (Total intensity) 2000-2001

Compact (Polarization) 2002-2004



Longer baselines

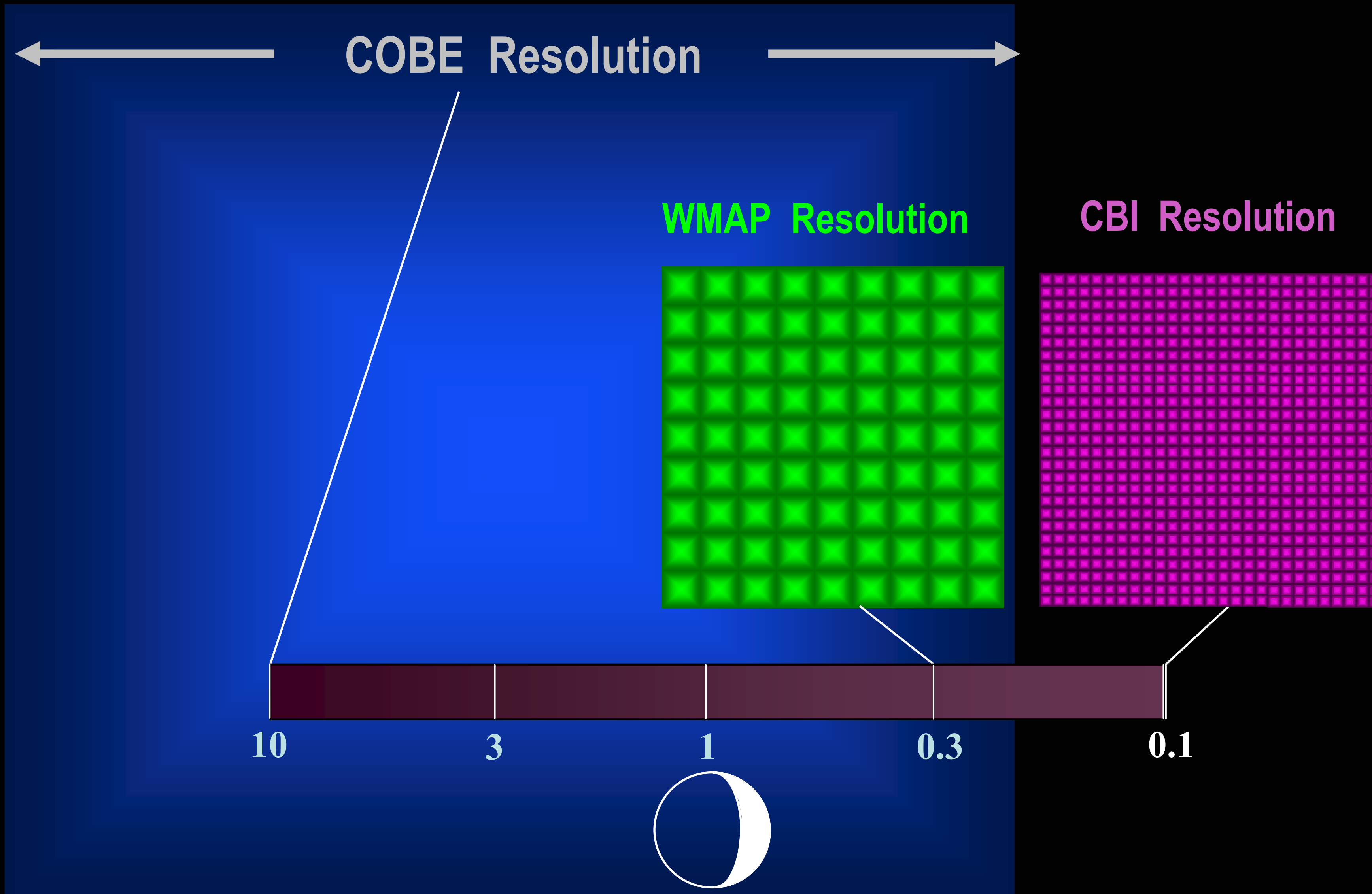
Shorter baselines

Angular scales 5' – 1°

Cosmic Background Imager

Detection of CMB polarization

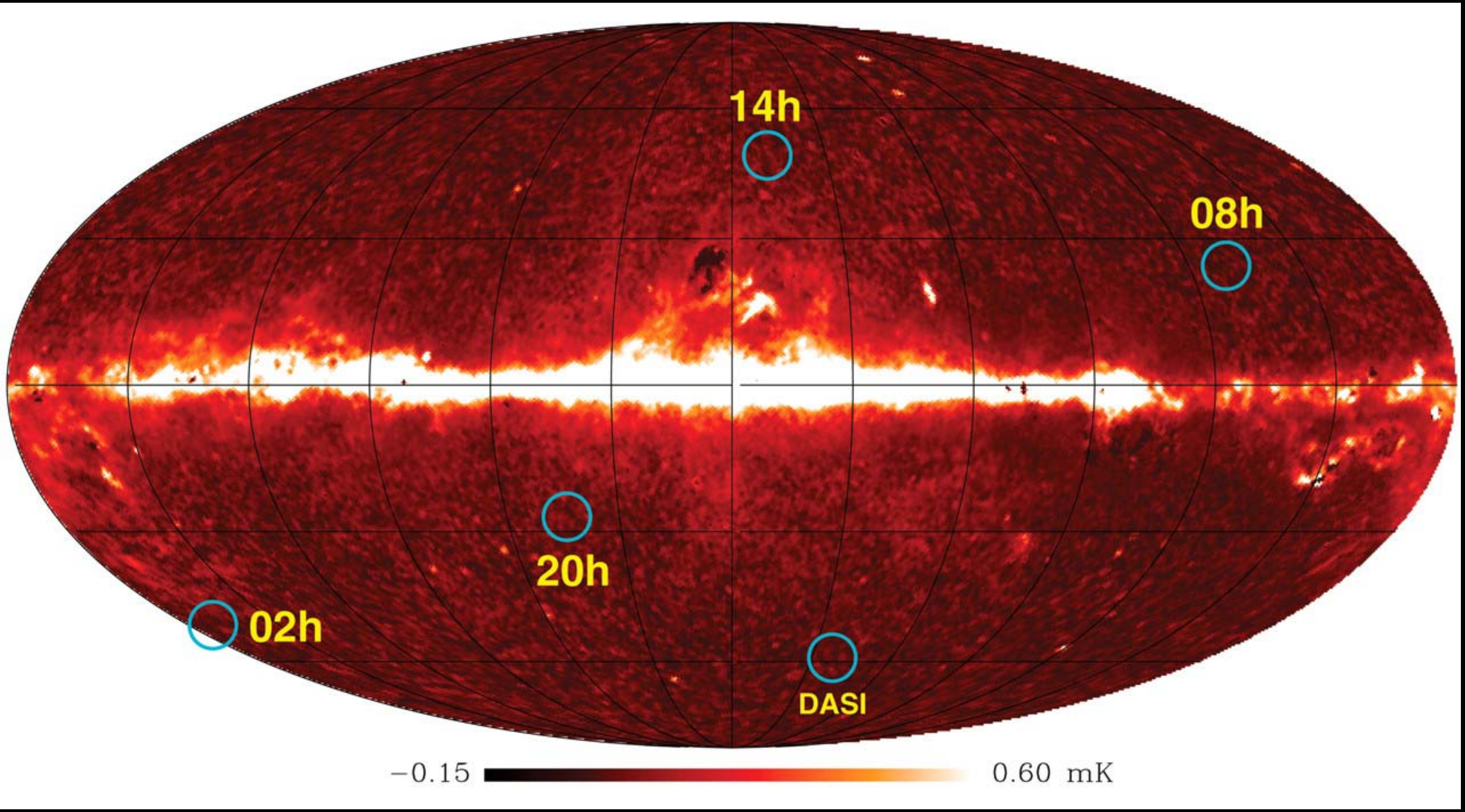
Cosmic Background Imager



Angular size on the sky in Moon diameters

Courtesy of R. Bustos

Cosmic Background Imager

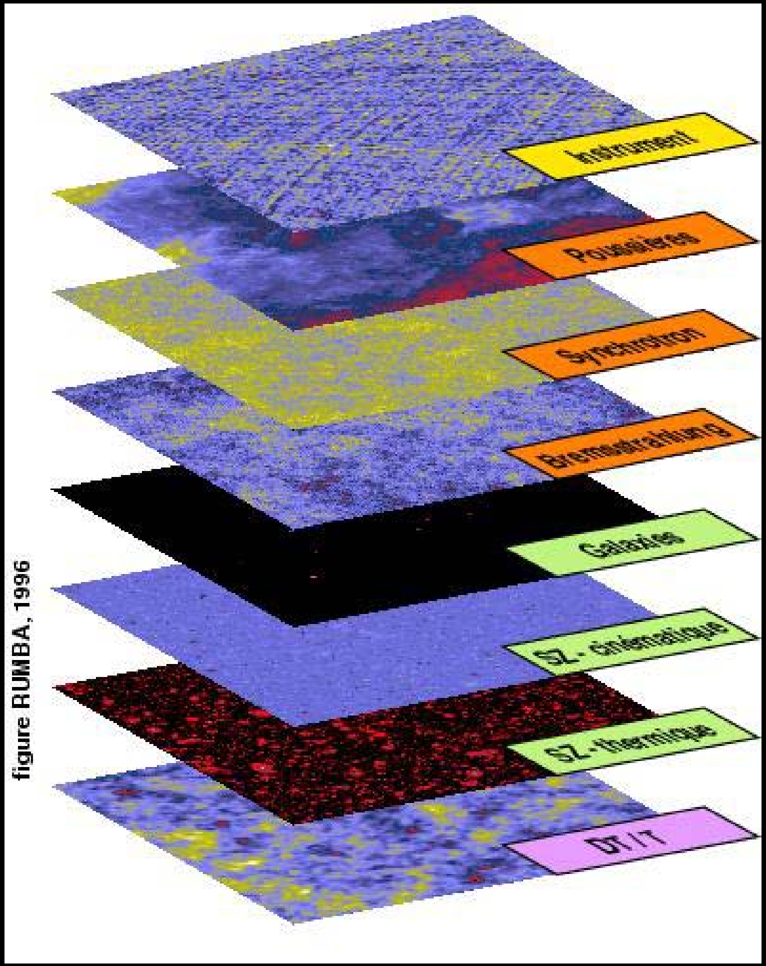


Synchrotron map Ka band from WMAP

Observes the anisotropies in the CMB at 4 “windows” in the sky covering ~125 deg^2

The problem

Foregrounds – Contamination



Cosmological factors:
CMB Kinetic/Thermal SZ effect, CIB

Galactic factors:
Thermal Dust, Free-free, Synchrotron, Spinning dust emission

Compact Sources:
Radio sources, Infrared sources

The problem

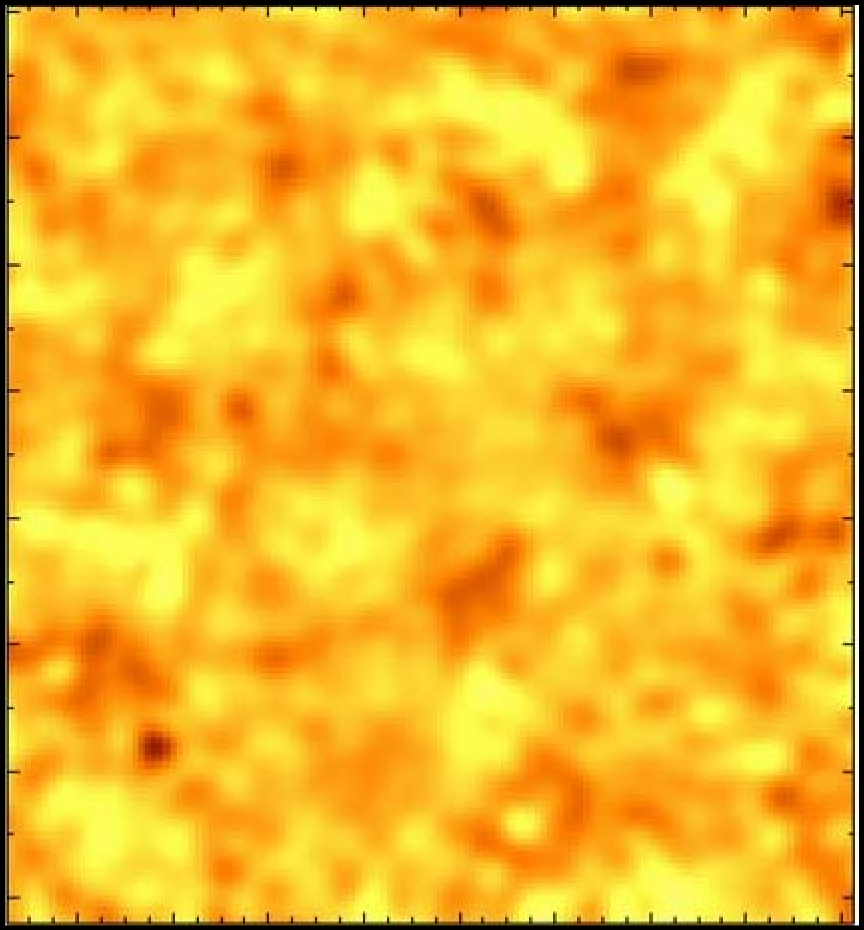
A Fact:

From the NRAO VLA SKY SURVEY (NVSS) catalogue at 1.4 GHz we know that there are 6000 point radio sources brighter than 2.5 mJy in the CBI fields probably causing severe contamination

The problem

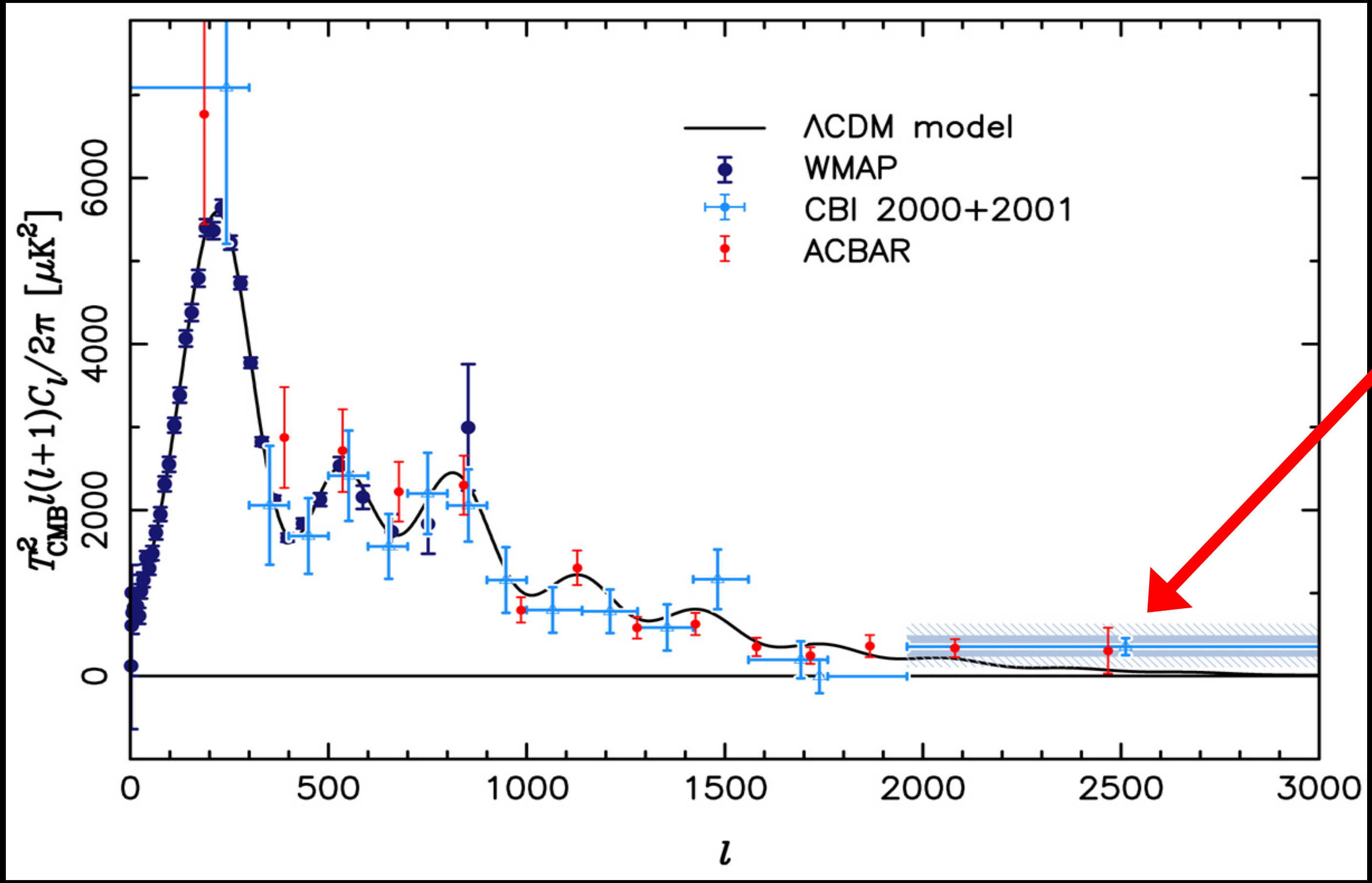
A necessary compromise: throw away data ⇔ losses of information

02h CBI field with NO point sources



The problem

A necessary compromise: throw away data ⇔ losses of information



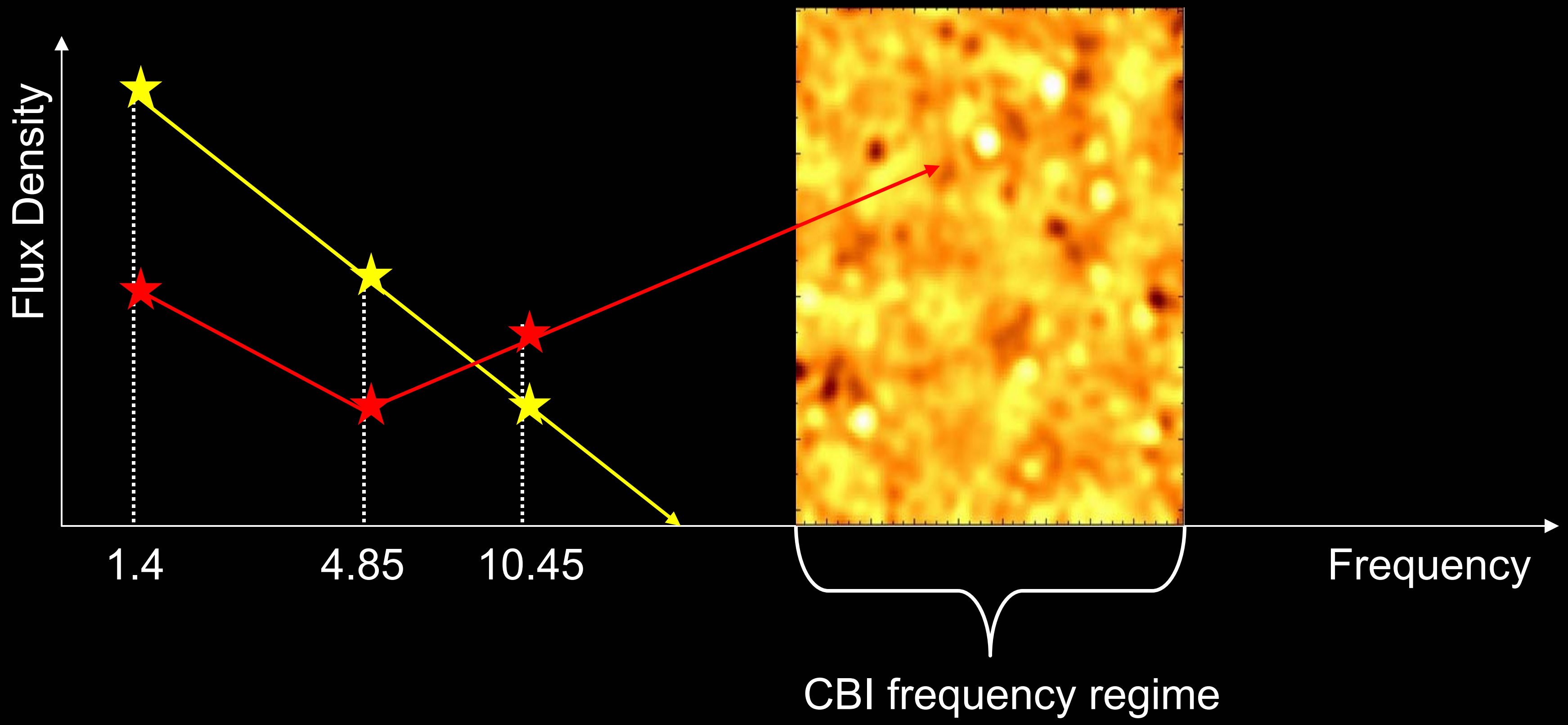
excess at high-ℓ

Is this real?

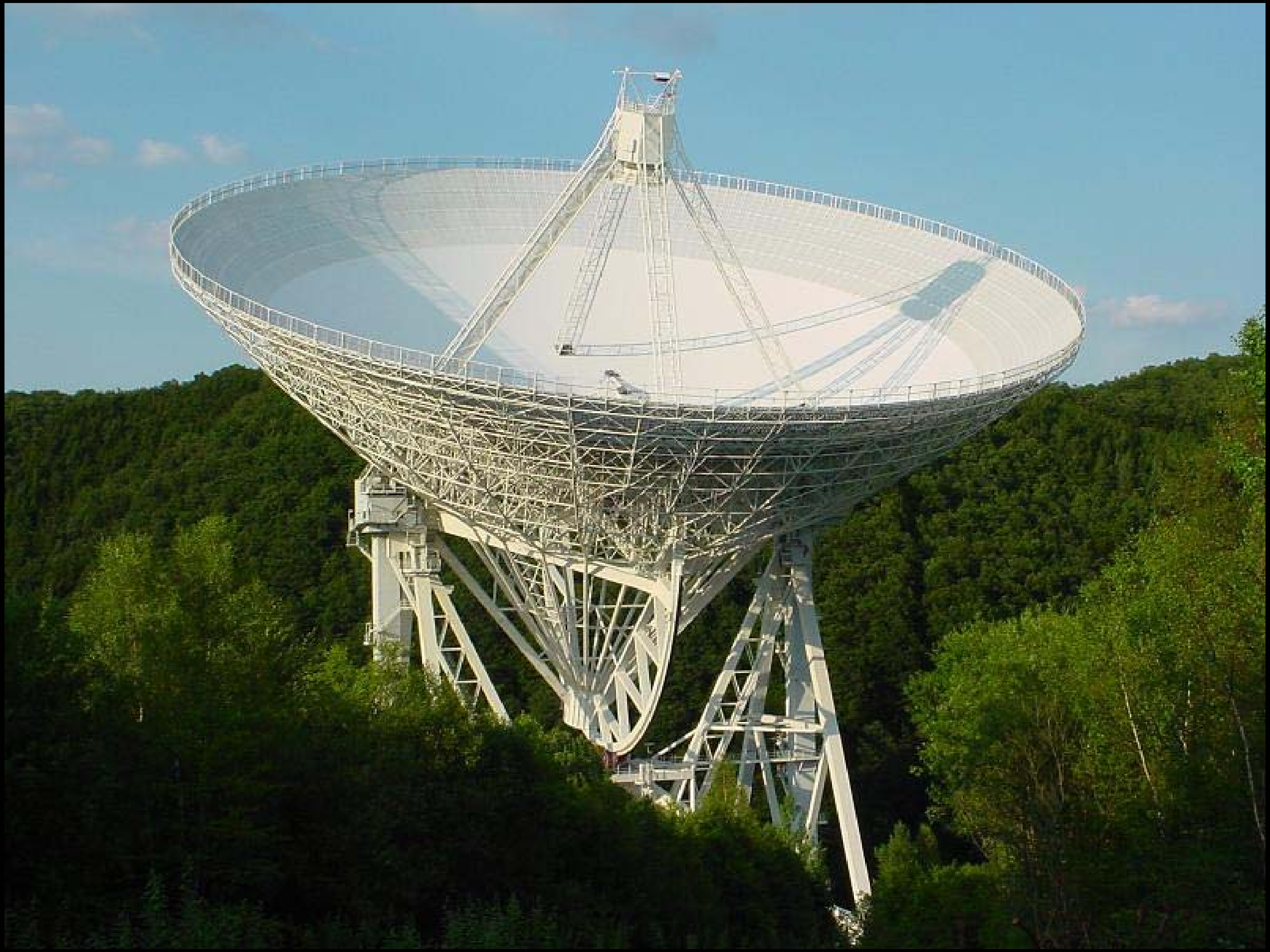
The Solution

Estimate the spectral behavior of the point source (6000):

- ► extract their strength in the frequency range CBI
- ► exclude only those that really cause contamination

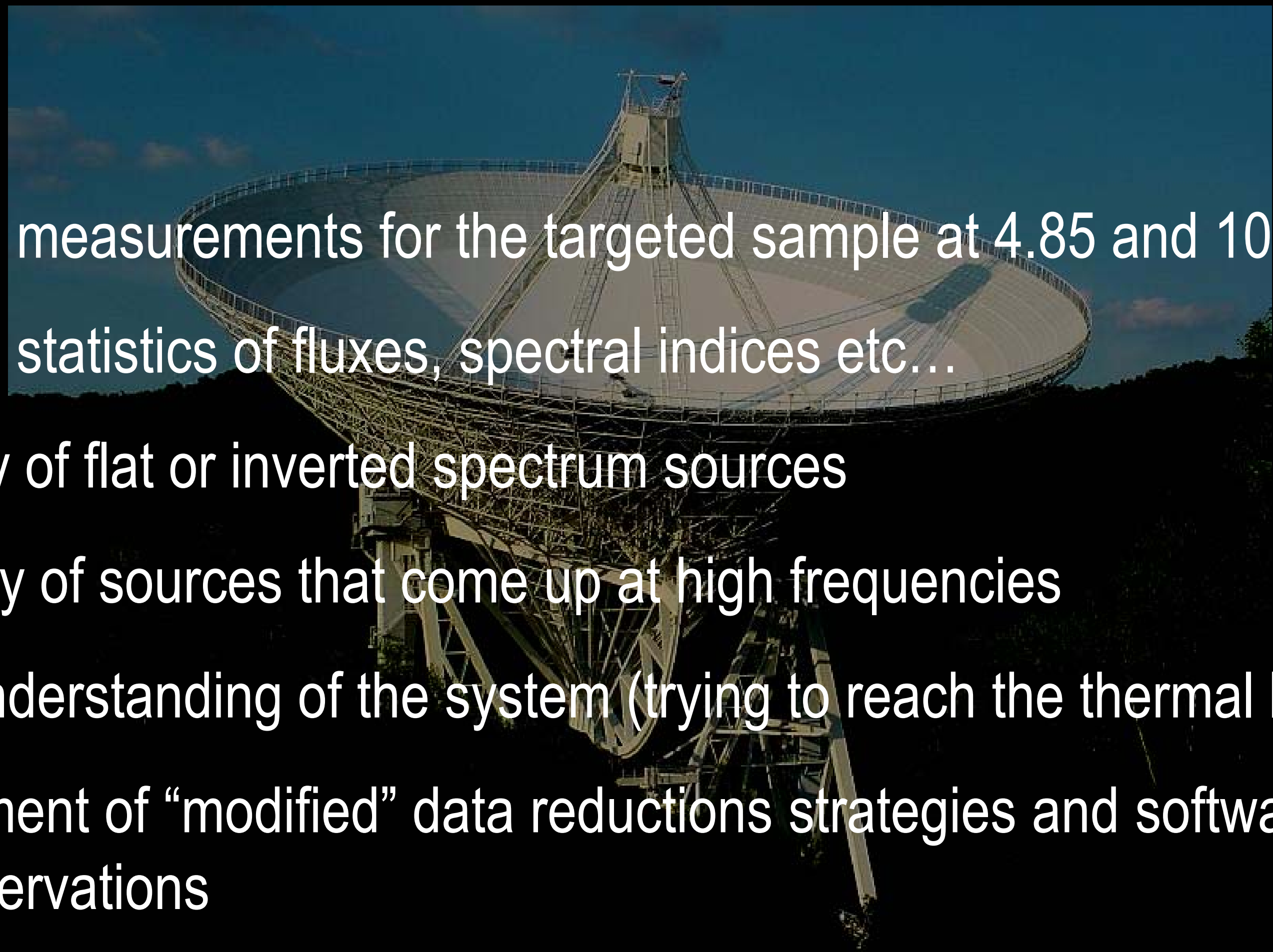


Our Project: the idea



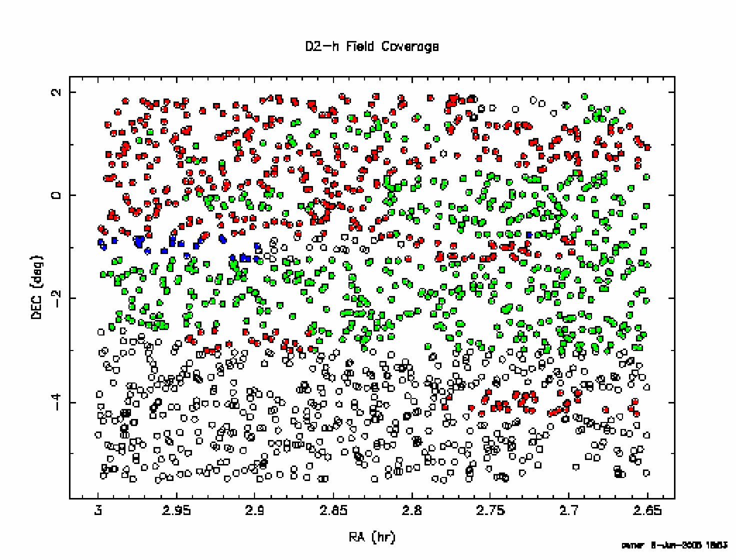
Measure the spectral index of the 6000 foreground sources at 4.85 and 10.45 GHz and estimate the expected flux at 30 GHz with an accuracy ~1 mJy.

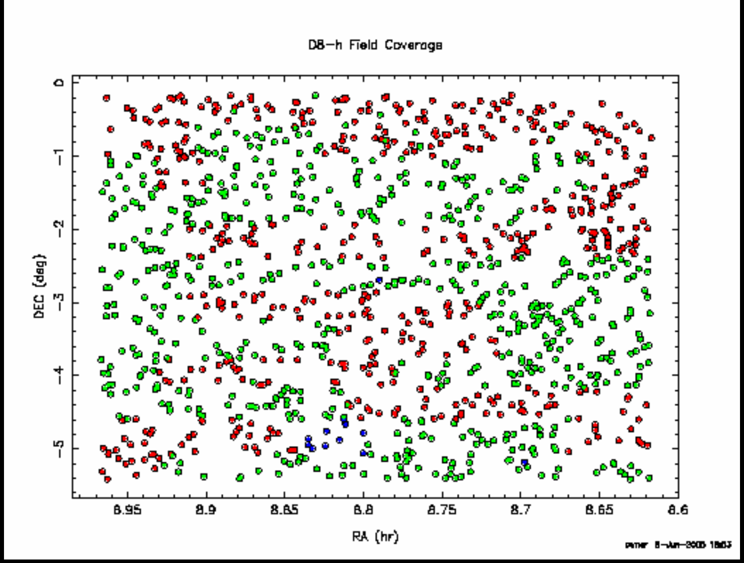
Our Project: immediate benefits

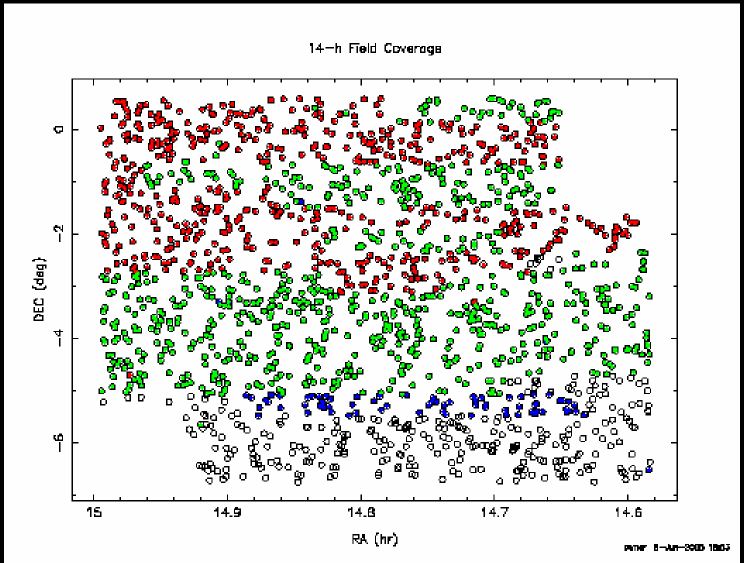


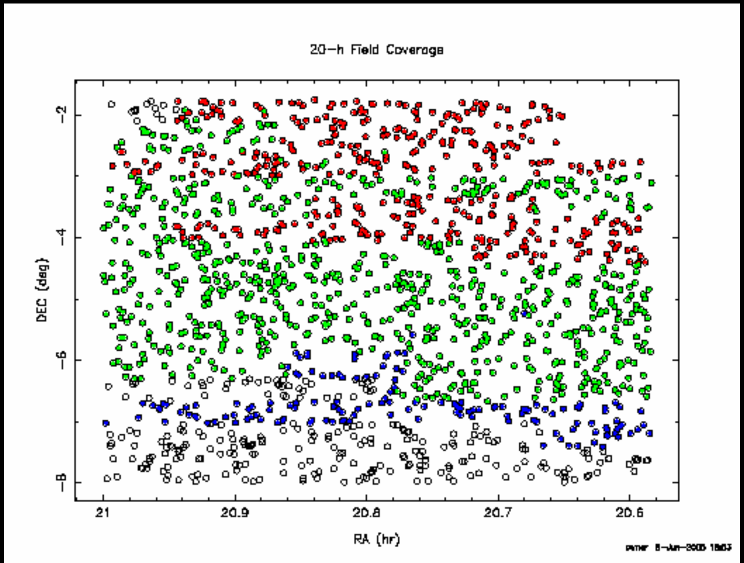
1. Accurate measurements for the targeted sample at 4.85 and 10.45 GHz
2. Accurate statistics of fluxes, spectral indices etc…
3. Discovery of flat or inverted spectrum sources
4. Discovery of sources that come up at high frequencies
5. Deep understanding of the system (trying to reach the thermal limit)
6. Development of “modified” data reductions strategies and software that allow deep observations

Our Project: completeness

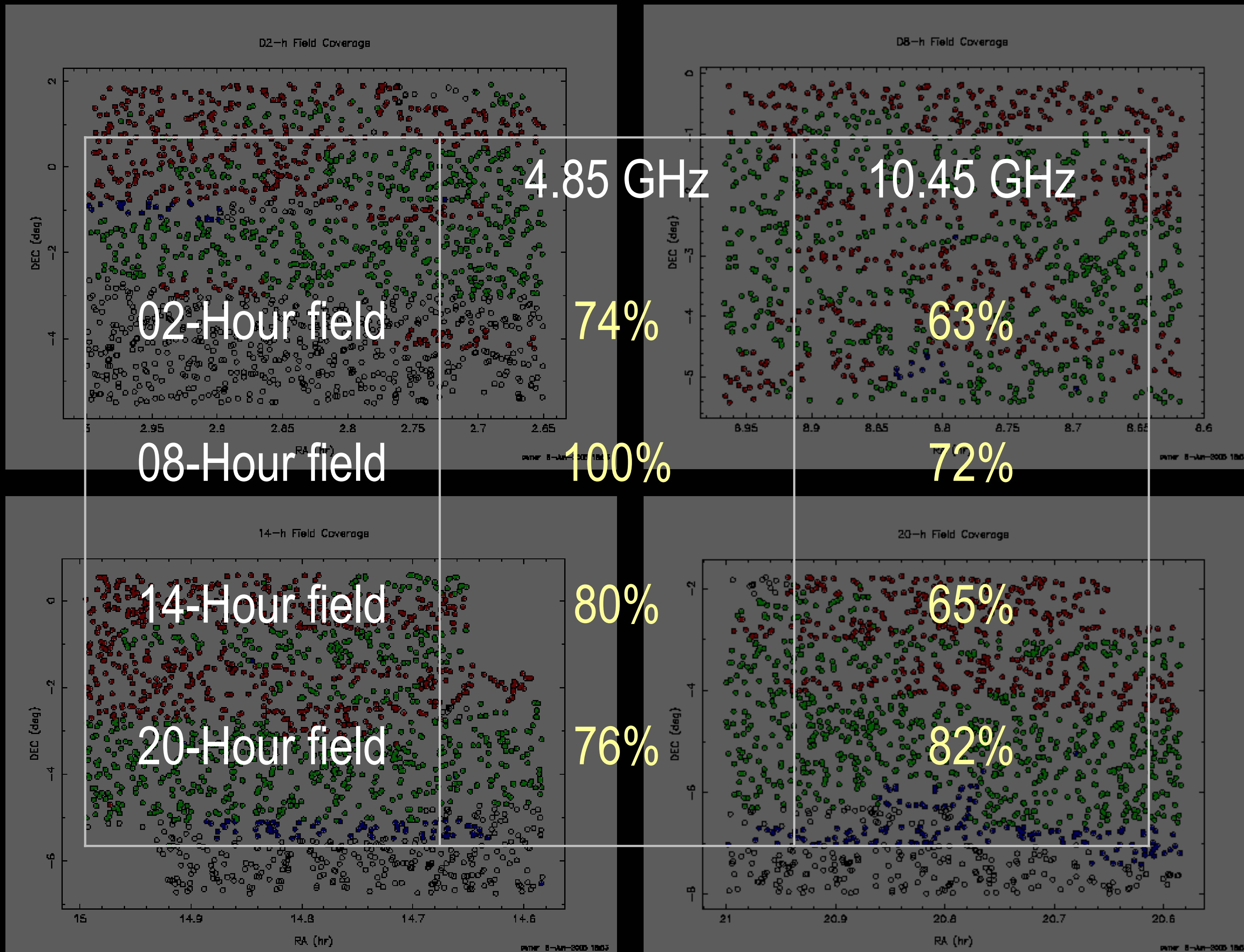






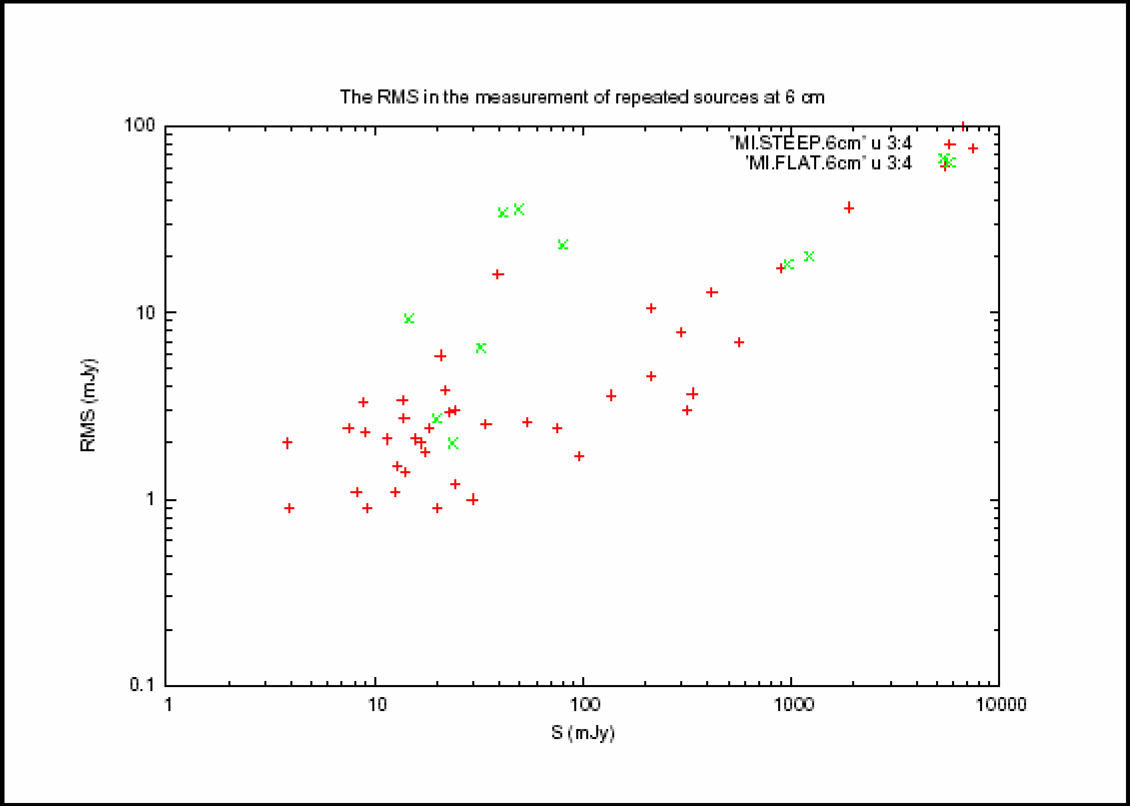


Our Project: completeness

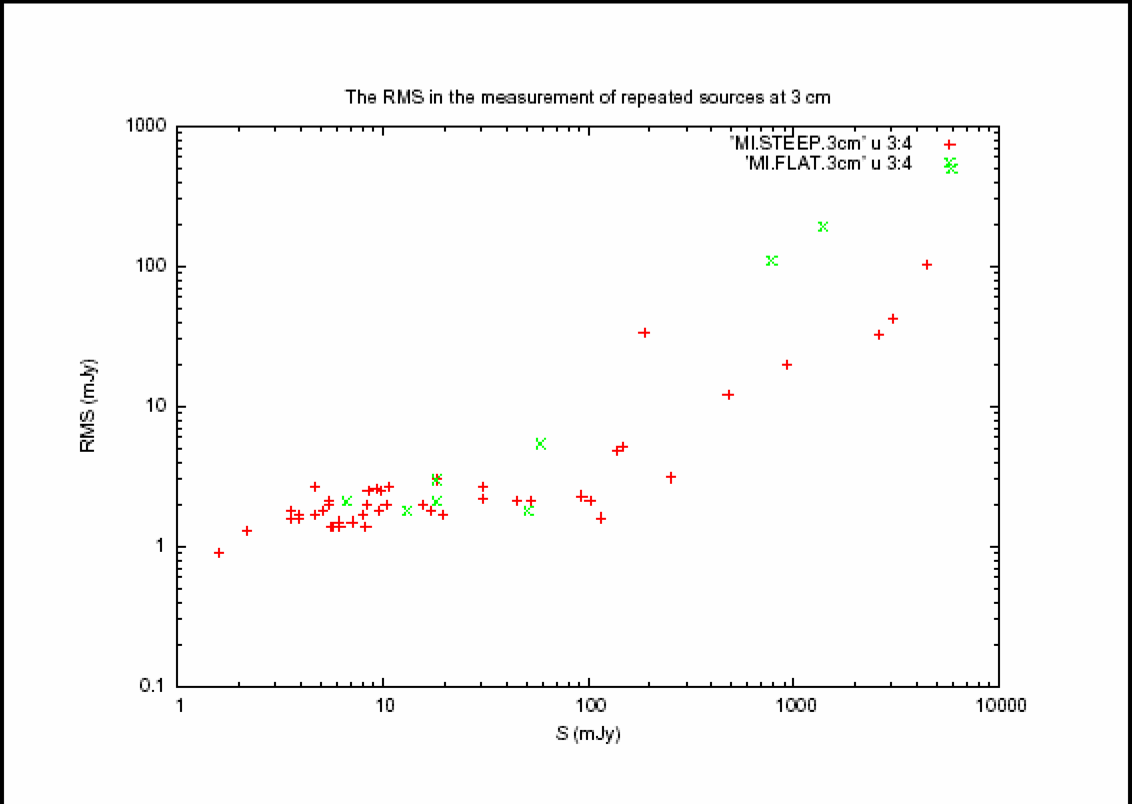


	4.85 GHz	10.45 GHz
02-Hour field	74%	63%
08-Hour field	100%	72%
14-Hour field	80%	65%
20-Hour field	76%	82%

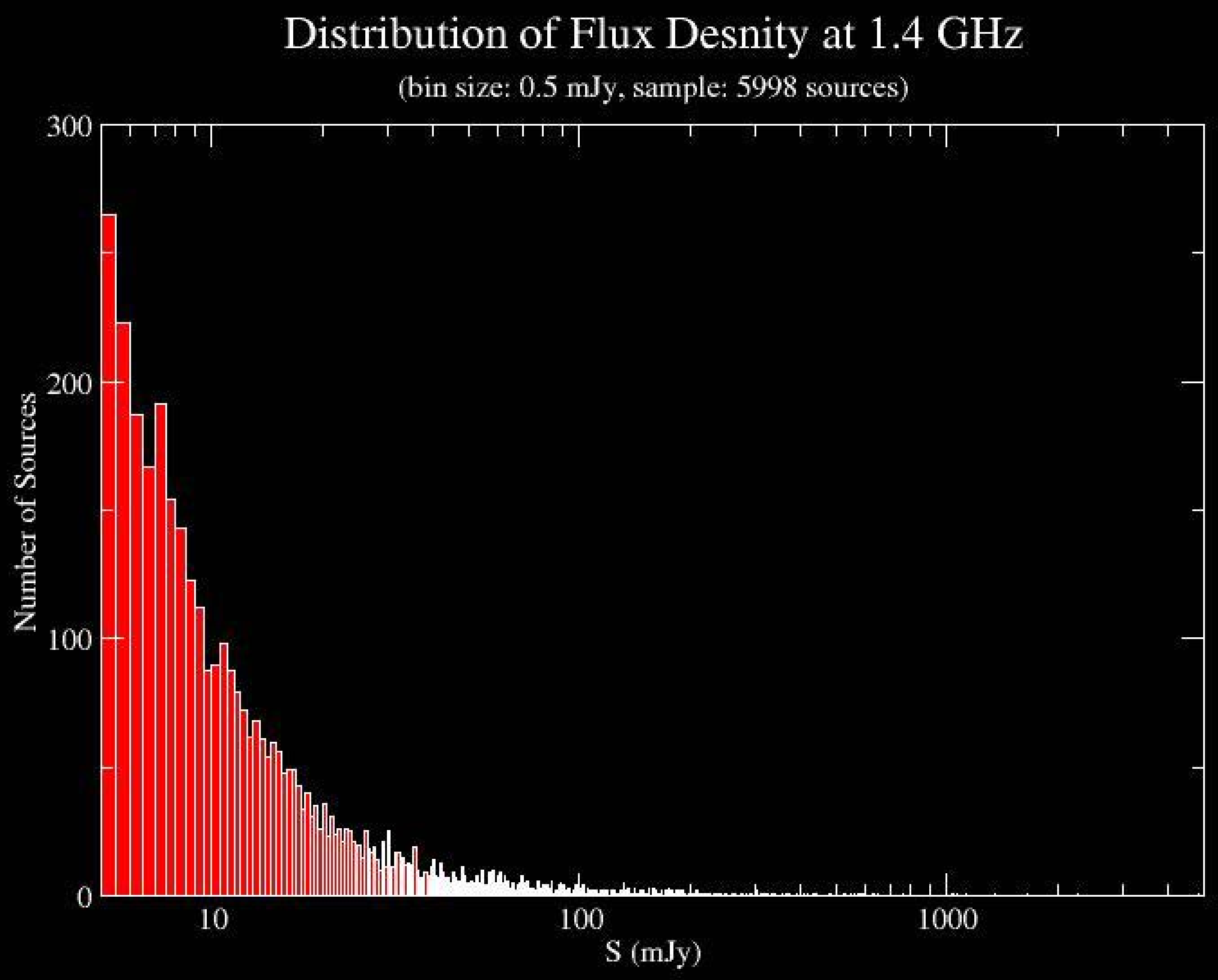
Our Project: system repeatability



Our Project: system repeatability



On the back of the envelope…



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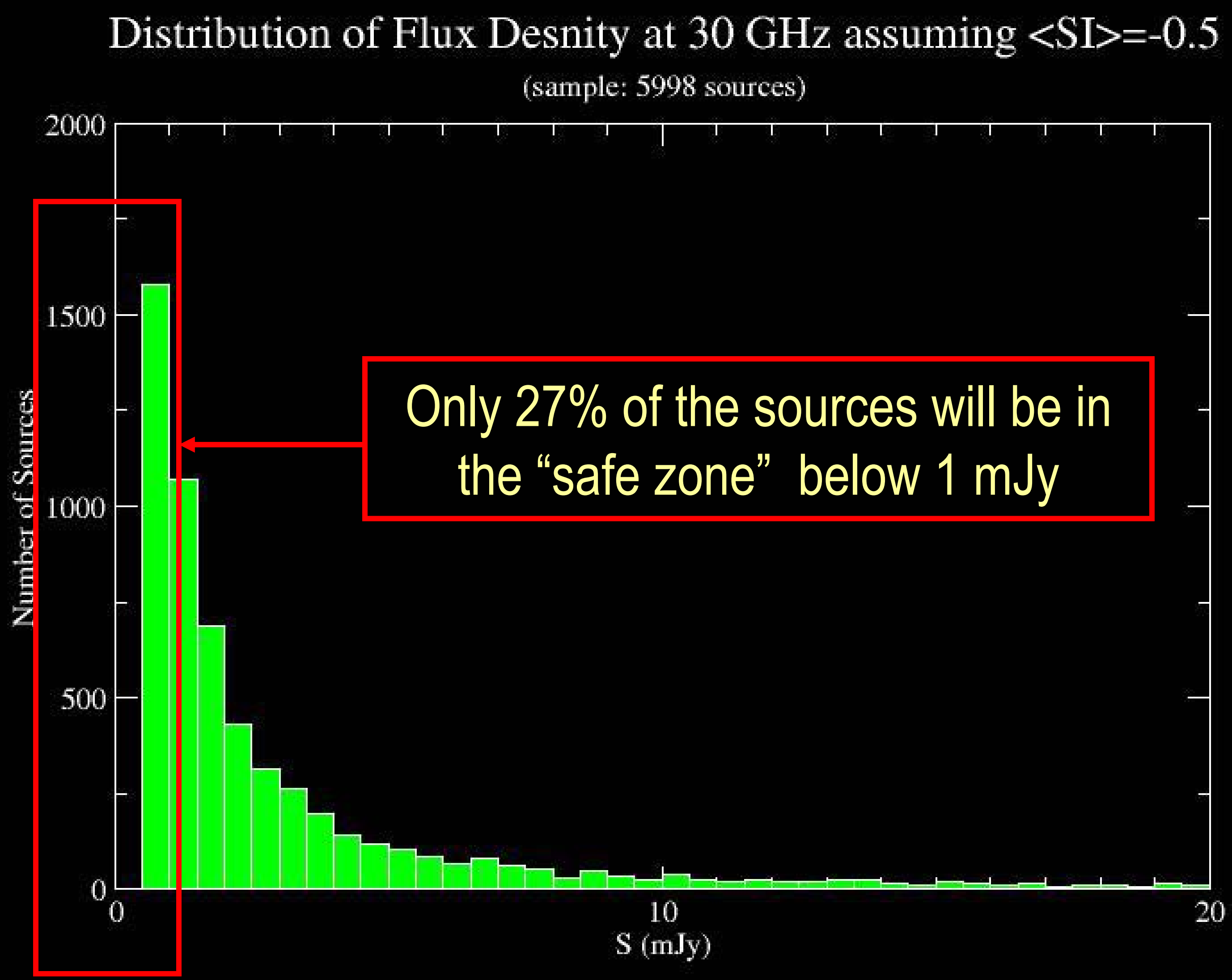
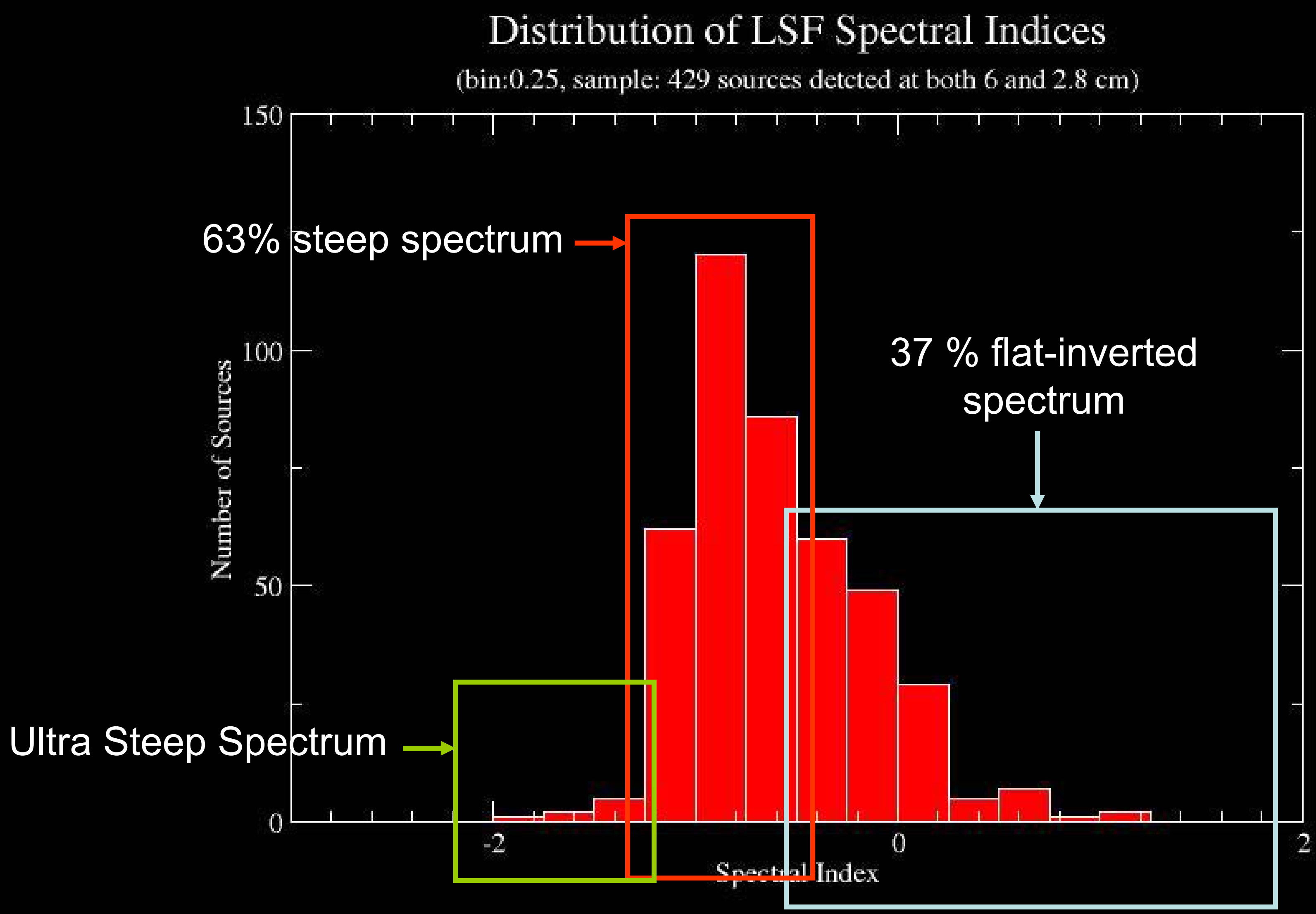


Our Project: what do we get?

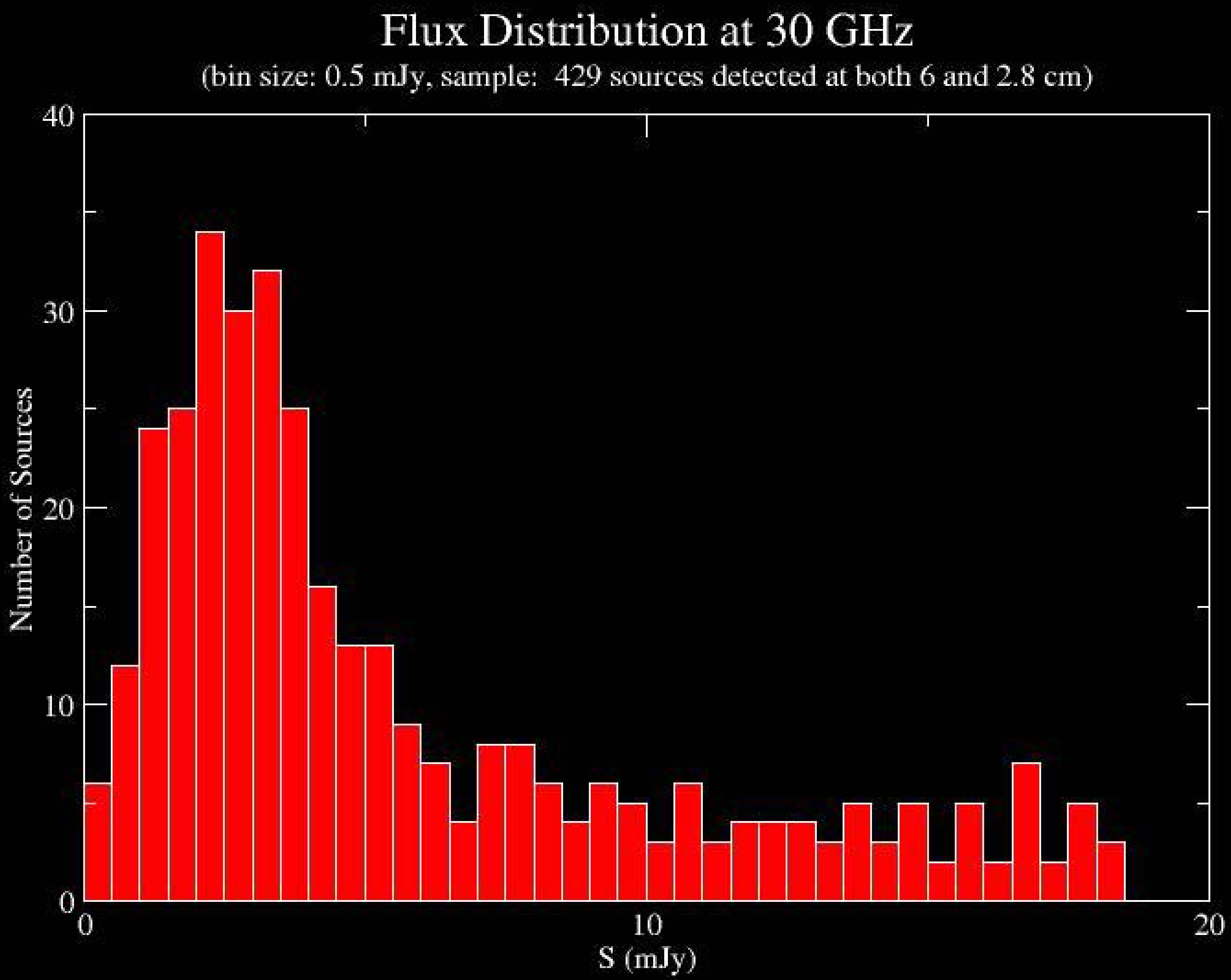
A selected sample of 2715 sources targeted at both frequencies:

- ► 1244 (46%): not detected at any frequency!
- ► 898 (33%): detected (5 sigma) only at 4.85 GHz
- ► 429 (16%): detected (5 sigma) at both frequencies
- ► 144 (5%): detected only at 10.45 GHz

Our Project: Spectral Index distribution



Our Project: distribution of Flux Density at 30 GHz



Our Project: Highly Inverted spectrum Sources

Sources with SI>=0.5

Source	S_{21} (mJy)	S_6 (mJy)	$S_{2.8}$ (mJy)	α_6^{21}	$\alpha_{2.8}^{21}$	$\alpha_{2.8}^{6}$
023923+0105	22.6	42.7	-	0.512	-	-
024050-0138	5.0	42.0	-	1.713	-	-
024138+0027	5.1	32.5	-	1.489	-	-
024203-0128	14.9	49.6	-	0.969	-	-
024342-0103	5.6	15.2	-	0.805	-	-
025156+0057	6.3	21.5	-	0.988	-	-
025233+0101	5.4	10.5	-	0.533	-	-
084025-0321	9.4	18.2	-	0.534	-	-
084031-0315	12.2	12.2	-	0.637	-	-
084050-0046	12.8	73.4	-	1.405	-	-
084549-0052	10.8	29.0	-	0.795	-	-
085031-0016	6.1	12.2	-	0.555	-	-
085212-0404	9.2	20.8	-	0.655	-	-
085630-0400	20.5	45.6	-	0.643	-	-
145002+0016	10.9	23.1	-	0.606	-	-
145202+0033	14.0	79.0	-	1.392	-	-
203511-0518	12.0	65.7	-	1.369	-	-
203641-0507	5.2	39.0	-	1.622	-	-
203742-0505	6.1	14.7	-	0.708	-	-
203807-0527	17.3	55.2	-	0.933	-	-
204038-0536	7.7	20.1	-	0.770	-	-
204235-0535	8.6	21.6	-	0.740	-	-
204250-0546	8.9	35.9	-	1.122	-	-
204305-0549	8.7	53.0	-	1.454	-	-
204740-0246	5.1	19.3	-	1.071	-	-
205357-0206	5.5	21.8	2.68	1.109	(-0.358)	(-2.722)
025333+0024	17.4	-	53.0	-	0.554	-
025515+0037	30.5	28.9	47.1	(-0.043)	(0.216)	0.635
025528+0144	27.7	31.3	52.2	(0.099)	(0.315)	0.666

Our Project: Highly Inverted spectrum Sources

Source	NVSS 1.4	Flux 4.85	Flux 10.45	Alpha	PMN 4.85	87GB 4.85	GB 4.85	GB 1.4	VLA 8.6	PK 1.4
25240+010	42.4	48.2	42.5	0.088	54	57				
25003+011	32.2	37.2	35.2	0.102		53				
25515+003	30.5	31.8	62	0.830	104	95				
25321+000	127.8	222.2	199.2	0.097		158		153		
024002-002	3.4	15.2	31.4	1.087						
024521-012	59.6	73.3	61.4	0.052	71		57			
024050-013	5	42	4.6	0.089						
024616-014	31.5	42	27.4	0.183						
024838-014	6.2	9.6	9.1	0.258						
025419-022	8.2	18.4	26.6	0.520						
023945-023	303.8	445.9	445.9	0.078	708			396	445	370
024314-024	12.5	13.6	12.8	0.045						
025111-02	5.7	12.8	12.4	0.529						
084050-00	12.8	73.6	13.7	0.589	93		98	190		
085035-01	8.8	11.3	7.8	0.058						
084857-01	10.4	10.5	10.6	0.006						
084958-02	4.8	4.5	6.8	0.147						
084014-02	30.7	121.9	88.1	0.667	128					
084004-03	7	26.8	5.9	0.127						
084032-03	12.2	16.4	40.6	0.676						
084025-03	9.4	19.1	27.1	0.548						
085212-04	9.2	16.6	18.5	0.390						
085559-03	15	13.9	27.5	0.263						
085205-04	4	5.8	4.5	0.033						
084758-05	368.2	502.1	446.5	0.019	332			345		
144916-00	191.1	227.5	198.3	0.001	251		193	277		
144500-00	7.8	10.7	5.6	0.073						
144308-00	69.8	126.9	78.7	0.062	104		82			

I appeciate your attention!

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Time Series Analysis of MKN421

Dimitrios Emmanoulopoulos

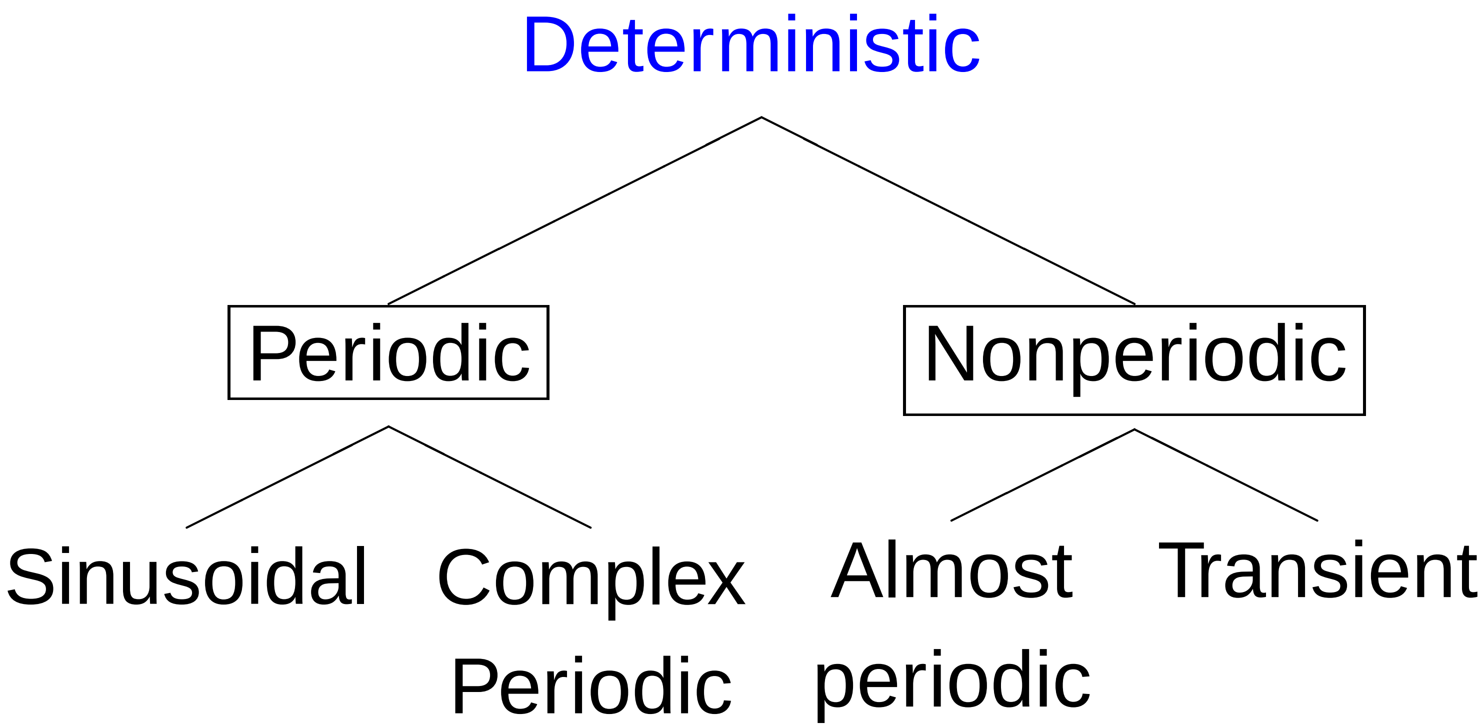
5th ENIGMA meeting, June 13-17 2005

Landessternwarte Heidelberg

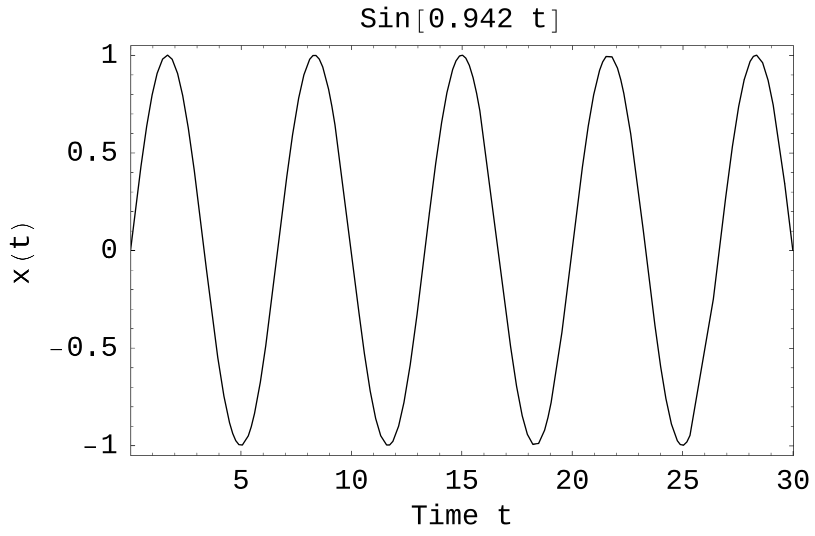
Overview

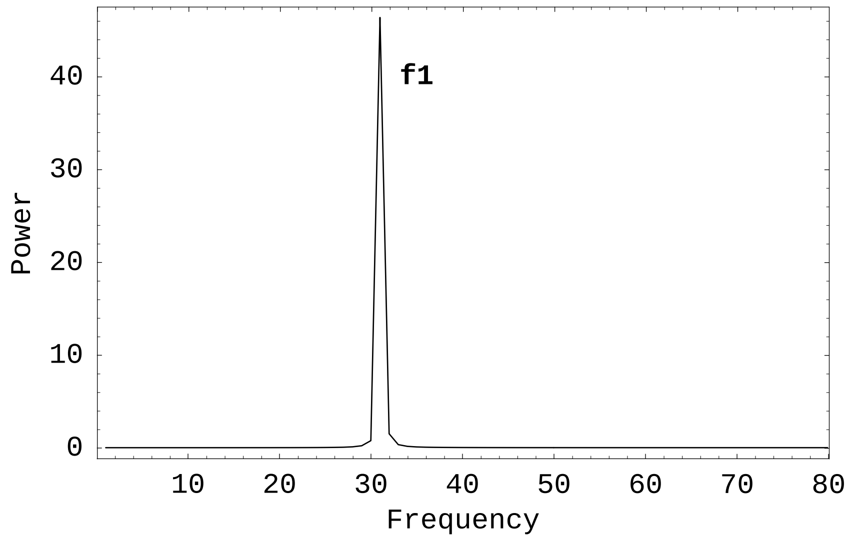
- Classification of Physical systems.
- The Variability Power.
- Artificial Light Curves-Properties of Red Noise lightcurves.
- A Variability Model.
- Application to MKN421.
- Conclusions.

Classification of Physical Systems



Classification of Physical Systems





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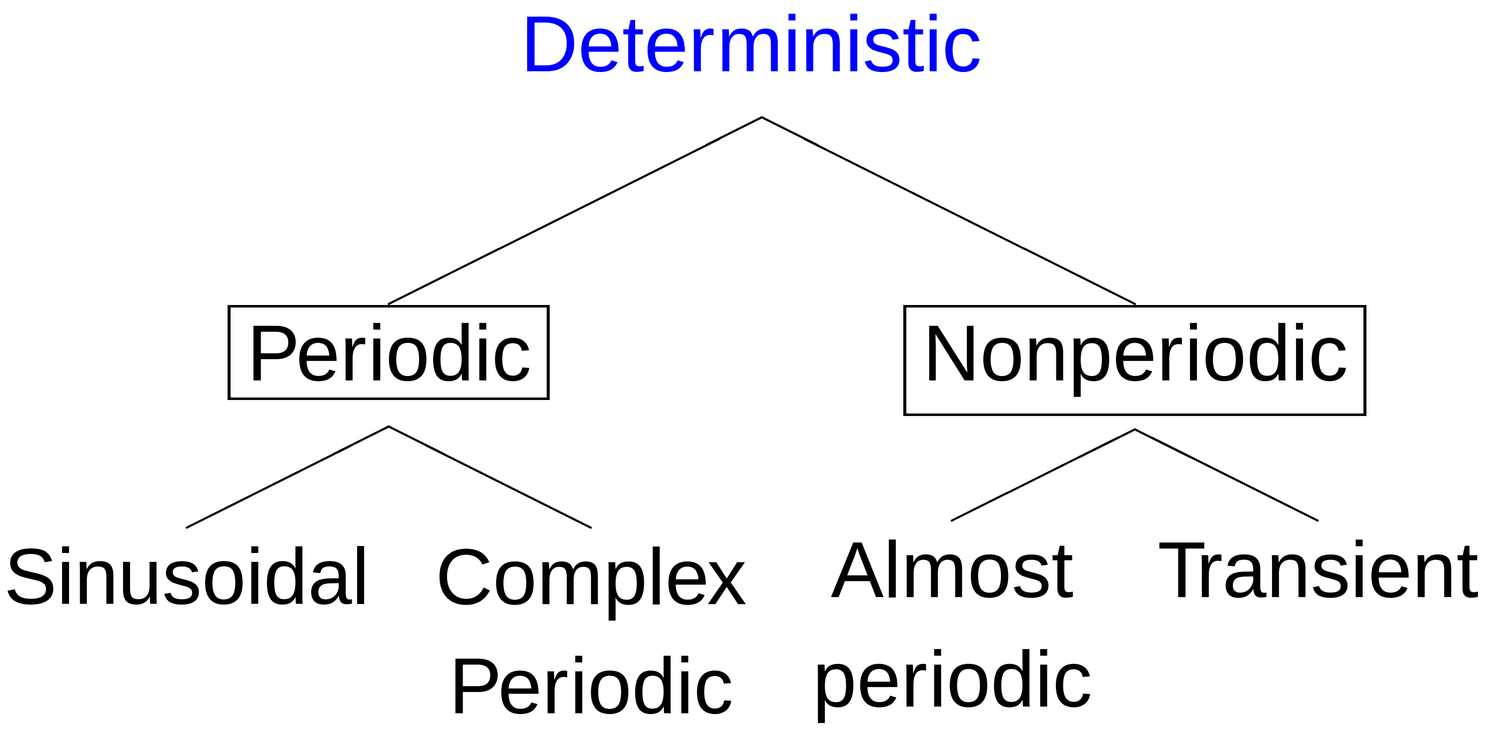
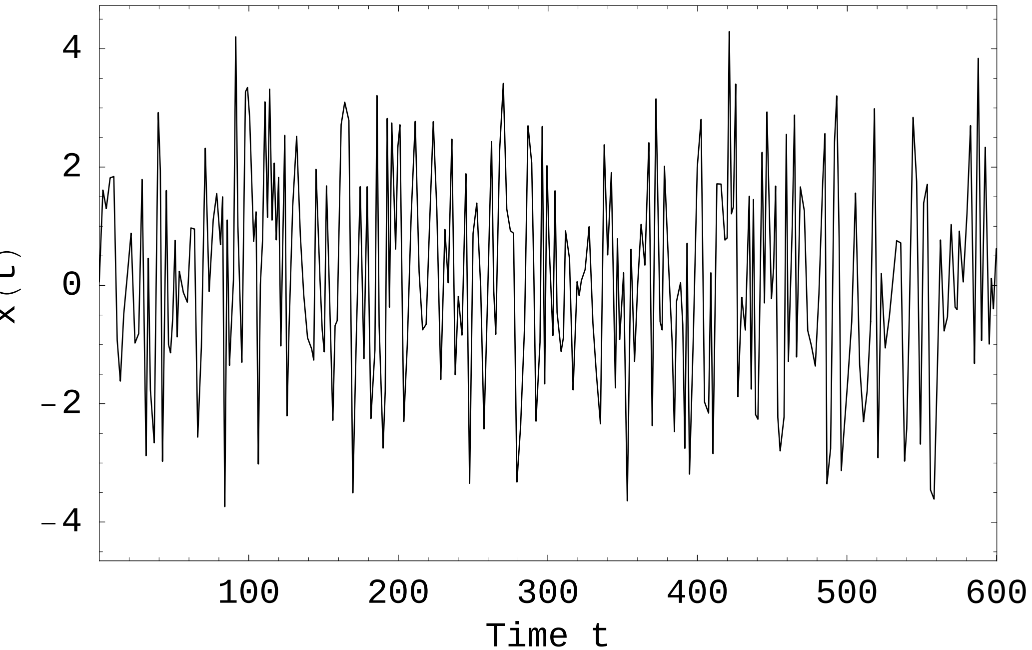
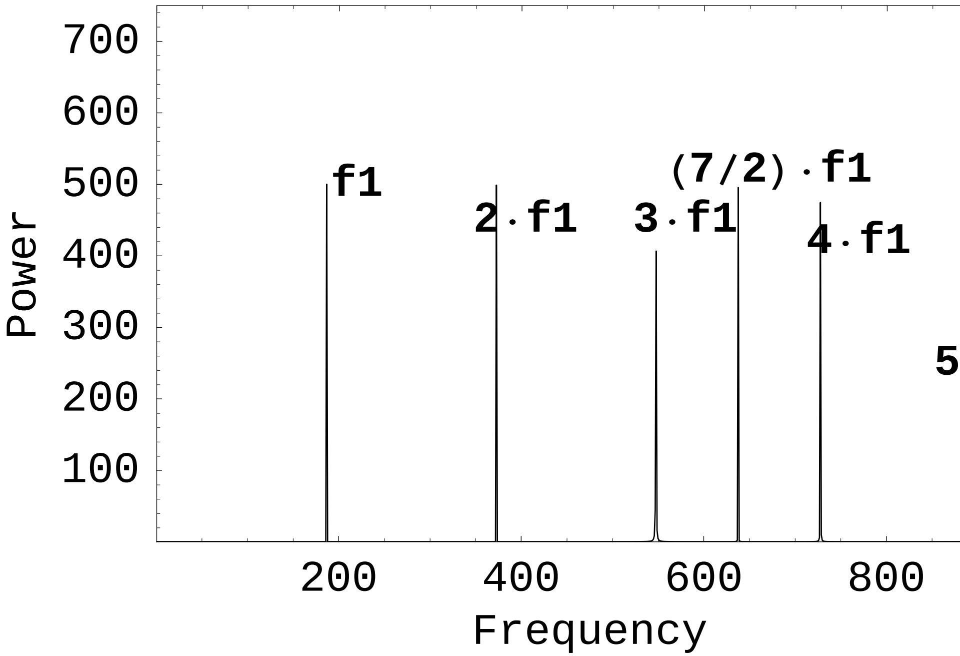


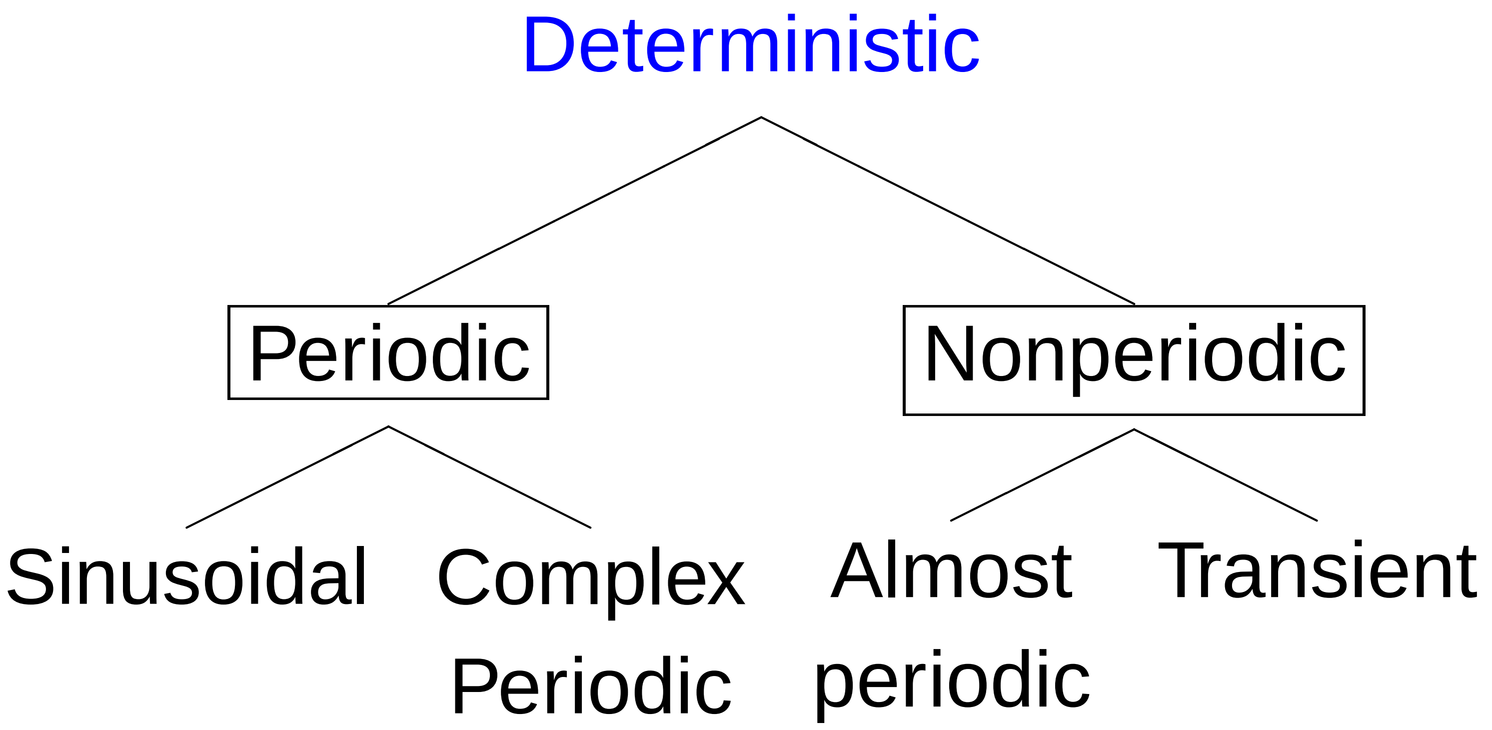
Classification of Physical Systems



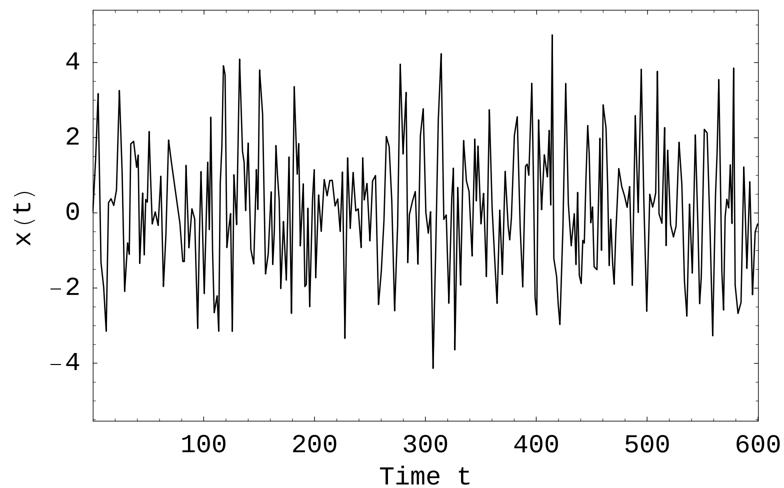


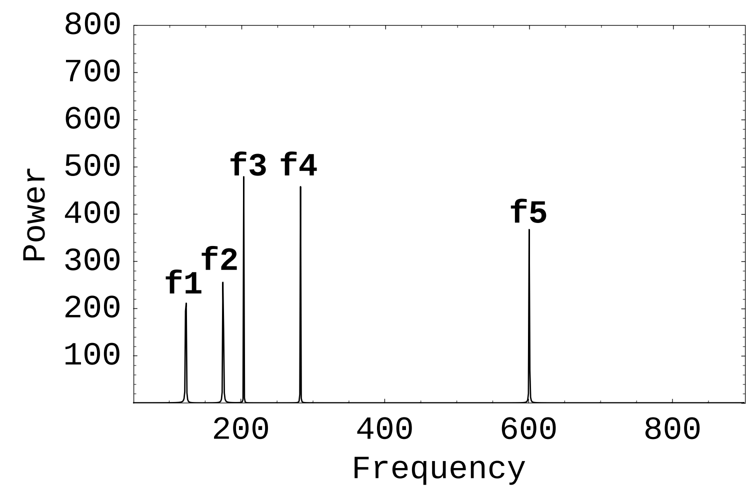
$$x(t) = \sin(2t) + \sin(4t) + \sin(8t) + \sin(16t) + \sin(32t) + \sin(64t) + \sin(512t)$$

Classification of Physical Systems



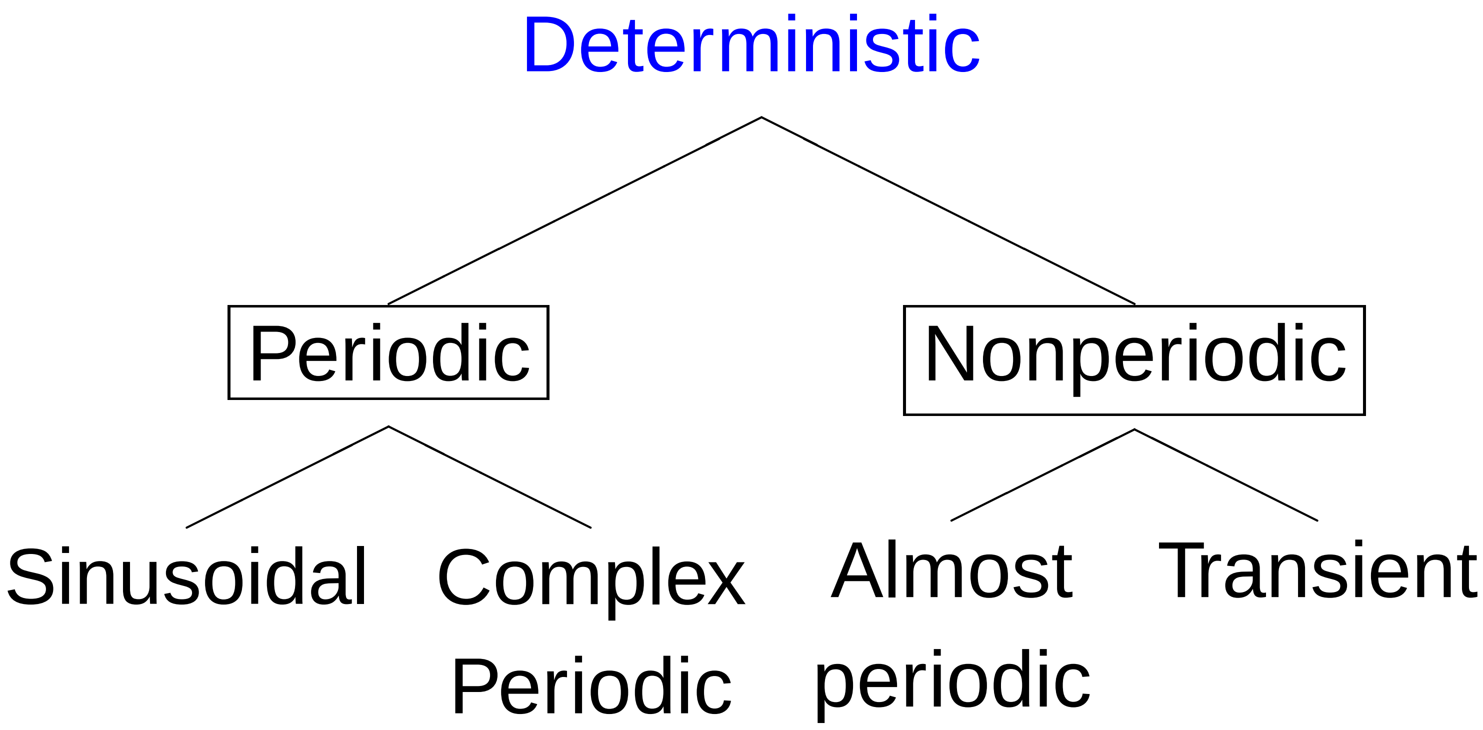
Classification of Physical Systems



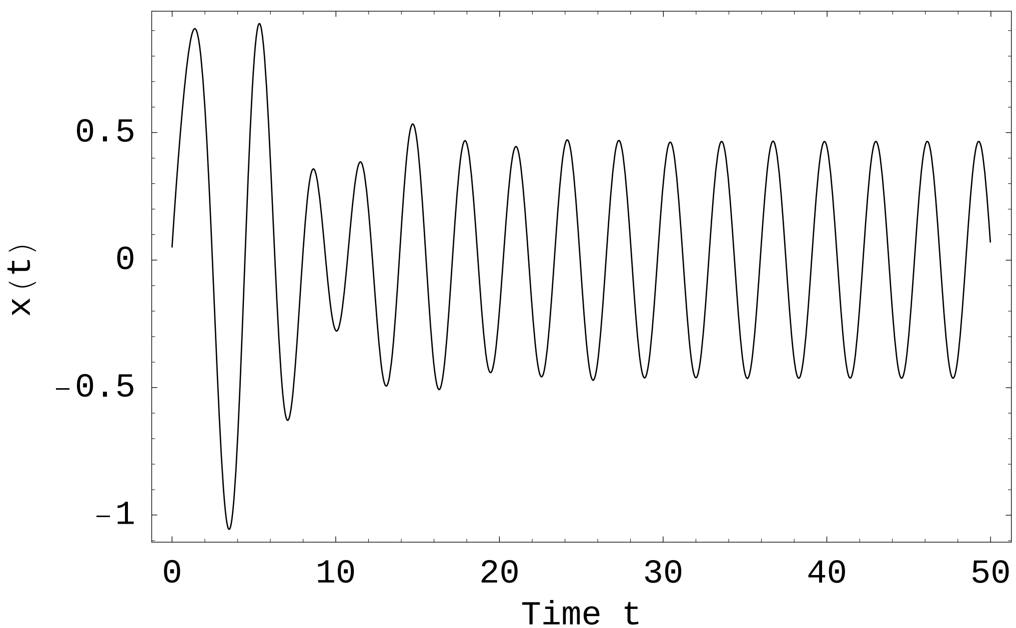


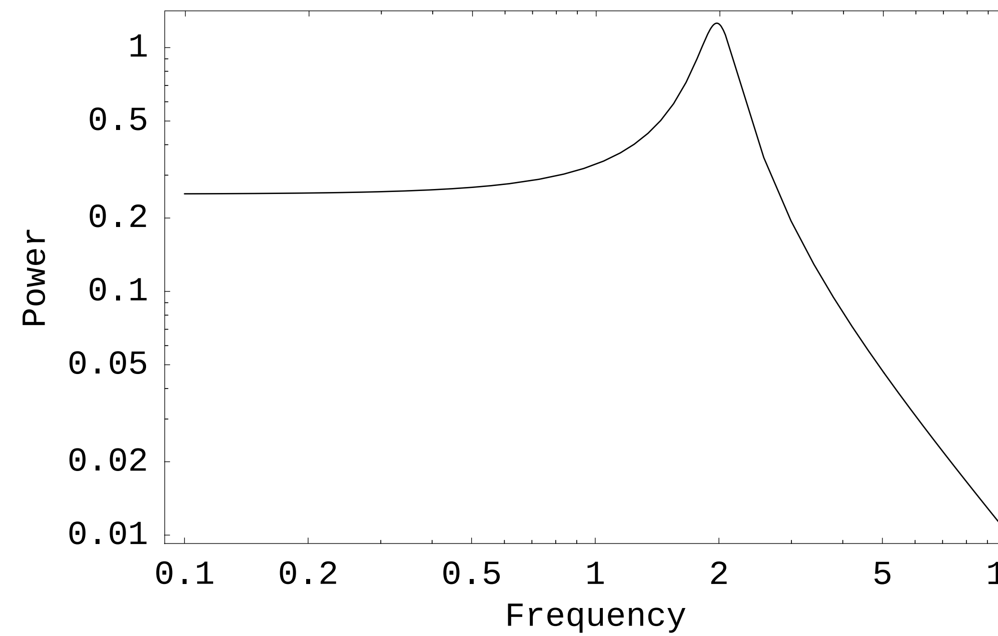
$$x(t) = \sin(70t) + \sin(71t) + \sin(72t) + \sin(\sqrt{0.148}t) + \sin(\sqrt{0.3}t) + \sin(\sqrt{600}t)$$

Classification of Physical Systems

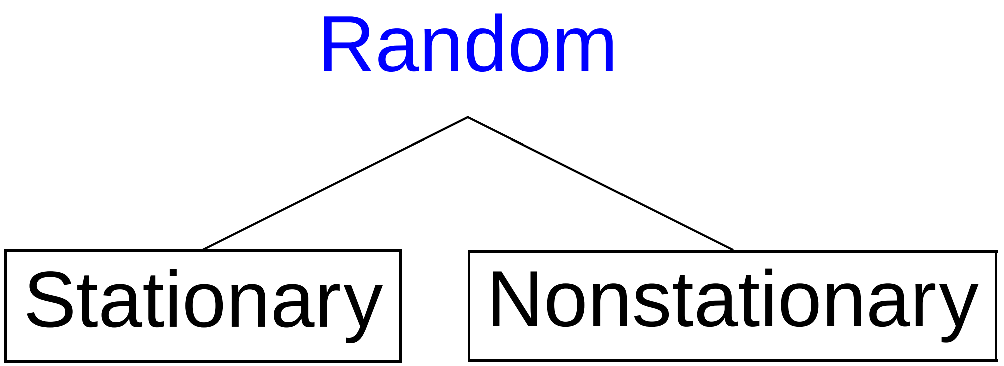


Classification of Physical Systems





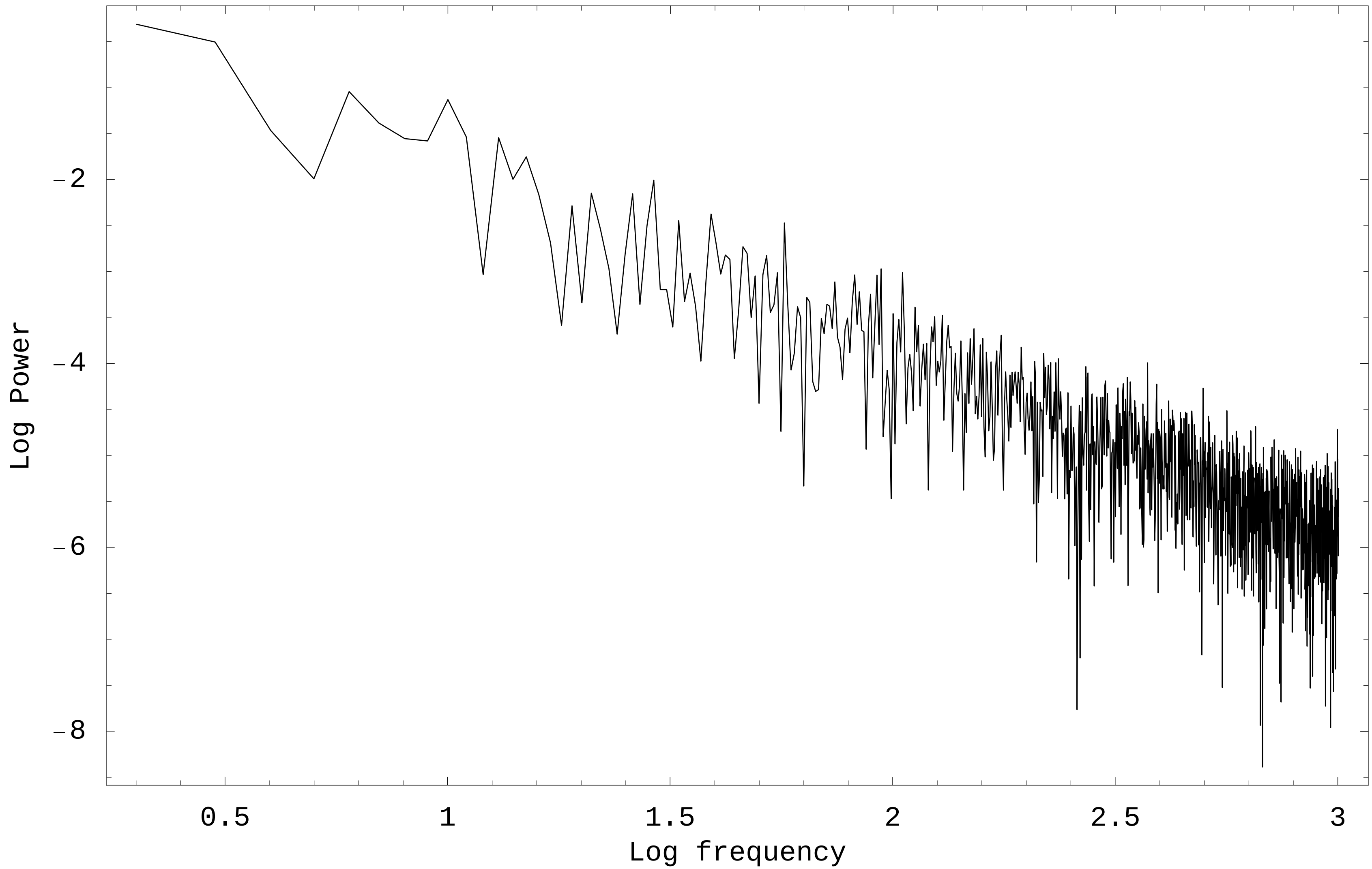
Classification of Physical Systems



Stationarity: Statistical moments (mean, variance) don't change with time.

Non-stationarity: Statistical moments are time-varying functions.

Classification of Physical Systems



The Variability Power

Periodogram

$$P(f_j) = \underbrace{\frac{2\Delta t}{N}}_{C} \left| \sum_{i=1}^{N} x_i e^{2\pi f_j t_i} \right|^2 =$$

$$C \left[\left| \sum_{i=1}^{N} x_i \cos 2\pi f_j t_i \right|^2 + \left| \sum_{i=1}^{N} x_i \sin 2\pi f_j t_i \right|^2 \right]$$

$f_j = \frac{j}{N\Delta t}$ and $j = 1, 2, ..., N/2$ ($f_{N/2} \equiv f_{Nyq}$).

The Variability Power

What can we learn from periodogram?

The total variance of the observed process
$S^2 = \sum_{j=1}^{N/2} P(f_j)\Delta f$

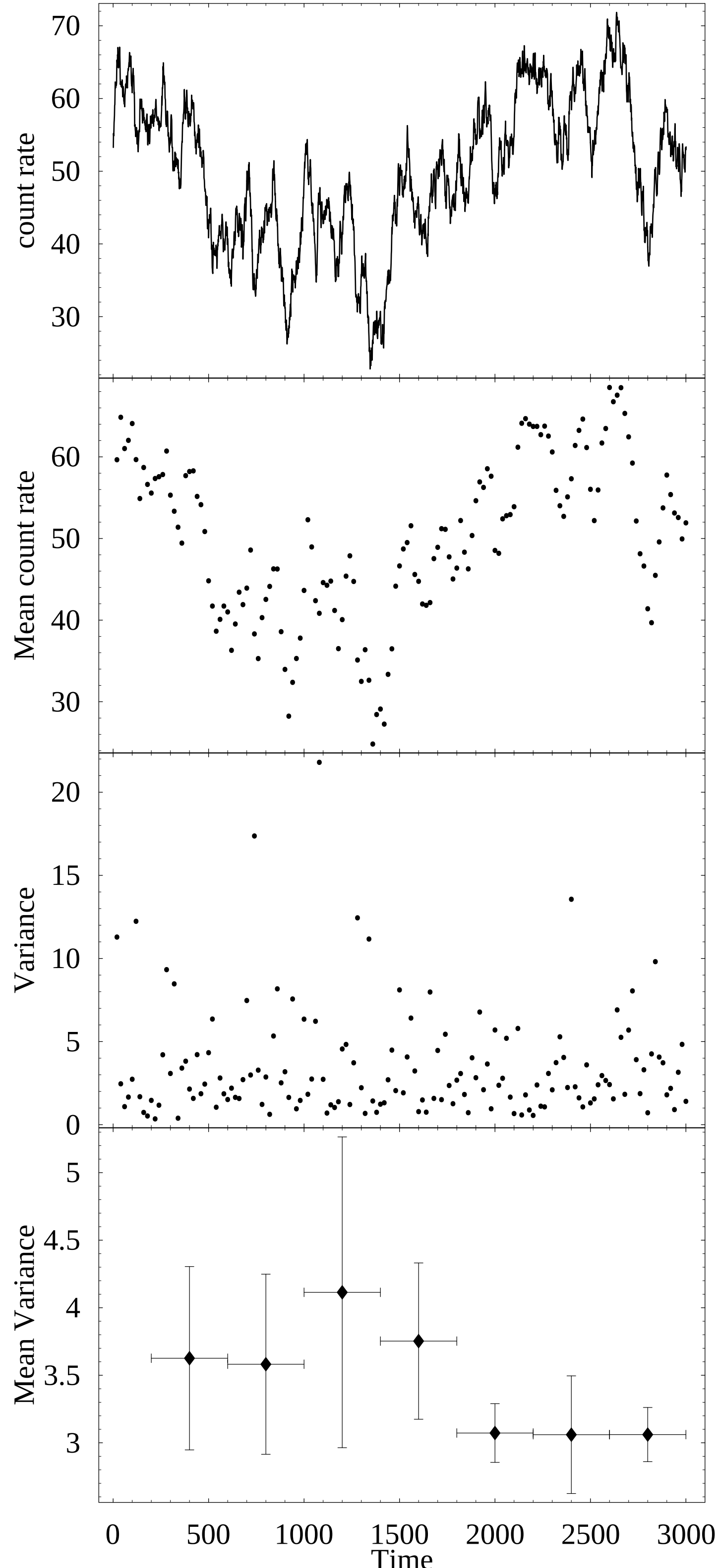
but also

$S^2 = \frac{1}{N-1}\sum_{j=1}^{N}(x_i - \overline{x})^2$

Artificial LC

Timmer and König A&A 300,(1995)

1. We choose a power law shape PDS $\mathcal{PDS}(f) = f^{-a}$
2. For each fourier frequency f_j we produce two Gaussian distributed random numbers and we multiply them by $\sqrt{\frac{1}{2}\mathcal{PDS}(f_j)}$.
3. For the negative frequencies $P(-f_j) = P^*(f_j)$.
4. Inverse Discrete Fourier transform of $P(f)$ from the frequency domain to the time domain.



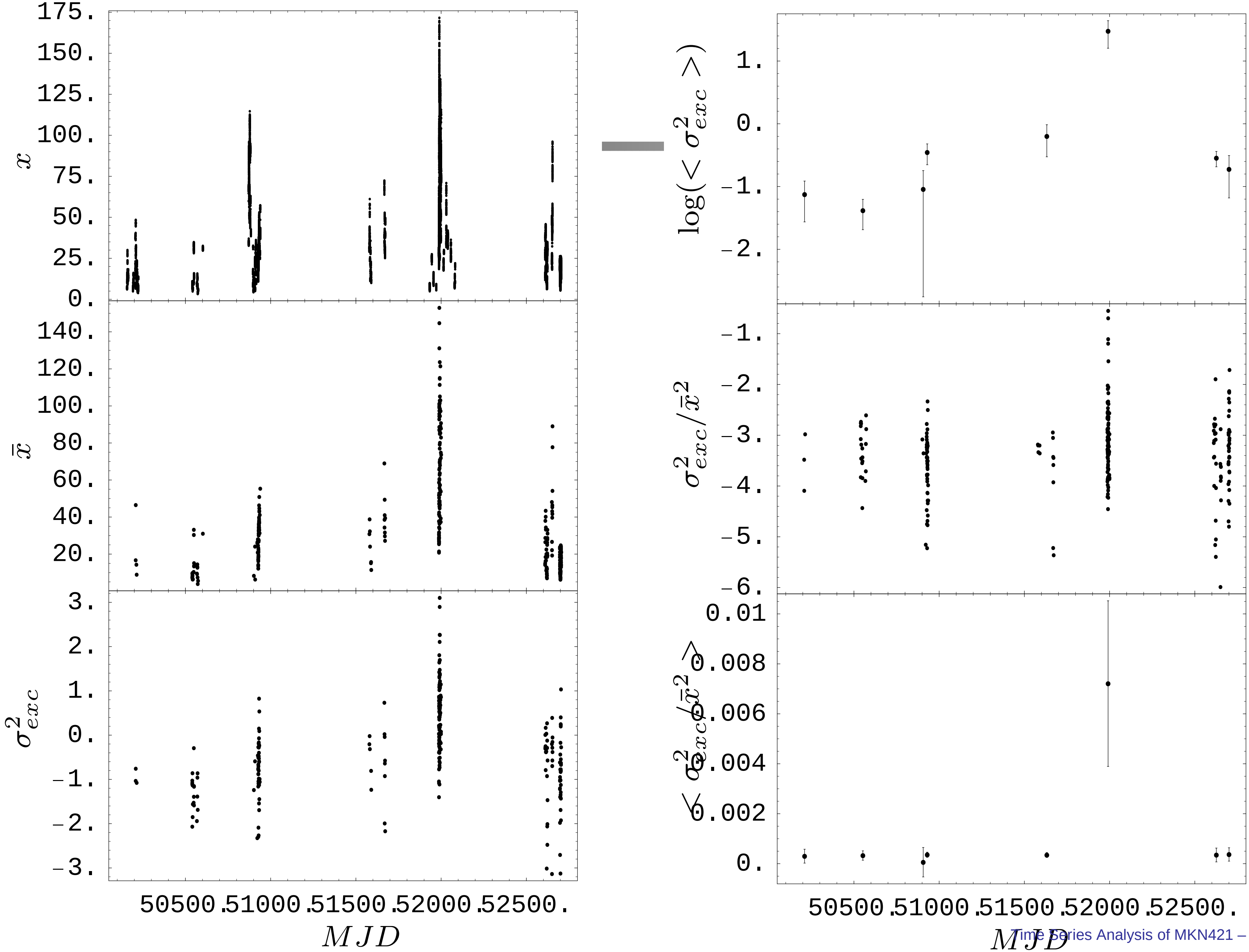
Artificial Red-Noise LC

PDS doesn't vary → Variance doesn't vary → Stationary process

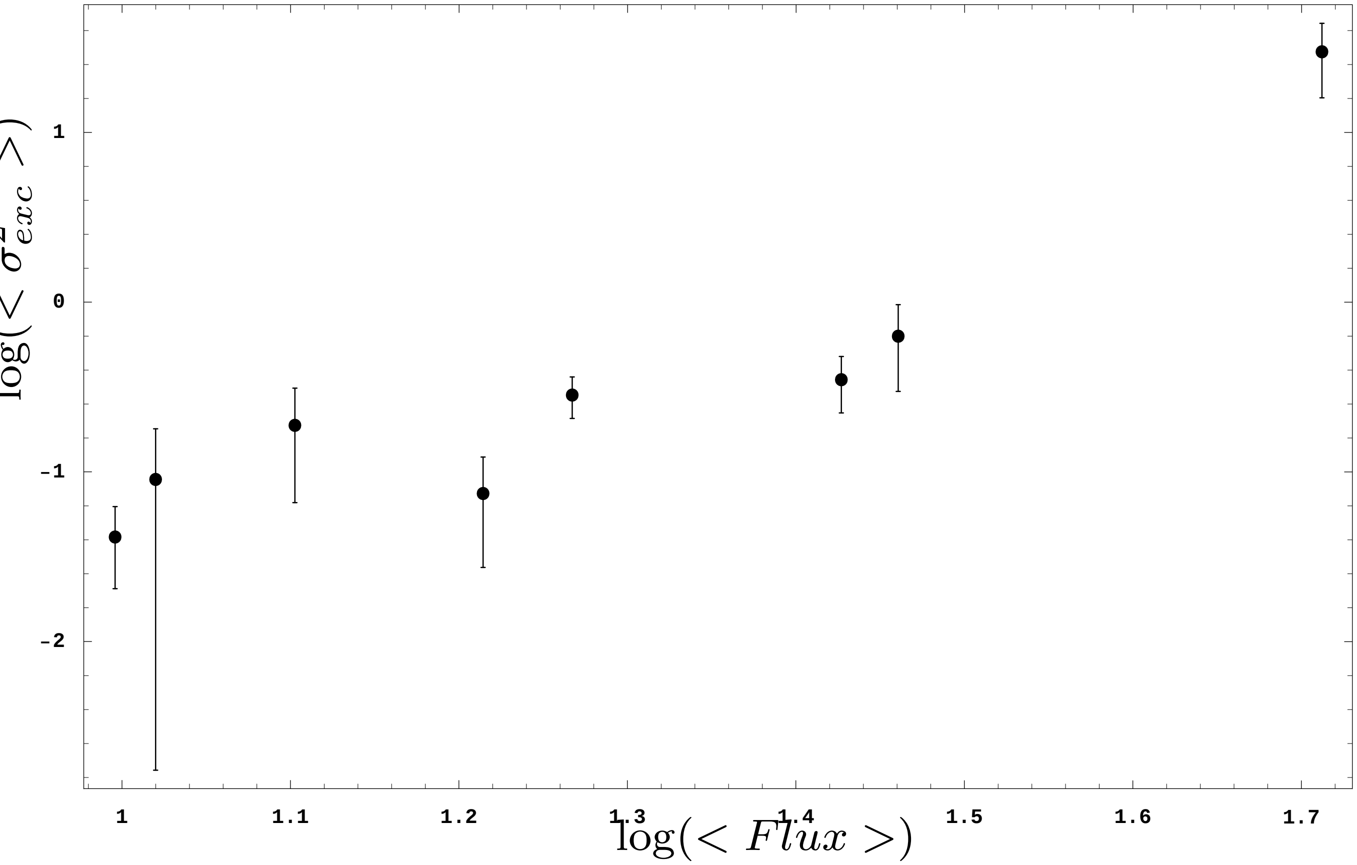
Mean and Variance change with time, What's wrong?

Fluctuations in the statistical moments are intrinsic in Red-Noise processes

For MKN421


175.
150.
125.
100.
75.
50.
25.
0.
x
140.
120.
100.
80.
60.
40.
20.
x̄
3.
2.
1.
0.
−1.
−2.
−3.
σ²exc
50500. 51000. 51500. 52000. 52500.
MJD
1.
0.
−1.
−2.
log(< σ²exc >)
−1.
−2.
−3.
−4.
−5.
−6.
σ²exc/x̄²
0.01
0.008
0.006
0.004
0.002
0.
< σ²exc/x̄² >
50500. 51000. 51500. 52000. 52500.
MJD

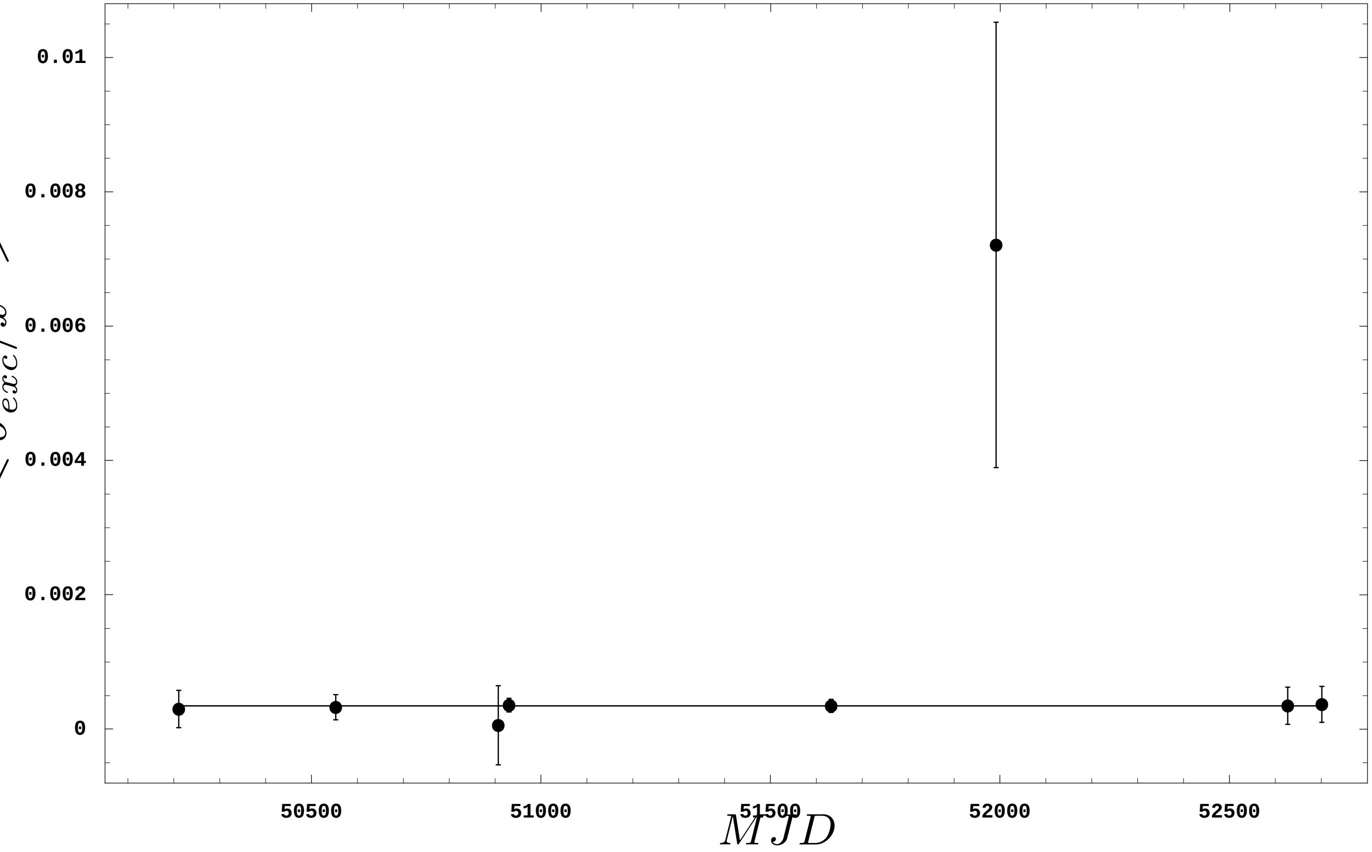
For MKN421



Non Stationarity

Correlation between $<\sigma^2_{exc}>$ and Flux

For MKN421



Two energetic states

x^2/d.o.f.=4.6/7

N.Y.P=0.656

A variability model

- The source can be characterized by two energetic levels.
- Genuine non-stationarity.
- The lower state occurs more often than the higher one (Higher probability).

A variability model

- The source can be characterized by two energetic levels.
- Genuine non-stationarity.
- The lower state occurs more often than the higher one (Higher probability).

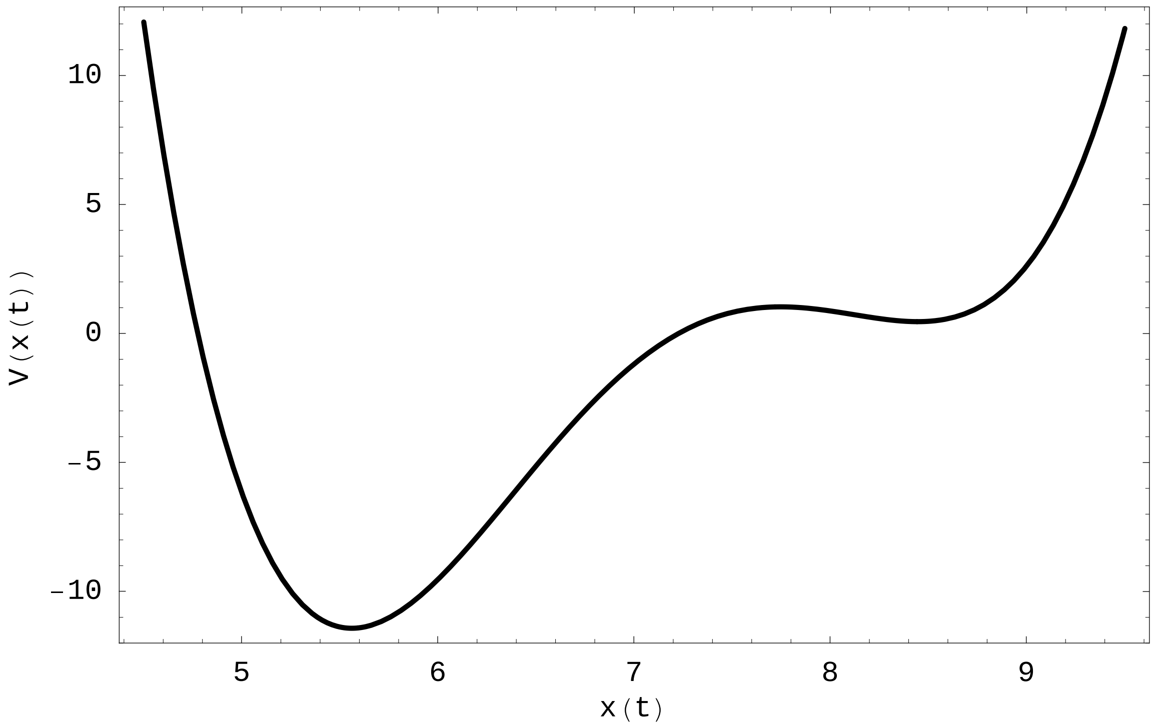
We consider the time evolution of an asymmetric double-well dynamical system.

$$V(x) = ax^4 - bx^3 + cx^2 - dx + e \text{ where } a, b, c, d, e \in R^+$$

suffering the influence of a continuous white noise process $x \cdot w(t)$.

A variability model

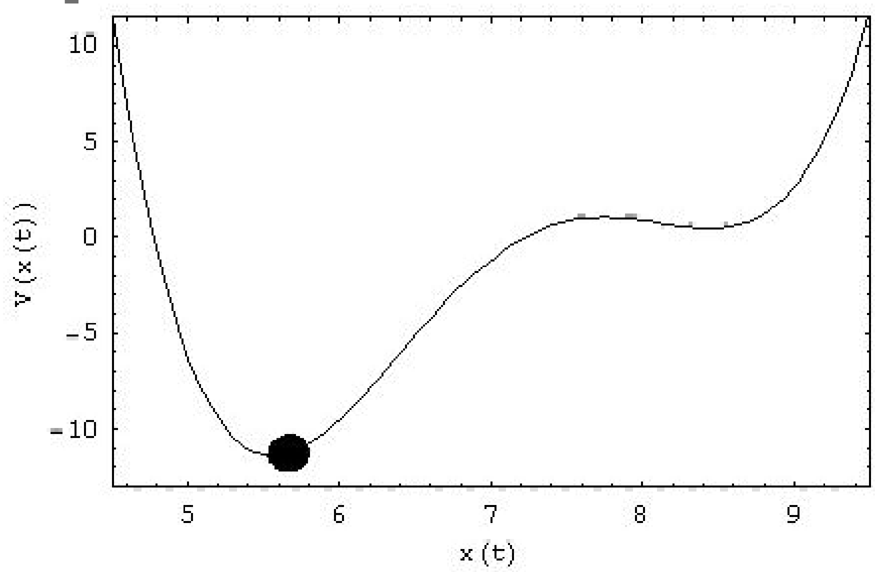
We consider the following system:

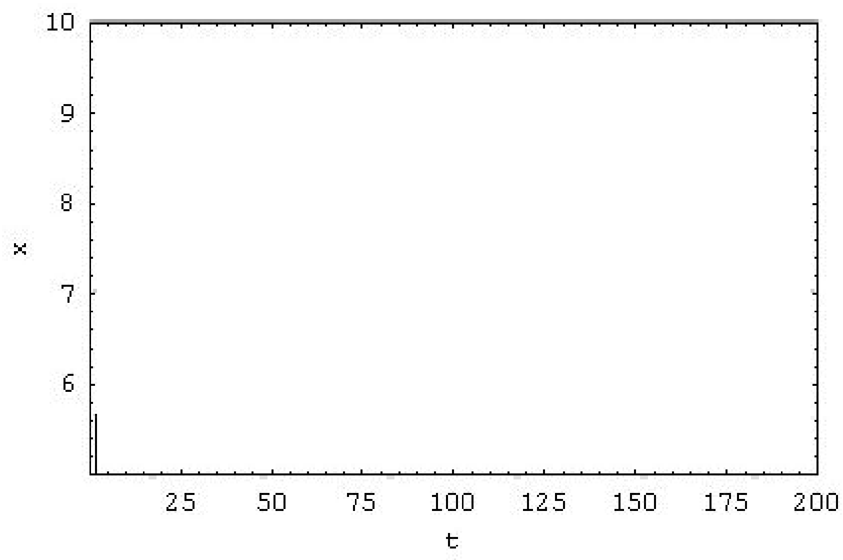


$$\dot{x} = -\frac{dV}{dx} + x \cdot w(t)$$

A variability model

The evolution of this system

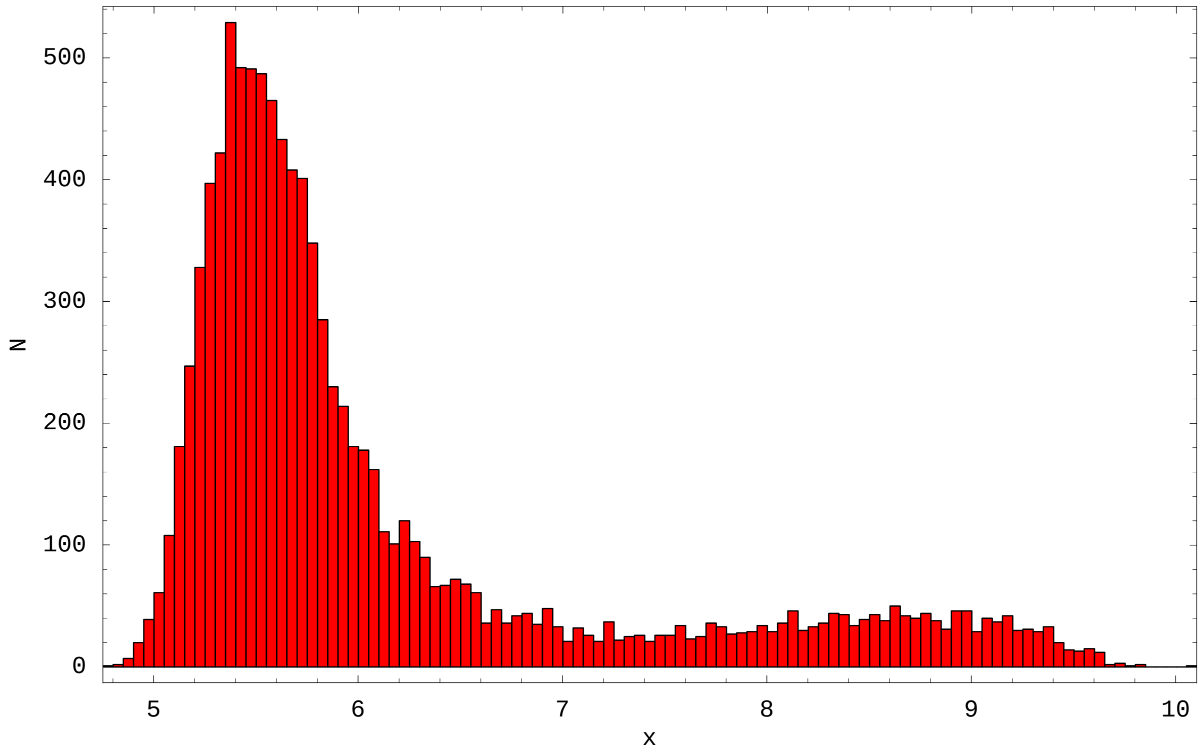




The Stohastic Component should be taken into account!

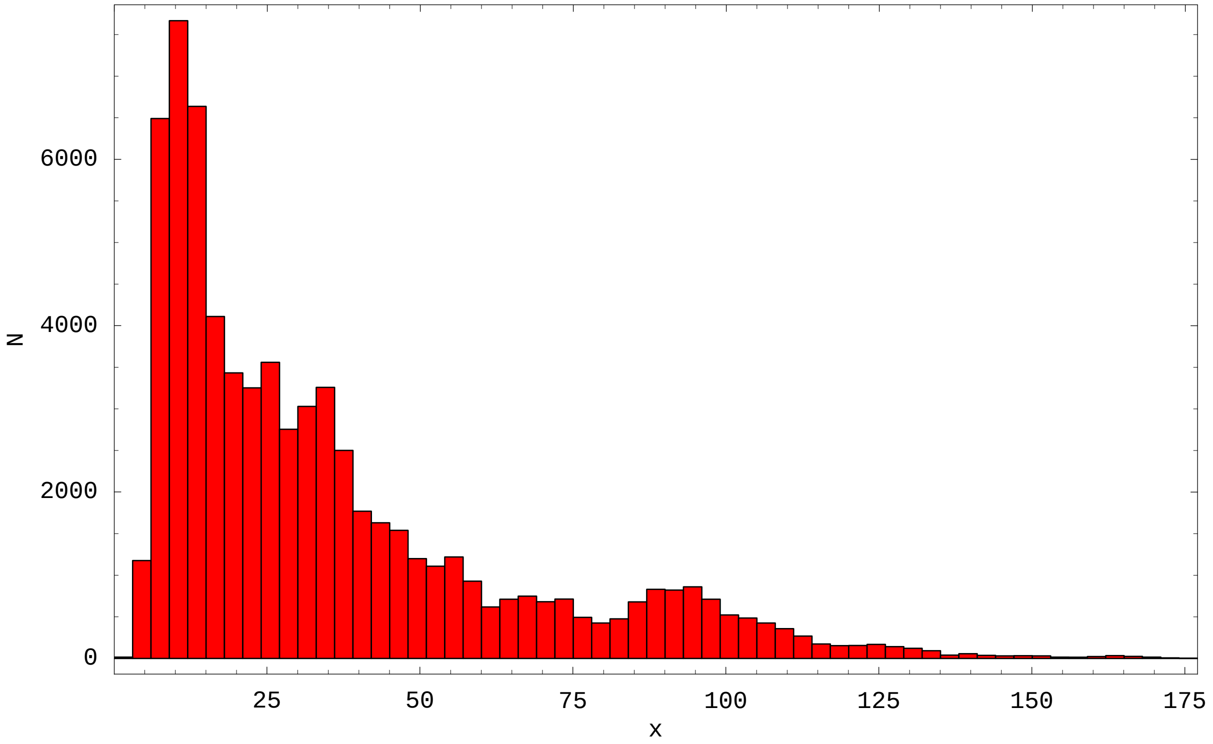
A variability model

The distribution of counts (Model)



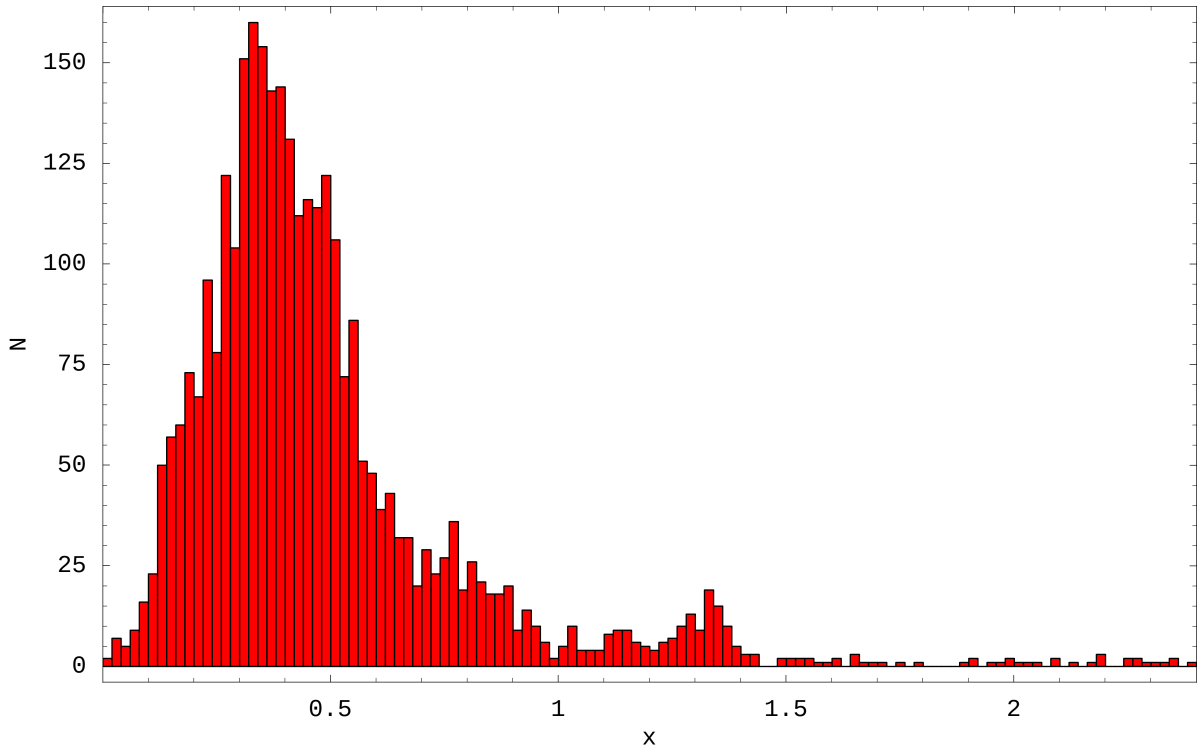
A variability model

The distribution of counts (MKN421)



A variability model

The distribution of counts (MKN501) ASM data



Conclusions

- The expectations values of the statistical moments give us a description of the physics of the system.
- MKN421 shows a form of genuine non-stationarity.
- The noise consists a fundamental component of the system.
- The time evolution of the source can be described from an asymmetric-double well energy state + noise.

Task 3

- Coordinated multi-frequency monitoring is an essential for the understanding of radiation mechanisms. The high-energy end of the synchrotron branch and the Compton-scattered emission are of special importance. The network shall develop efficient techniques for the long-term operation of a network of robotic stations. First steps include the establishment of an archive, and development of efficient statistical tools for detailed analysis of variability data. It will set up strategies for coordinated long-term monitoring programs, which will be used to carry out such long-term simultaneous observations in parallel with the European Missions AGILE and INTEGRAL and which will act as a trigger to the European TeV facilities HESS and MAGIC. Detailed studies shall be carried out for periods of about two weeks together with XMM, INTEGRAL, and ground-based Cerenkov telescopes about twice a year on sources of different overall properties. The results of short-term and long-term monitoring will be used to improve our understanding of radiation mechanisms and particle acceleration in different environments.
- We plan to arrange and carry out coordinated multi-frequency campaigns, making use of the first-time availability of a complete wavelength coverage, including radio-, mm-, near-IR, optical, X-ray, and gamma-ray instrumentation.
  Convener: L. Takalo, Tuorla, Finland, Depute: S. Wagner, LSW, Germany

Archive

- http://www.astro.utu.fi/enigma.html

”Old” Campaigns

- 0716+714 (Luisa Ostorero)
- AO 0235+164 (Claudia Raiteri)
- 3C 66A (Markus Böttcher)
- PKS 2155-304 (Stefano Ciprini, Stefan Wagner)
- OJ 287 (Stefano Ciprini)

New Campaigns: OJ 287

- http://www.astro.utu.fi/OJ287MMV
- Next outbursts (Kari Nilsson)
-
- Long-term 2005-2008 campaign started in late 2004. Recommended sampling: at least 1 data point per filter/band per week (minimum 1 R-band data point per week, with possible regular monitoring, see details below).
- Intensive intra-night observations at **NOT** (Feb.1 2005): almost totally lost due to bad weather in Europe (PI: K. Nilsson).
- **VLBA** radio-structure/polarization observations in 5 bands granted: 6 times, 8h for the period 2005-2006 (PI: T. Savolainen). More observations planned in the period 2007-2008.
- **VLBA** and global 3mm-**VLBI** radio-mm-structure/polarization observations on 4 and 17 April 2005, (PI: I. Agudo).
- **ESO VLT** spectroscopic observation awarded: period April-Sept. 2005 (ESO Period 75, PI: K. Nilsson).
- **XMM**-Newton X-ray observation awarded: 2 pointings of about 40 ksec each, on 12 April 2005 and around beginning of November 2005 (Cycle AO-4, PI: S. Ciprini).
- ToO **Effelsberg 100m** flux/polarization observations during the XMM pointing on 12 April (ToO PI: L. Fuhrmann)
- 4 sessions of Global 3mm-**VLBI** observations awarded in period Oct.2005-Apr.2007 (PI: E. Rastorgueva, K. Wiik).
- 2-years **ITP-time** application on **Canary Islands** **Observatories** submitted on Feb. 28, 2005 (PI: L. Takalo).
- OTHERS??????????

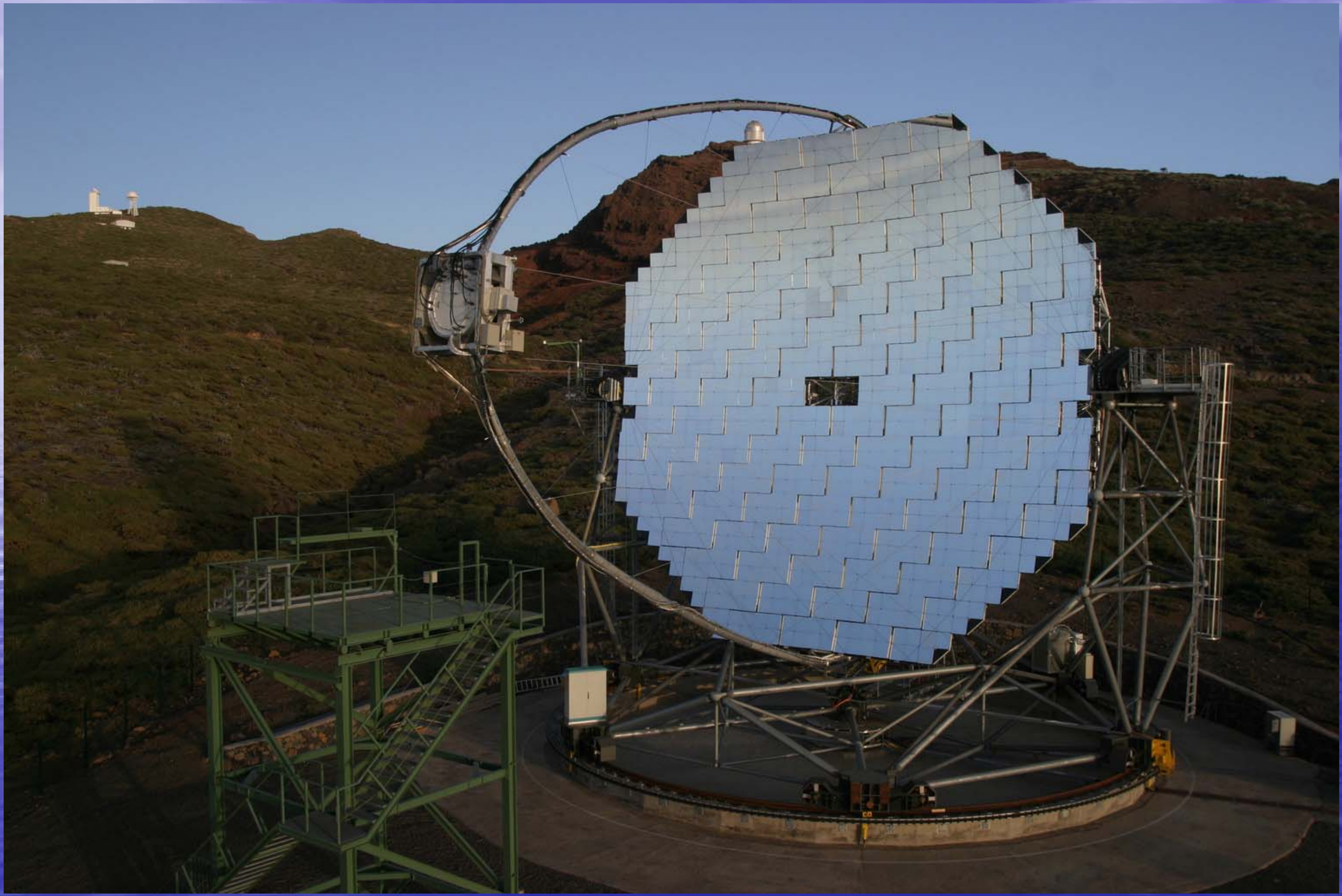
MAGIC

Regular observations since fall 2004
AGNs: Mkn 421, 1ES 1959+650

http://wwwmagic.mppmu.mpg.de

KVA

Enigma/WEBT campaigns
MAGIC support



Blazar astrophysics with HESS

Stefan J. Wagner
LSW Heidelberg

Dimitrios Emmanoulopoulos, Elisa Ferrero,
Marcus Hauser, Gerd Pühlhofer

HESS collaboration

Stefano Ciprini, Luisa Ostorero, Kari Nilsson

Blazar astrophysics with HESS

Introduction part I: AGN at high energies
Introduction part II: TeV studies with HESS

Galactic “Blazars“

Blazars: Detections, Variations, Physics

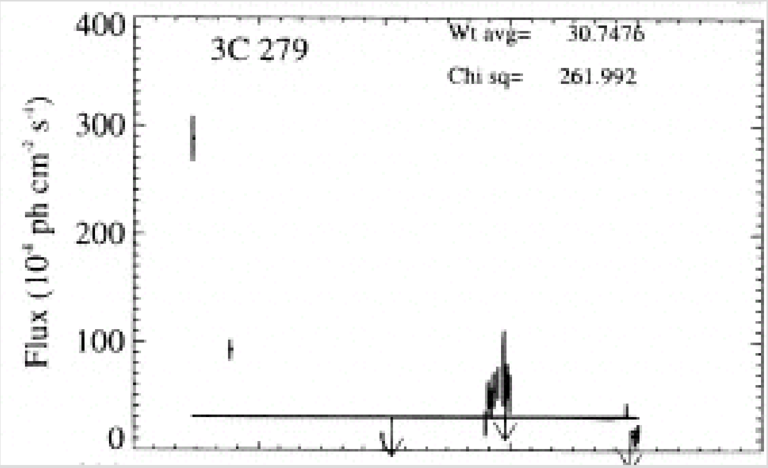
TeV emission from misaligned Blazars

Summary & Outlook

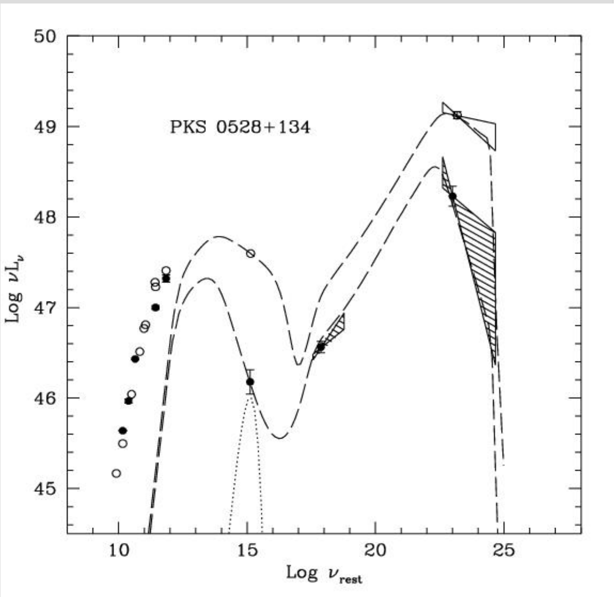
1990s: CGRO

EGRET (70 MeV up to a few GeV):

Blazars dominated
by gamma emission

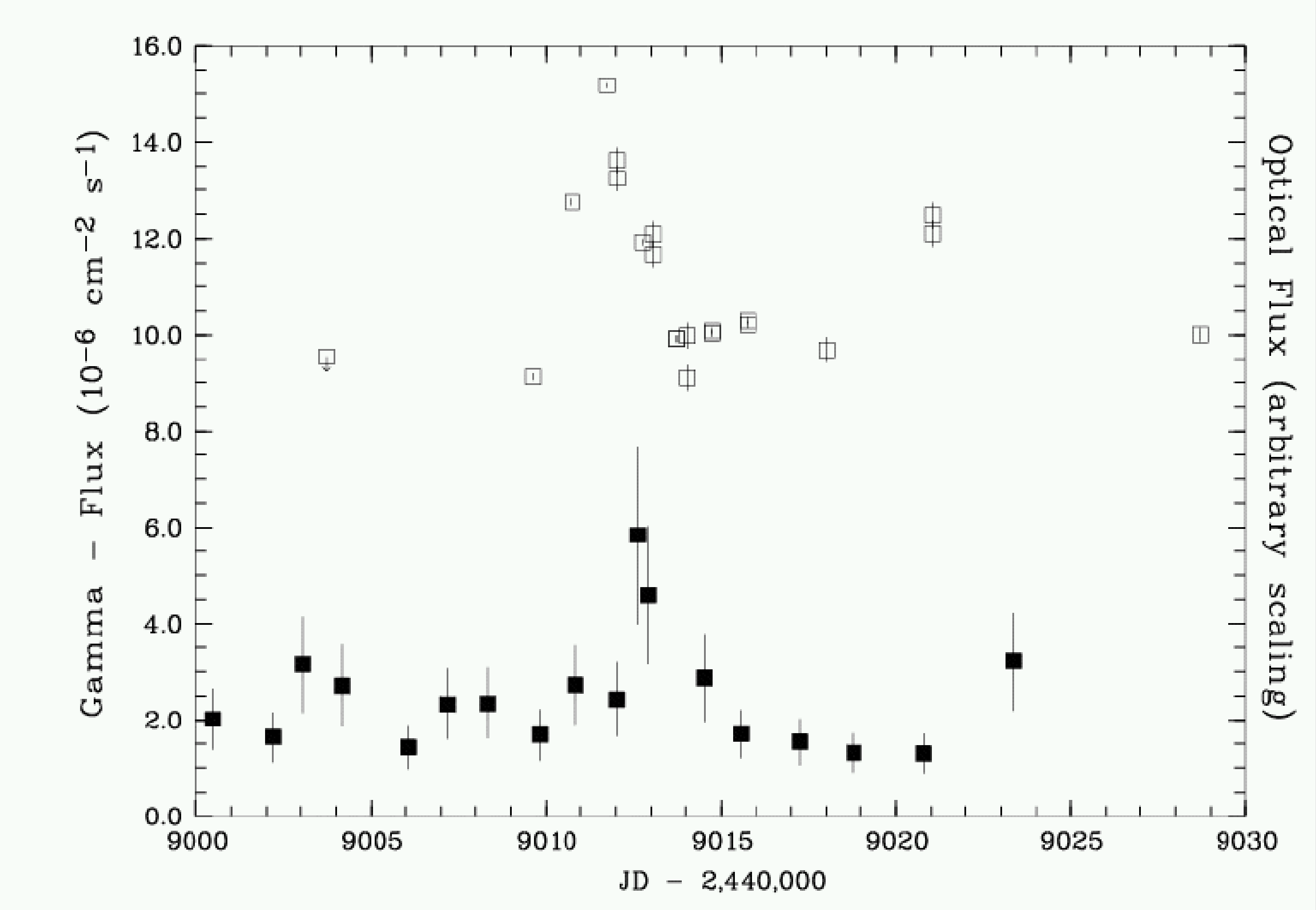


significant
variability



challenge: simultaneous SED required
Many sources observed simultaneously

Blazar Variability



PKS 1406-076 Wagner et al., ApJ 454, L97, 1995

Blazar Variability

Variability was key to identification
(PSF > 1 degree, astrometry to ~0.3 degree).

Coincidence of high-b sources with Blazars
simultaneous variations.

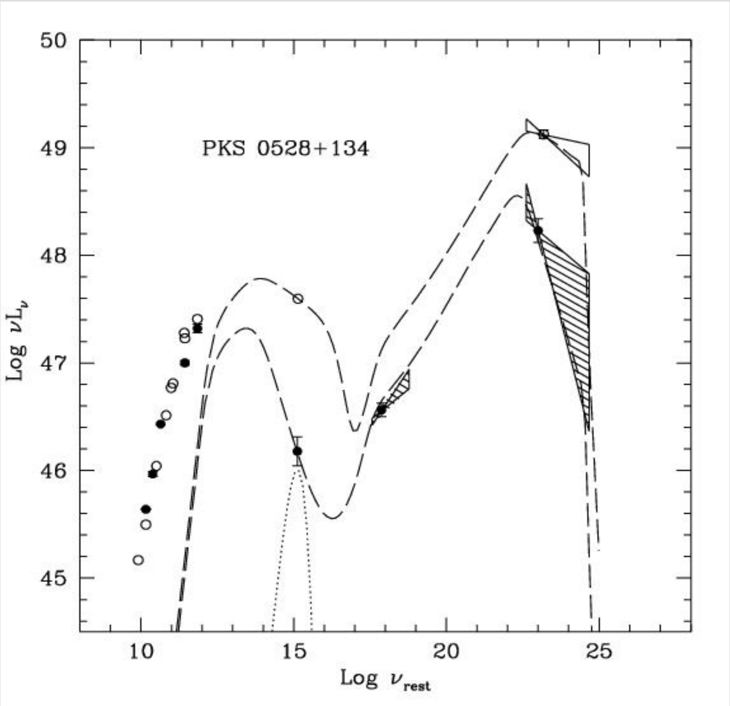
Detections only during (unpredictable)
flares, but large (0.6 sr) fov.

~70 Blazars “identified“

High energy emission

Variability requires relativistic amplification
Gamma-ray emission originates in jets
Compton scattering related to synchrotron emission

PKS 0528+134
von Montigny , et al. 1999



SSC
Scattering of ambient radiation

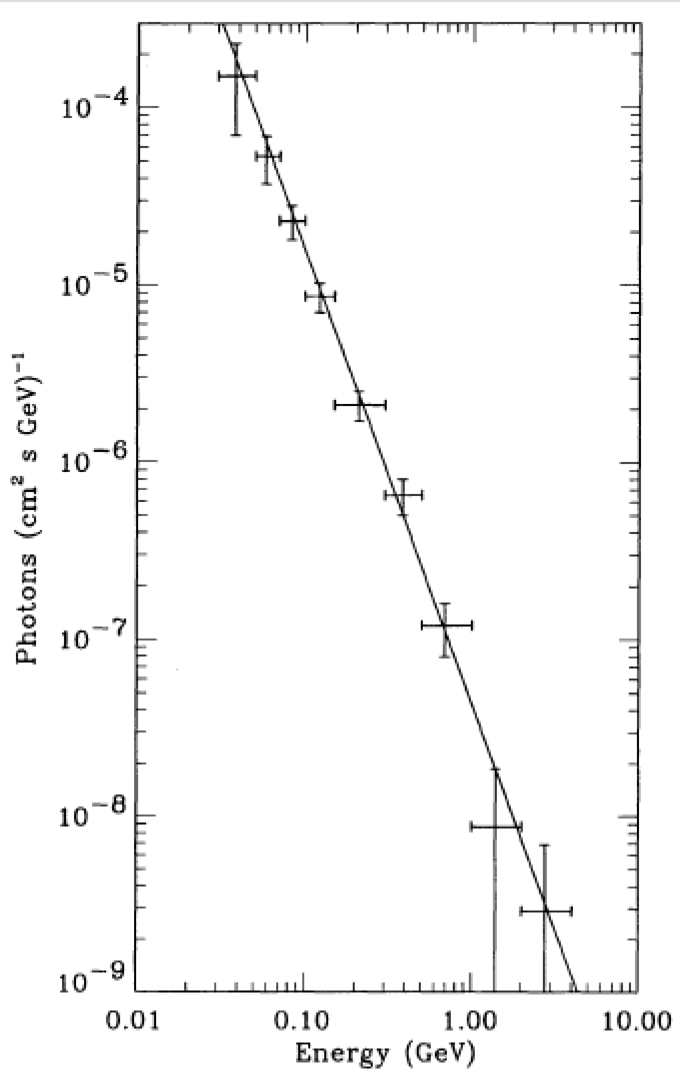
unknowns:
unbeamed radiation fields
energy spectra of particles
(e.g. E_{max})

Going beyond GeV

GeV : TeV, 1 000 000 : 1 ph.
EGRET detected a few 1000 ph.
space-borne detectors insufficient

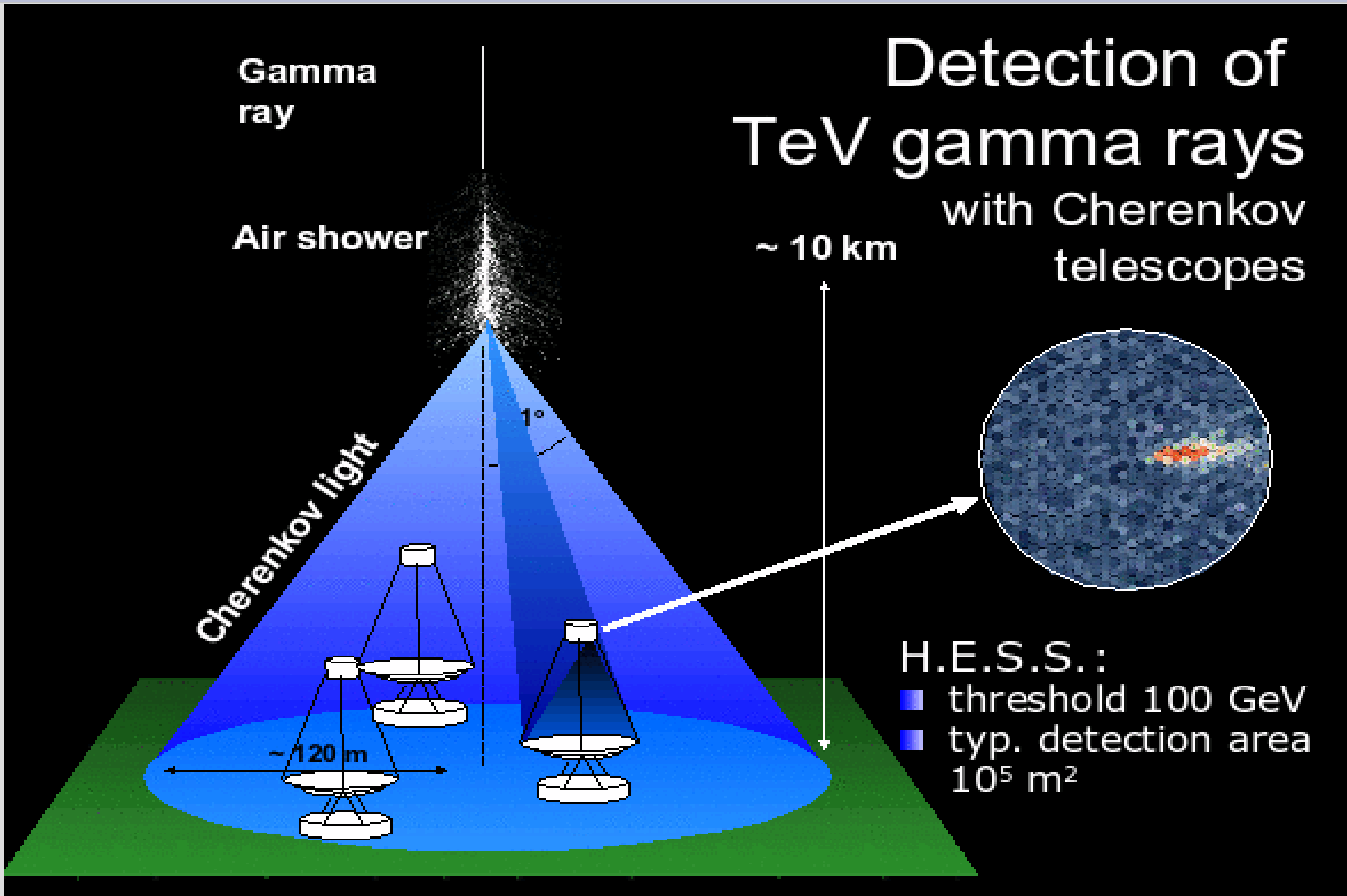
Make atmosphere your detector

Cherenkov flashes from particles
surface-brightness > night-sky
(within a few ns)
[In 100 sec 25mag below sky]

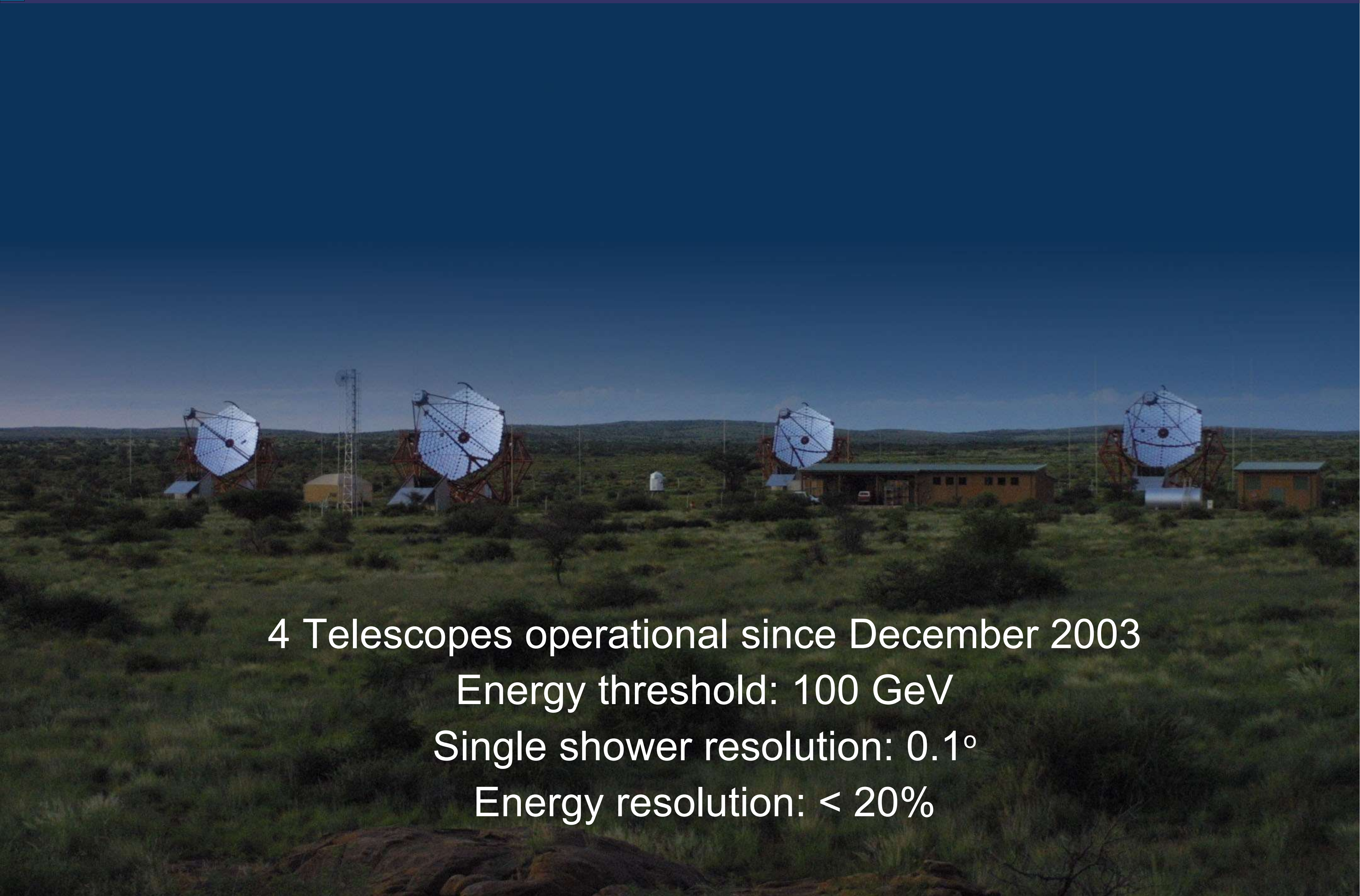


needs: fast detectors, large collection area, wide fov

Recording TeV radiation



The H.E.S.S. experiment



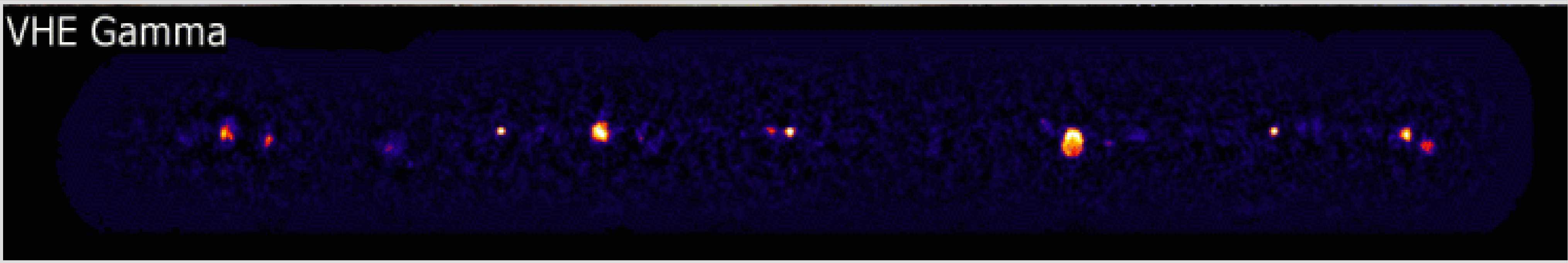
4 Telescopes operational since December 2003

Energy threshold: 100 GeV

Single shower resolution: 0.1°

Energy resolution: < 20%

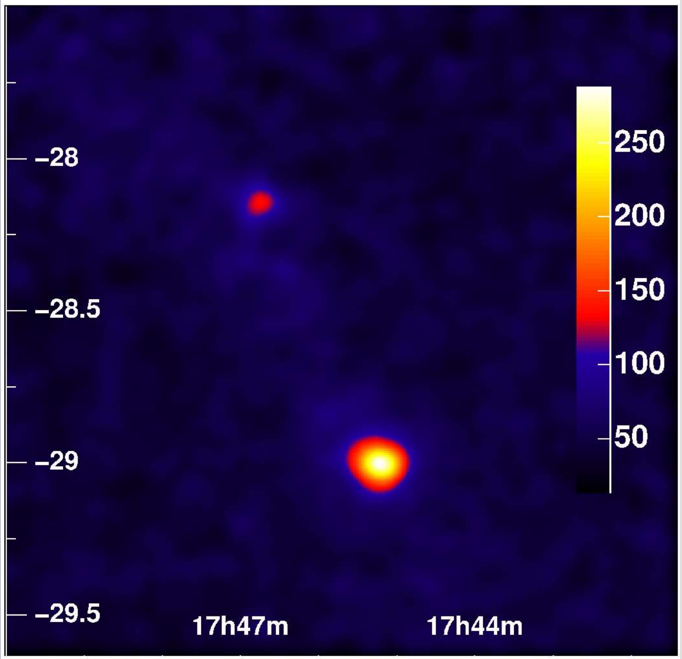
Galactic Black Holes I



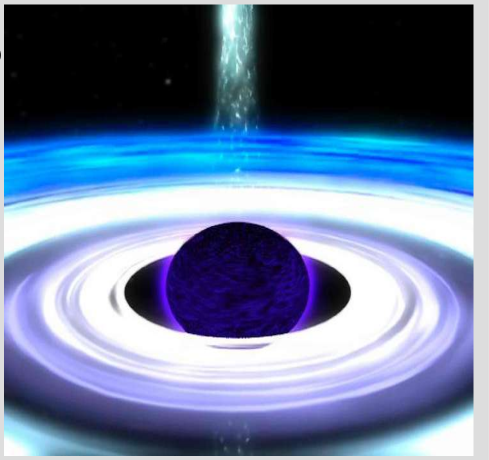
Supermassive ($M \sim 3 \cdot 10^6$ M) rotating black hole embedded in a magnetic field

$\Rightarrow$ large *emf*

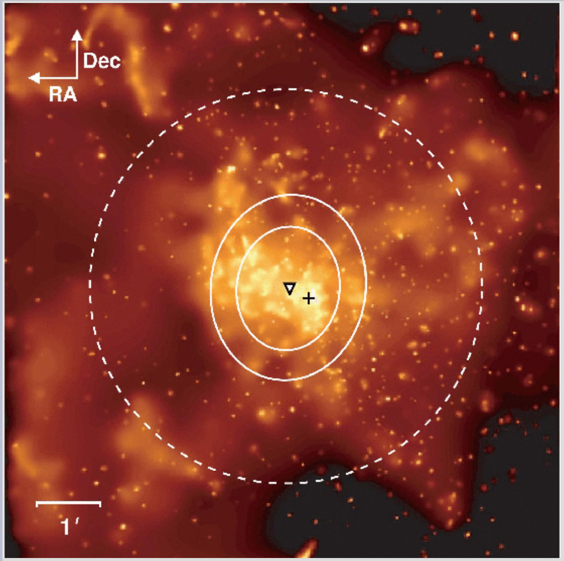
- accelerate protons up to 10^{18} eV ($\pi^0 \rightarrow \gamma\gamma$)
- or accelerate electrons (γ-rays via IC)



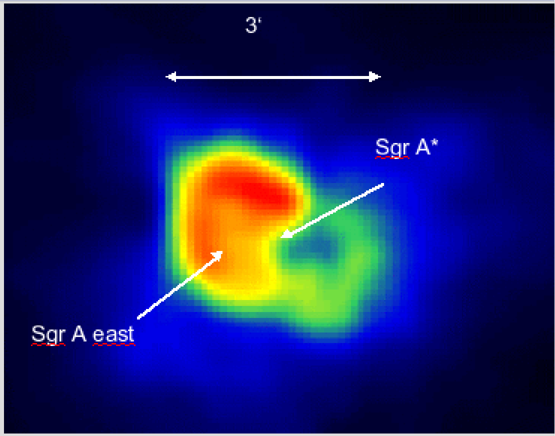
TeV emission from Sgr A*?



TeV source at the galactic centre



TeV emission from Sgr A*?
... or from another source?



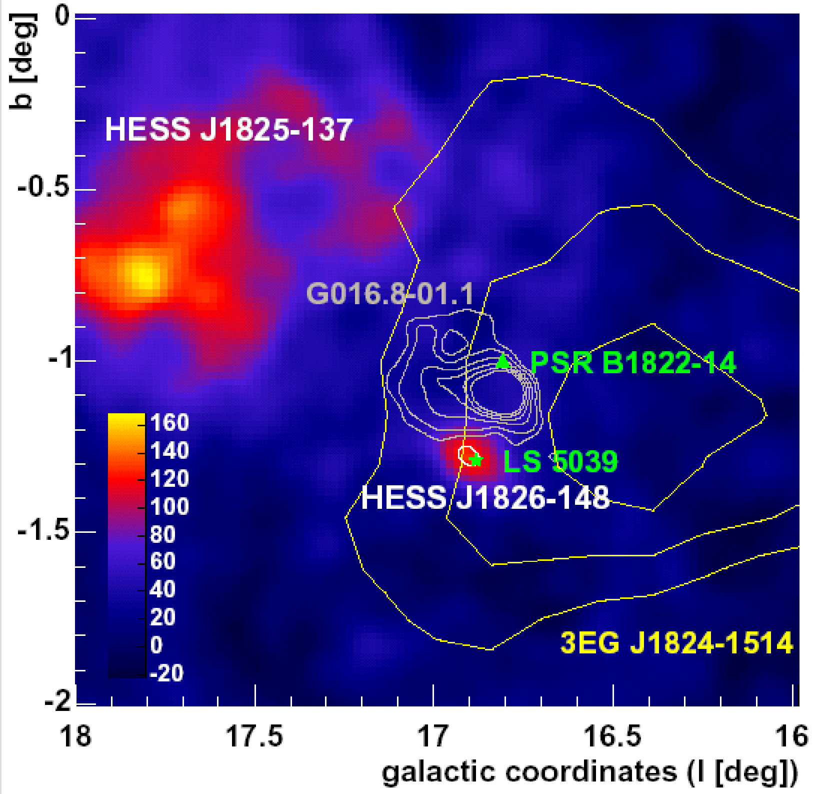
Variability may tell...

So far no variability has been detected,
but variability with amplitudes as seen in the
X-rays (Baganoff et al.) cannot be excluded.
Idea: Beat on 2 keV data
Multifrequency observations scheduled for 2005

Galactic Black Holes II

LS 5039, one of 2 XRB with mas radio source. (Microquasar)

Massive O6.5V star, orbiting a compact source.



Separation between 2R* and 6R*

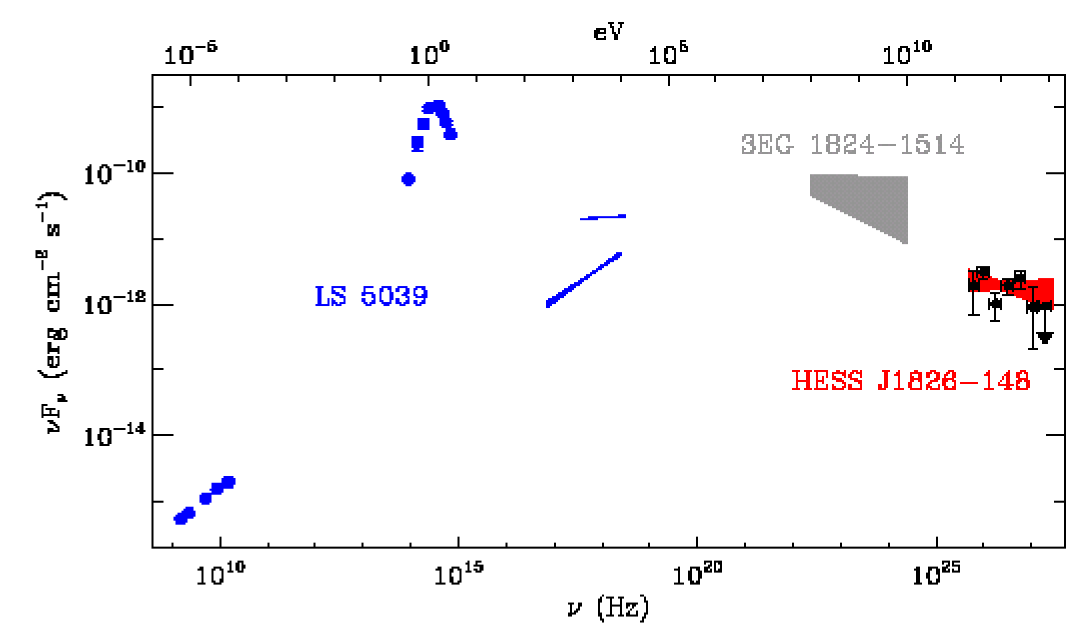
Plenty of photons for IC radiative losses within 300 s

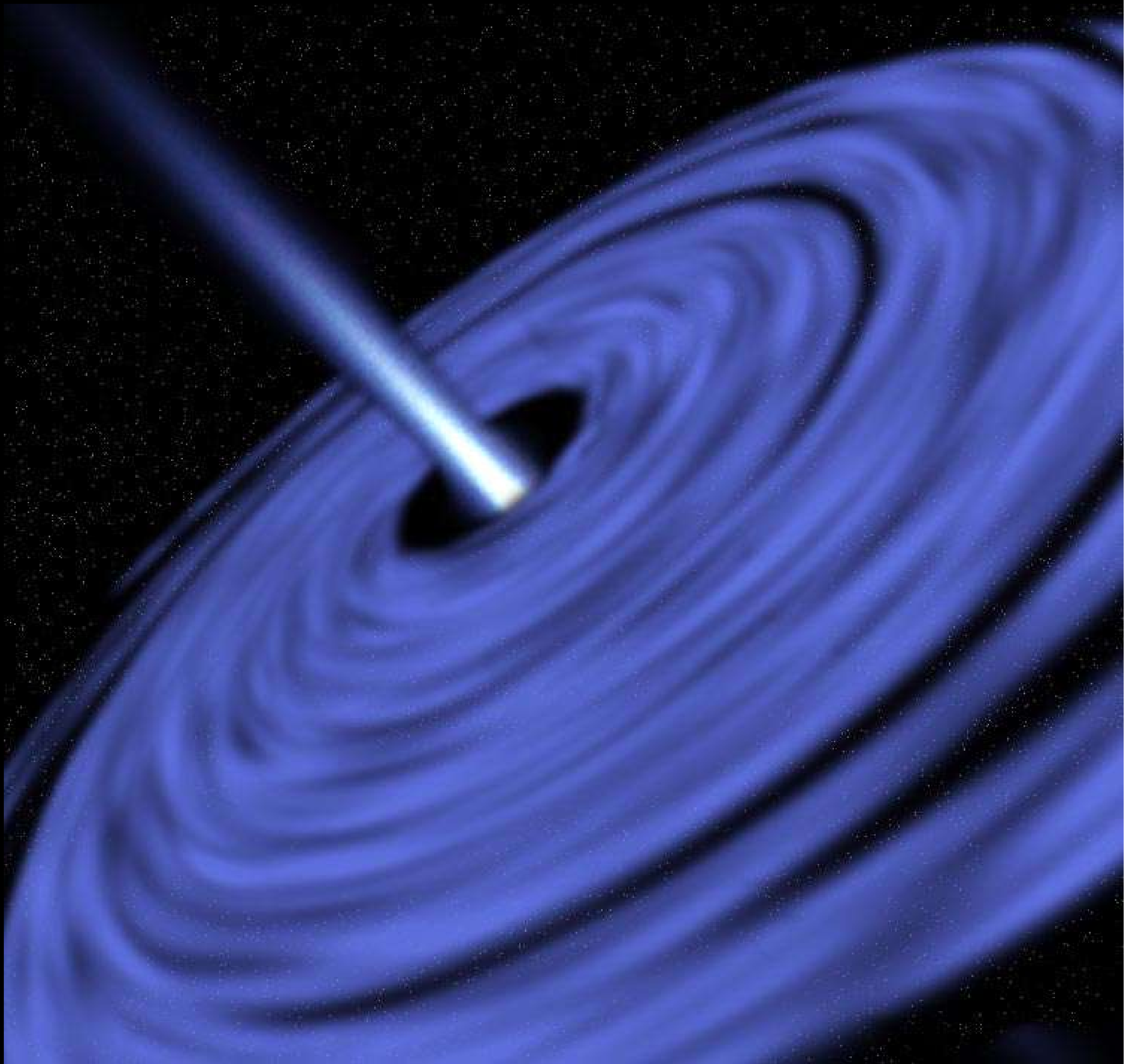
might limit acceleration.

TeV via pp on stellar wind?

Galactic Black Holes II

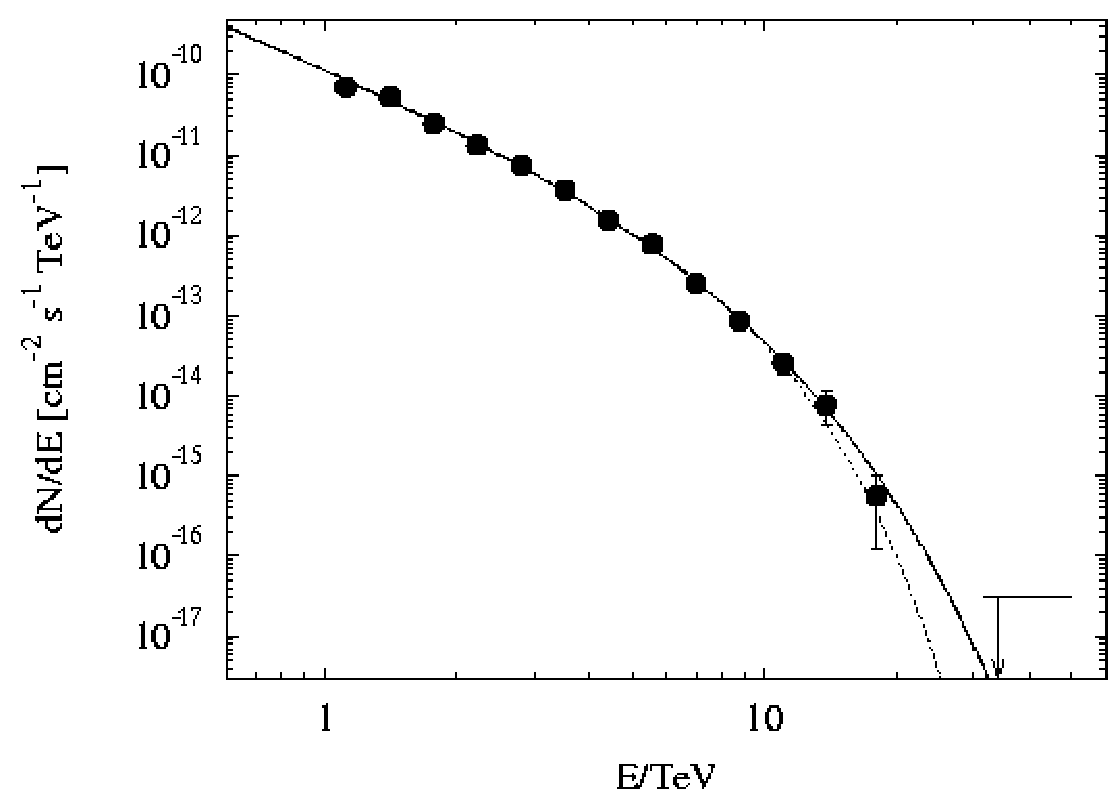
Emitted HE photons get absorbed on 3.5 eV field.
Opacity ~20 for distance ~ binary separation.
VHE photons always generated within photosphere.
Pair cascade, redistributing absorbed radiation.



Mrk 421 I (Spectrum)

Confirmation,
improved sensitivity (spectra)



Observations 3 months in '04

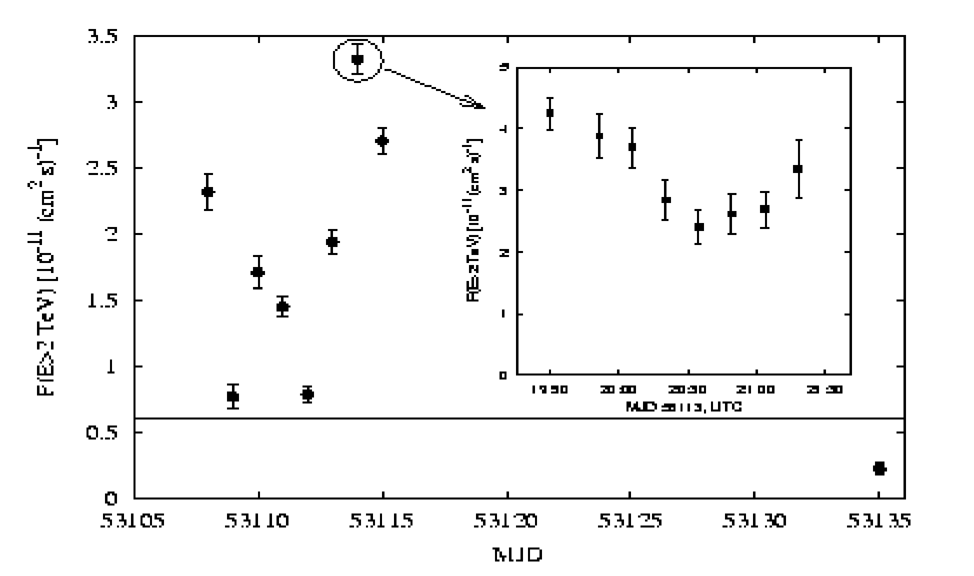
Range of zenith angles:
60.3 d < ZA < 65.4 d
Large collection area: 2 km
at 10 TeV energy threshold
High significance:
7000 photons, 100 sigma

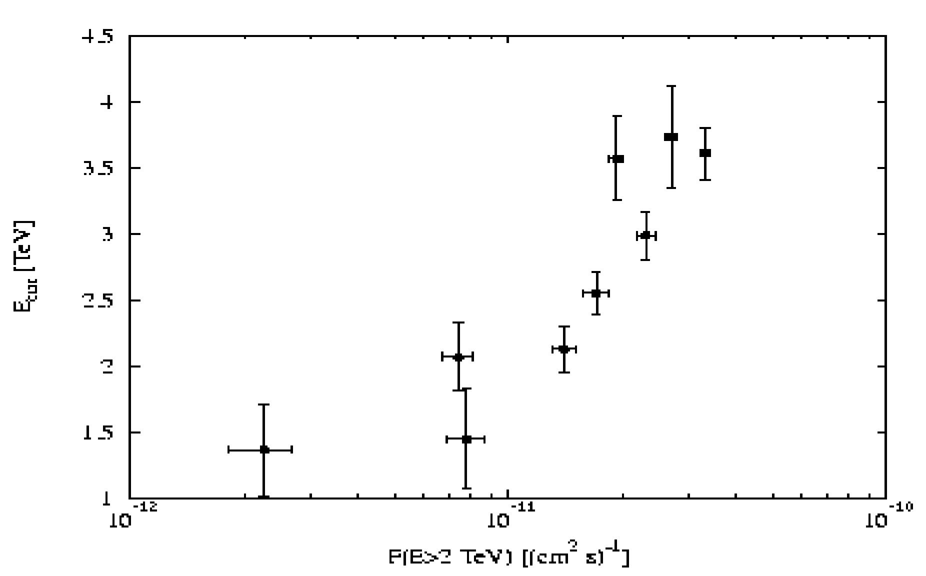
$\Gamma = 2.1 \pm 0.1_{stat} \pm 0.3_{sys}$ $E_c = 3.1(+0.5 \ -0.4)_{stat} \pm 0.9_{sys}$ TeV

Curved spectra (Power-law with exponential cutoff):

Mrk 421 II (Variability)

Variability on all time-scales (ksec – months).
Power-law index and cut-off correlated in nighly averages
Spectral variability prohibits integrating long enough
Flux correlates with cut-off energy (hardness?)
SED monitoring (X-rays, MAGIC?)



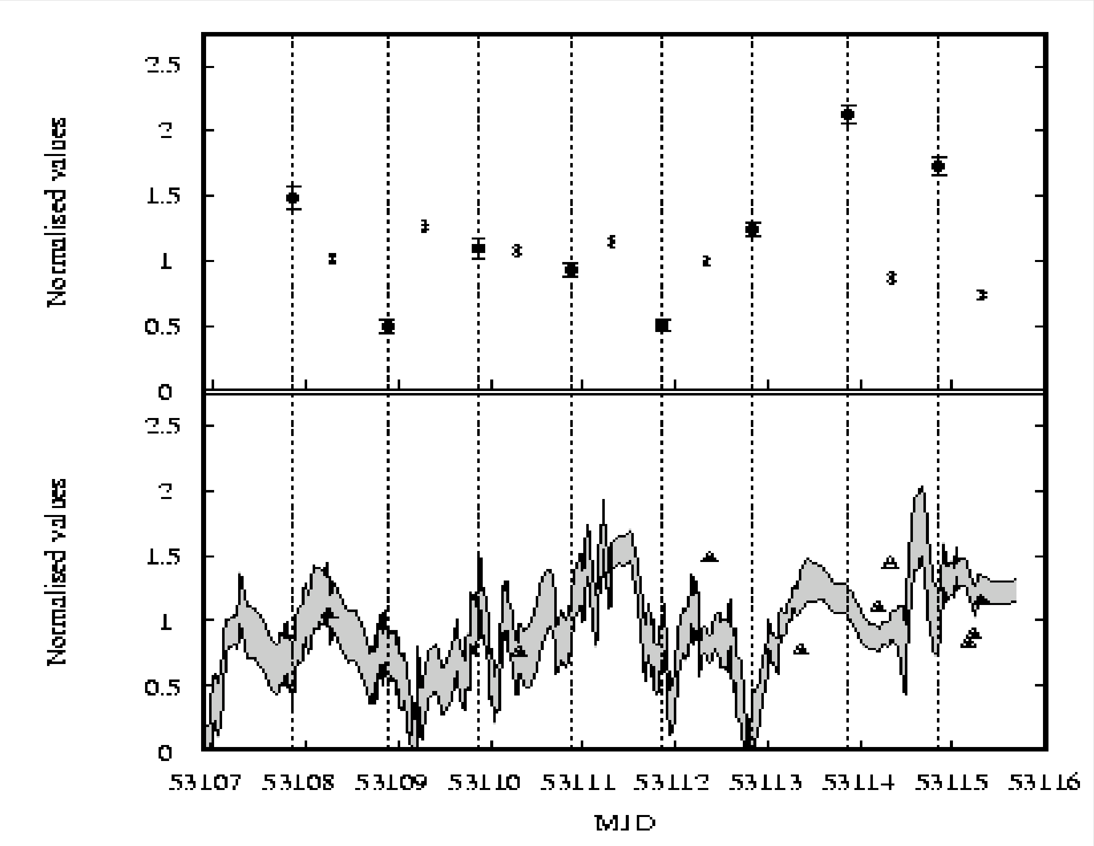


A clue to studying spectral evolution with full temporal resolution

Mrk 421 III (Correlations)

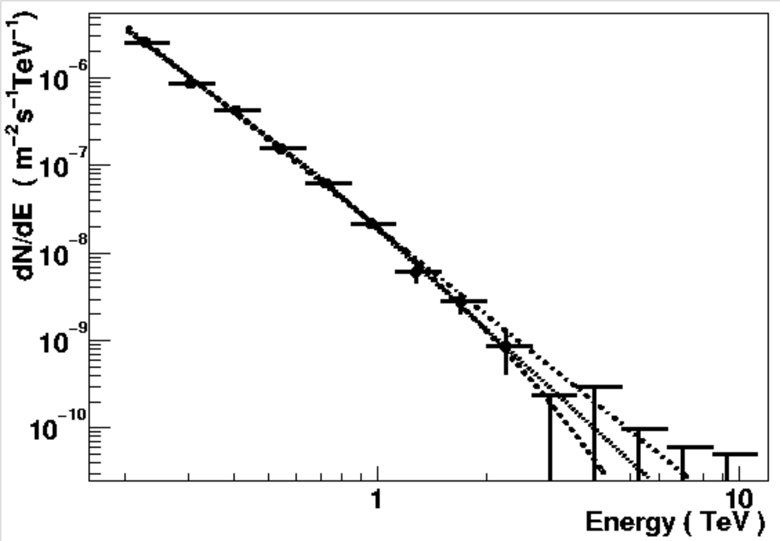
Comparison to other wavebands/contemporaneous data
(Whipple data taken from Cui et al., 2004)

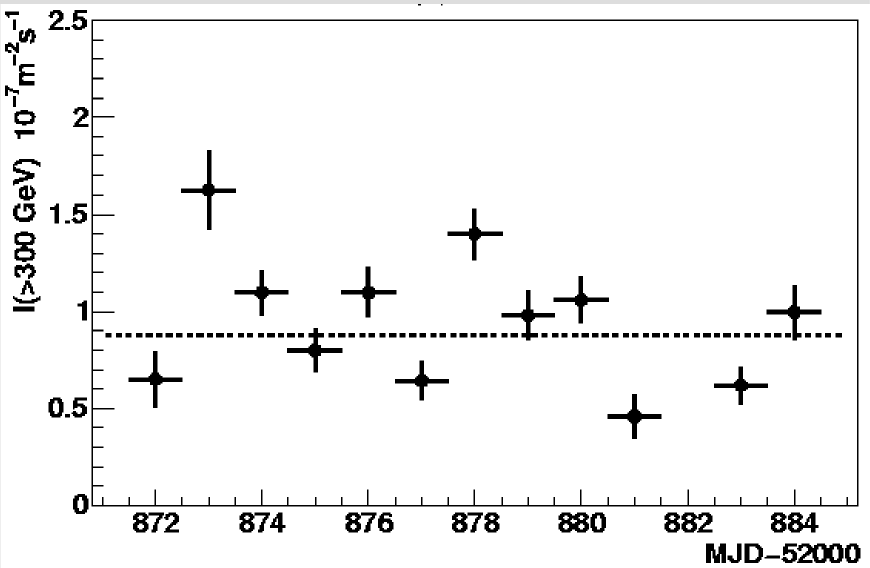
TeV-data not simultaneous
Little overlap in time (ZA)
normalized lightcurves
variability amplitudes:
HESS: 80 %, Whipple 30 %
Different energy ranges
Beware of missing siblings



Poor correlation to X-rays
Variability too fast ?

PKS 2155-304

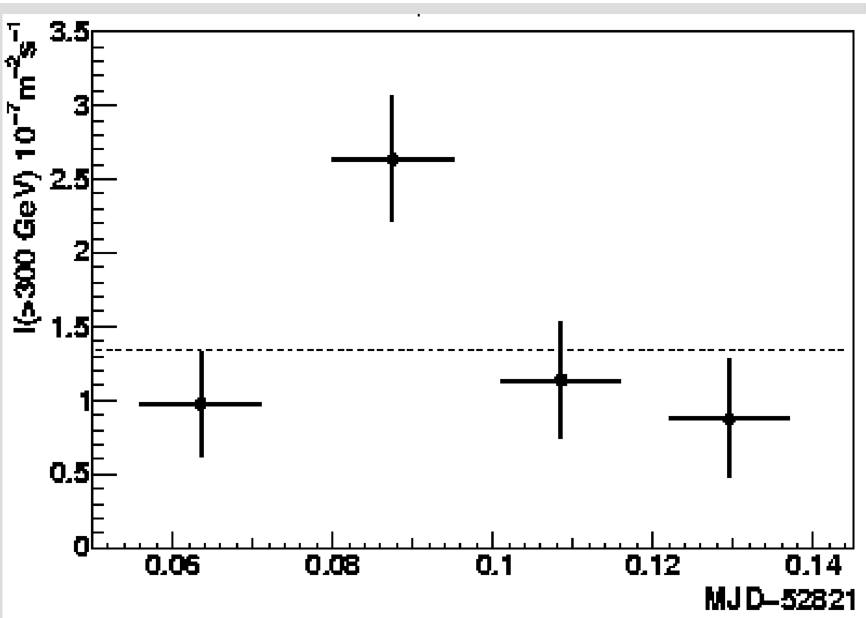




Detection in 2002, 2003 with single telescope already: astro-ph/0411582

Powerlaw spectrum, Index: -2.9
variability: years – minutes

Suggests Doppler factor $\mathcal{D}$ ~ 50



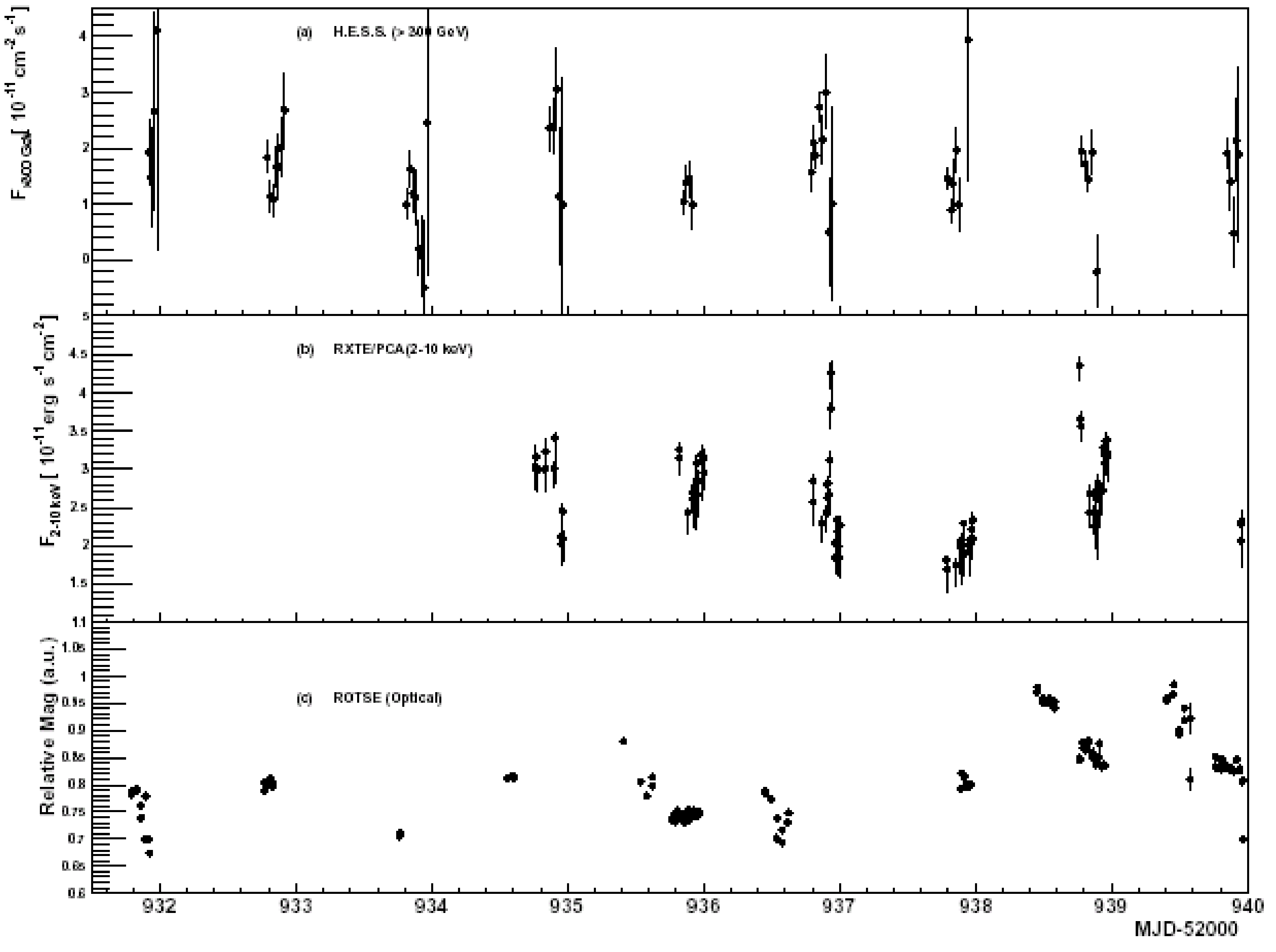
PKS 2155-304

2003 campaign

H.E.S.S.

XTE/PCA

Optical

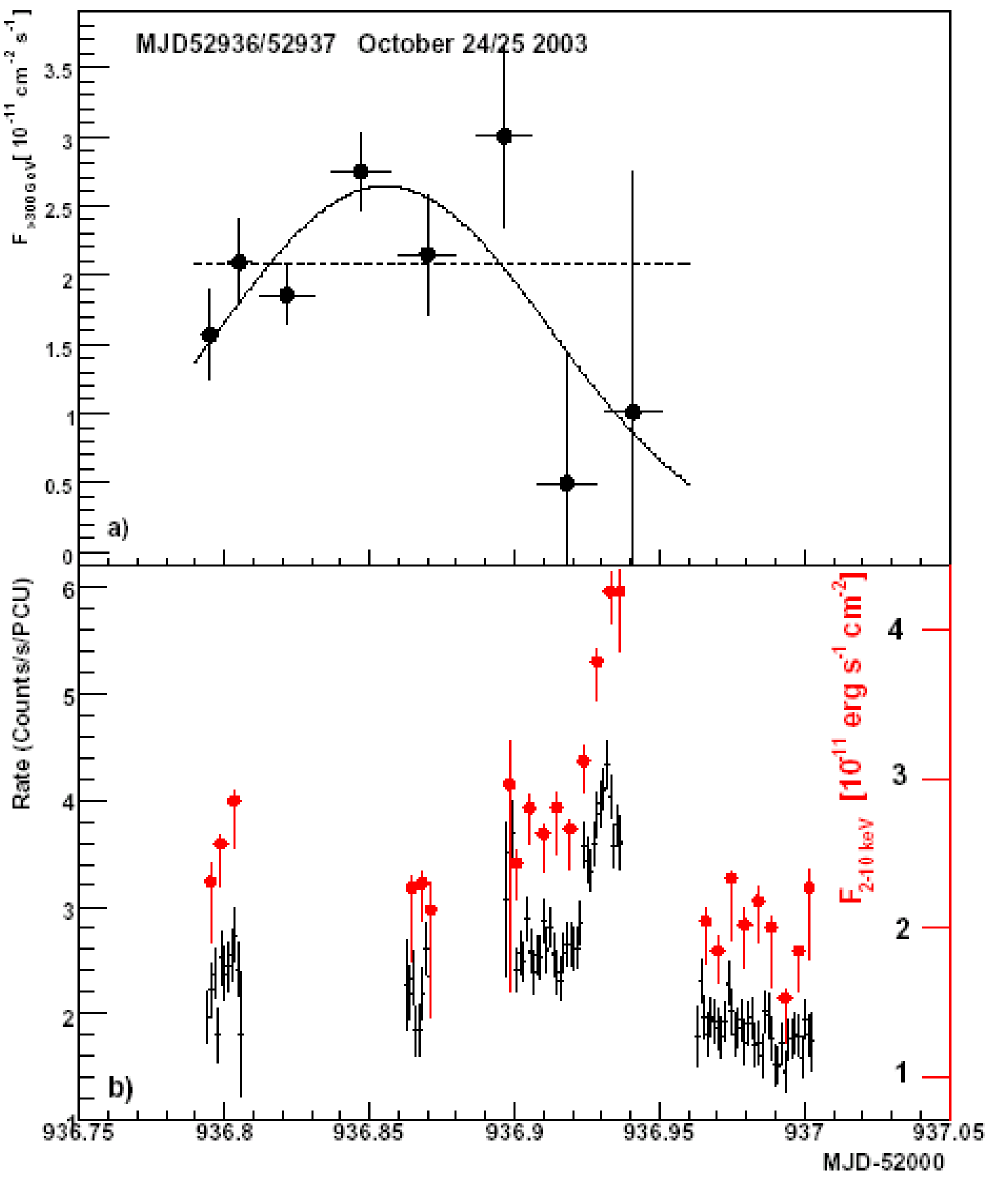


PKS 2155-304

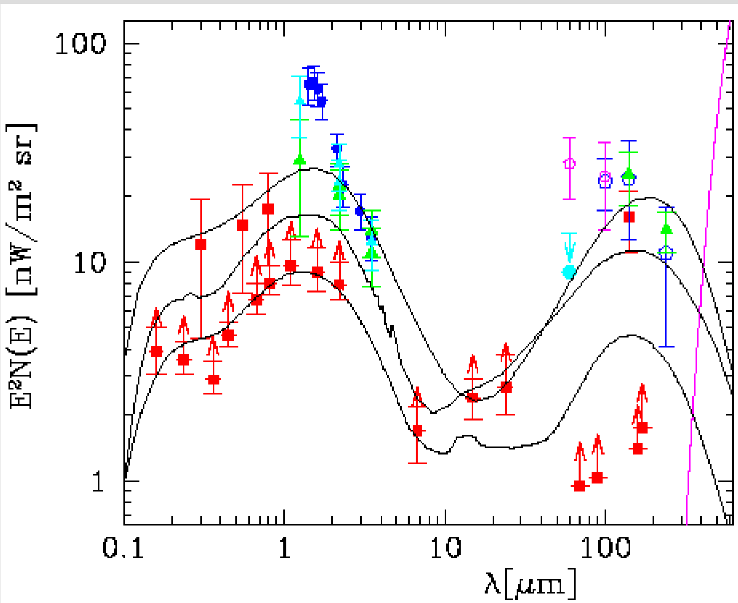
TOO campaign triggered by a high state

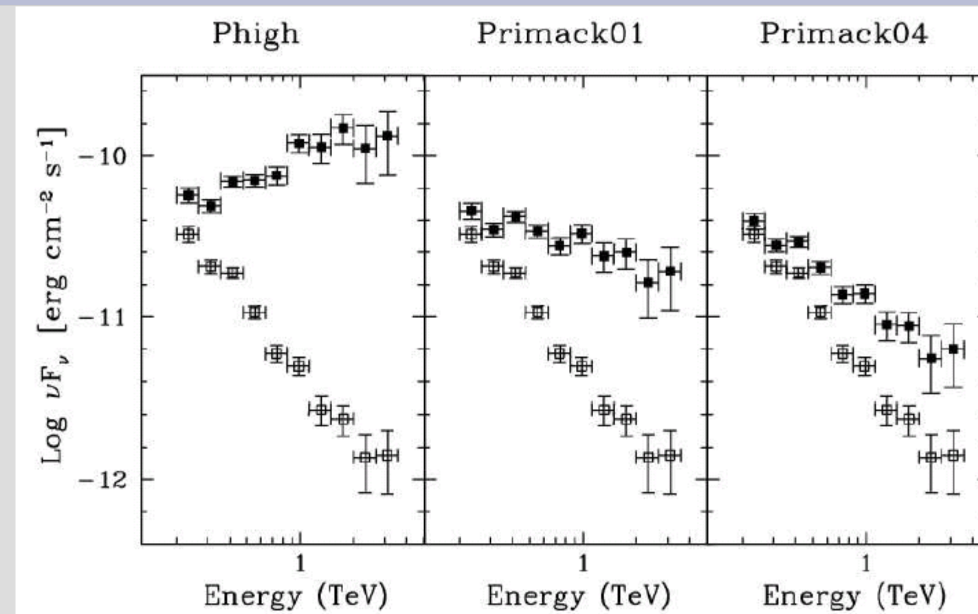
Trigger activation delayed by 8 days,
PKS 2155-304 had faded

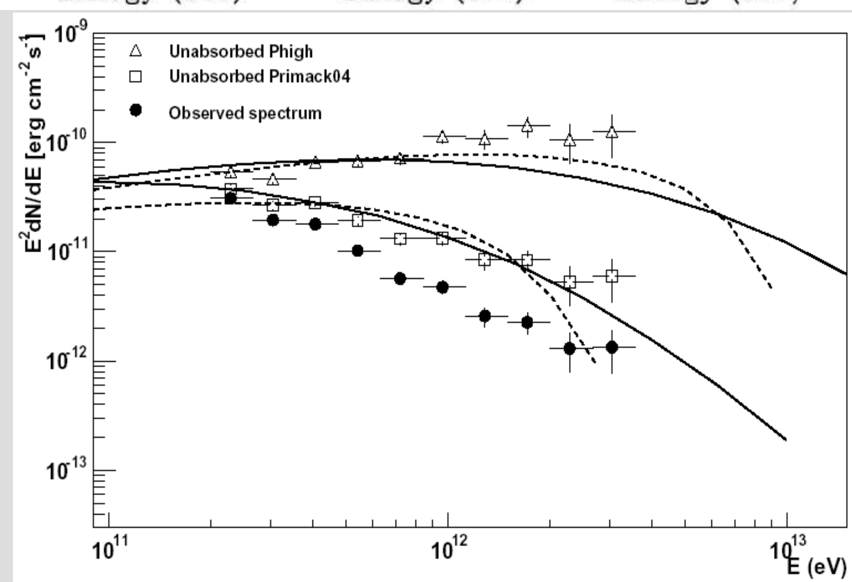
run-by-run detections
X-ray variability
weak VHE variability
no correlation run-by-run



Modelling PKS 2155-304

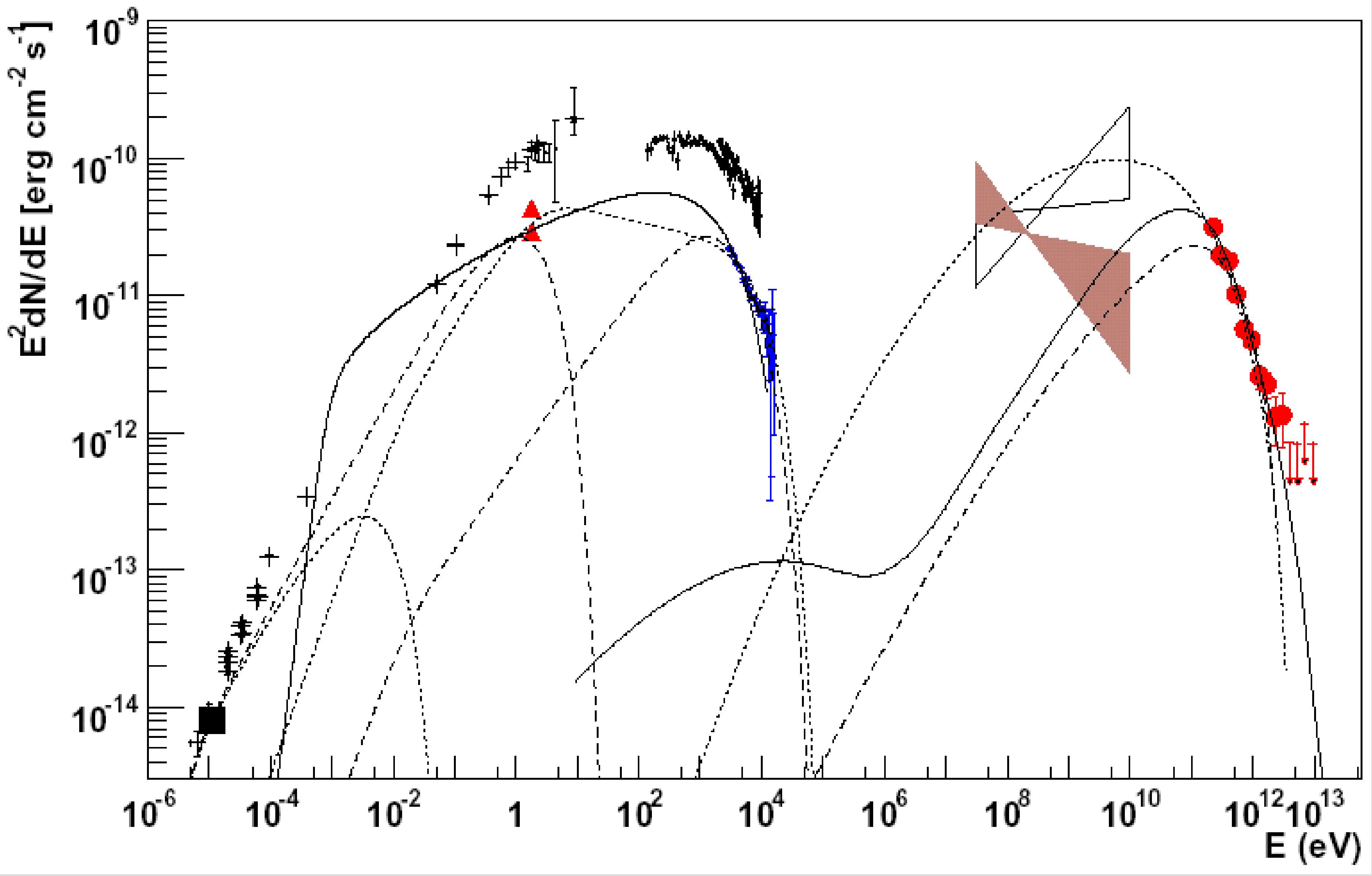






Interpretation of SED
linked to
Knowledge of EBL
Klein-Nishina or
IC in Thomson Regime?

Modelling PKS 2155-304



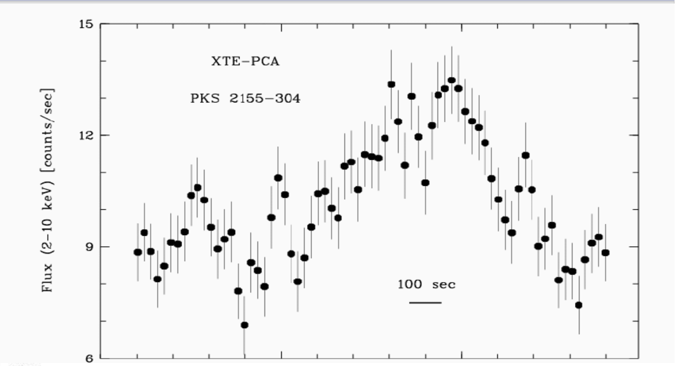
PKS 2155-304

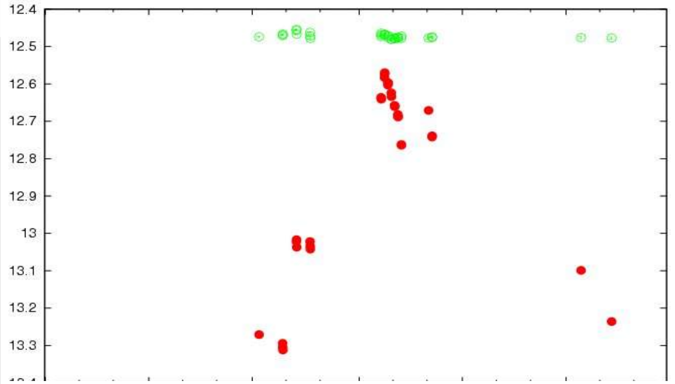
PKS 2155-304 can vary much more rapidly than found in the past (ROSAT, ASCA, SAX, XTE)

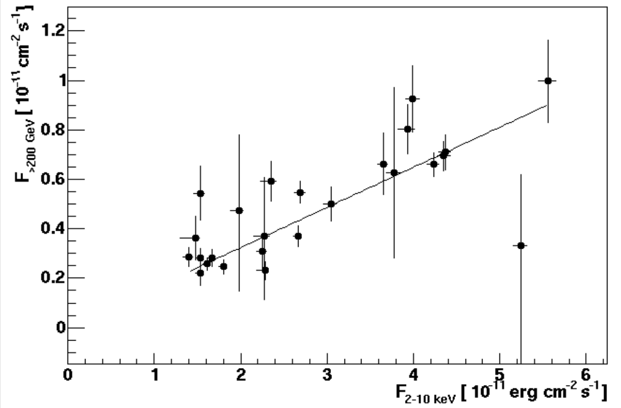
Rather bright optical state (X-ray state normal)

TeV data set partially affected by low atmospheric transmission (more problematic to correct than optical, mm observations)

Partial data set correlated with X-rays

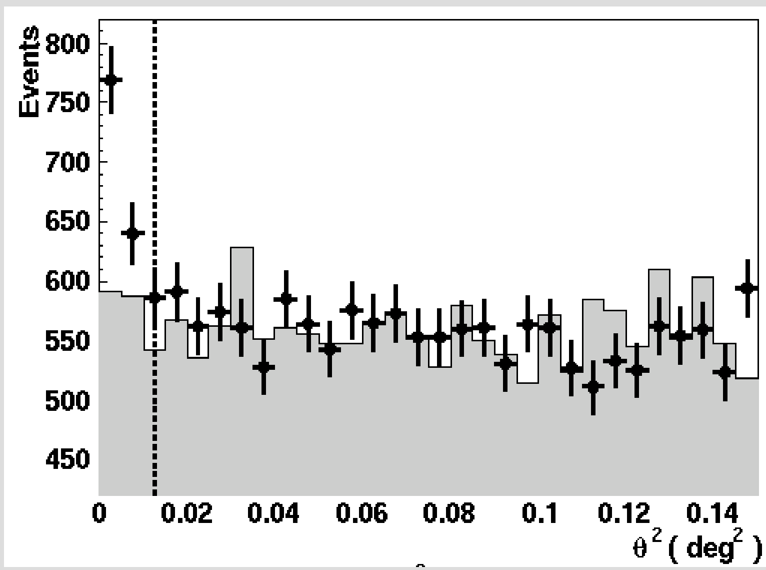


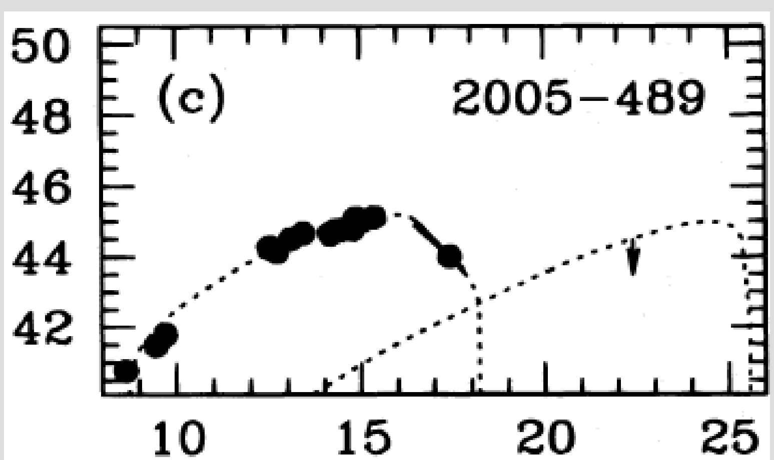


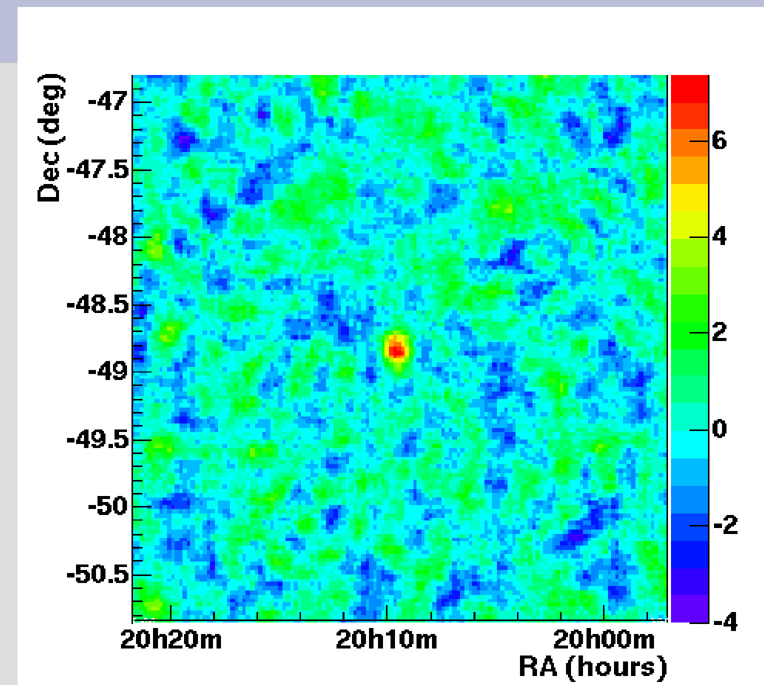


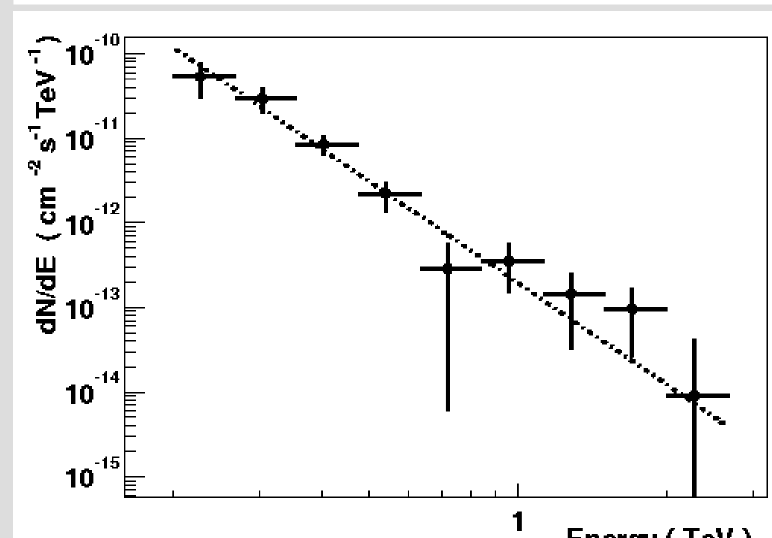
PKS 2005-489 (detection)

PKS 2005-489

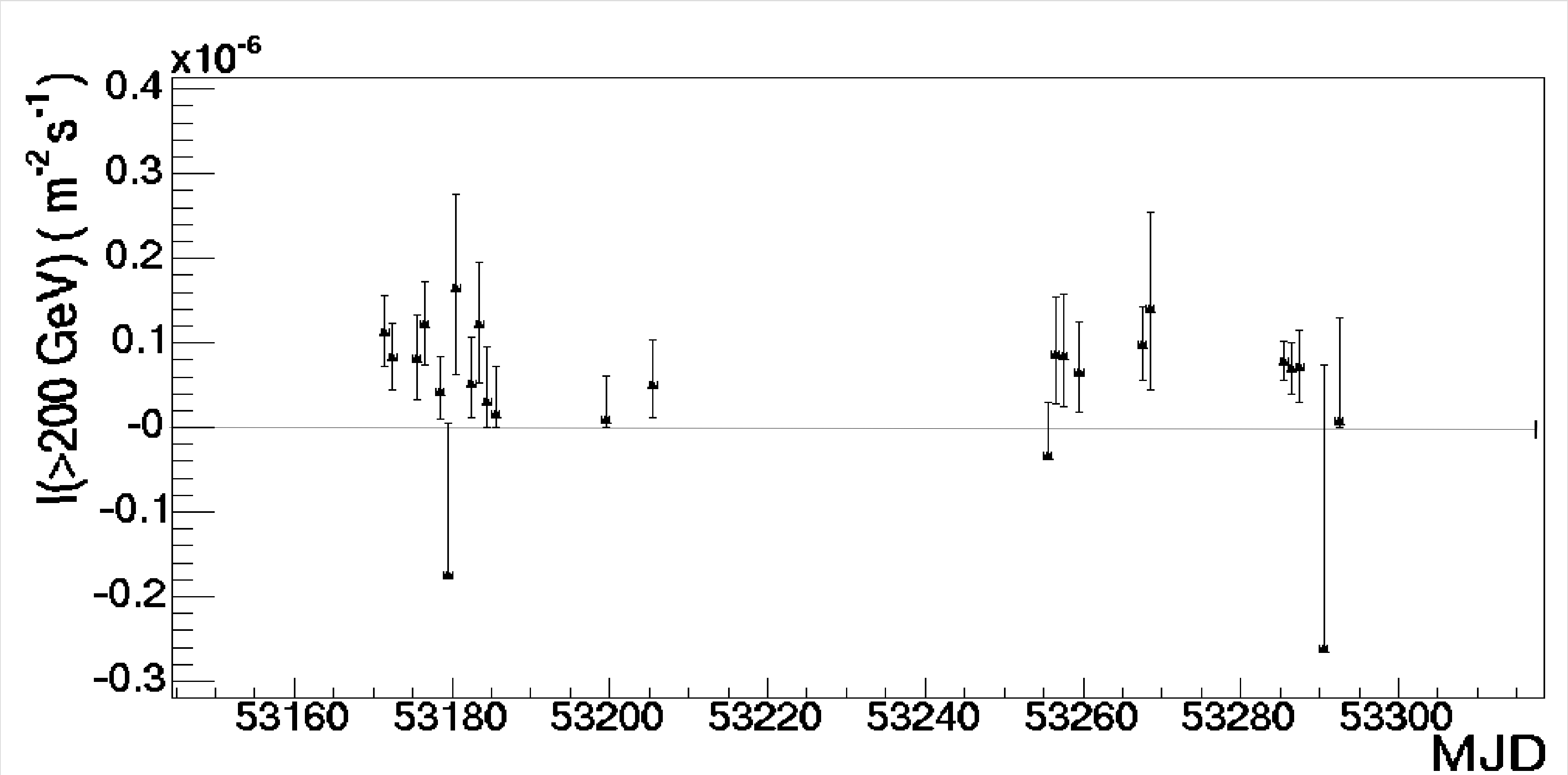




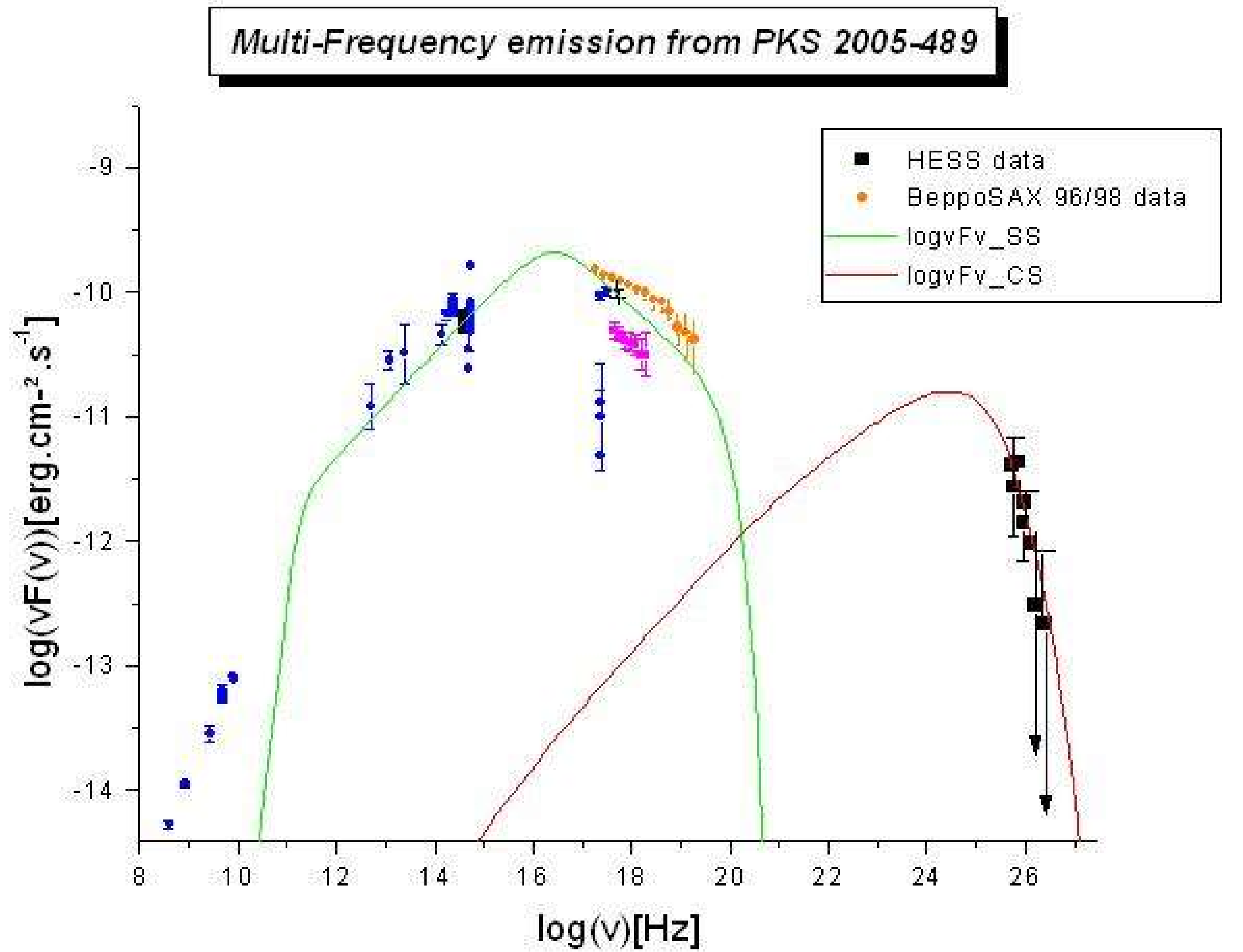




PKS 2005 – 489 (low state?)



PKS 2005 – 489 (SED)



PKS 2005 - 489

- PKS 2005 is detected in 2004 (6.7 σ)
  - PKS 2005 is not detected in 2003 (1.4 σ)
  - Combined significance is 6.3 σ
- Steep spectrum: Γ = 4.0 +/- 0.4
- not significantly affected by pair-extinction
- Low flux: I (>200 GeV) = ~2.5% Crab in 2004
- 2003 99.9% flux upper limit: I(>200 GeV) < 2.2% Crab
- Light curve is constant in 2003, 2004 (Runwise & Nightly)
- No indication for spectral variability
- No significant variations in ASM during 2003 or 2004
- ASM flux in 2003 lower than in 2004 (as in TeV)
- In 2003, and 2004 X-ray flux historically low.

further new sources

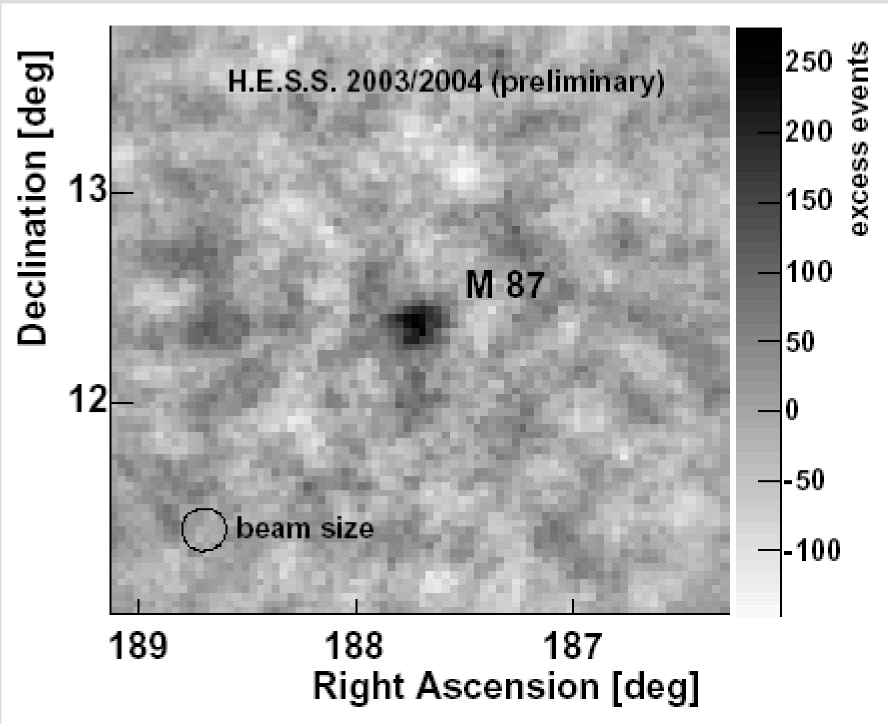
More sources probably detected (guesses, how to find out?)
TeV workshop

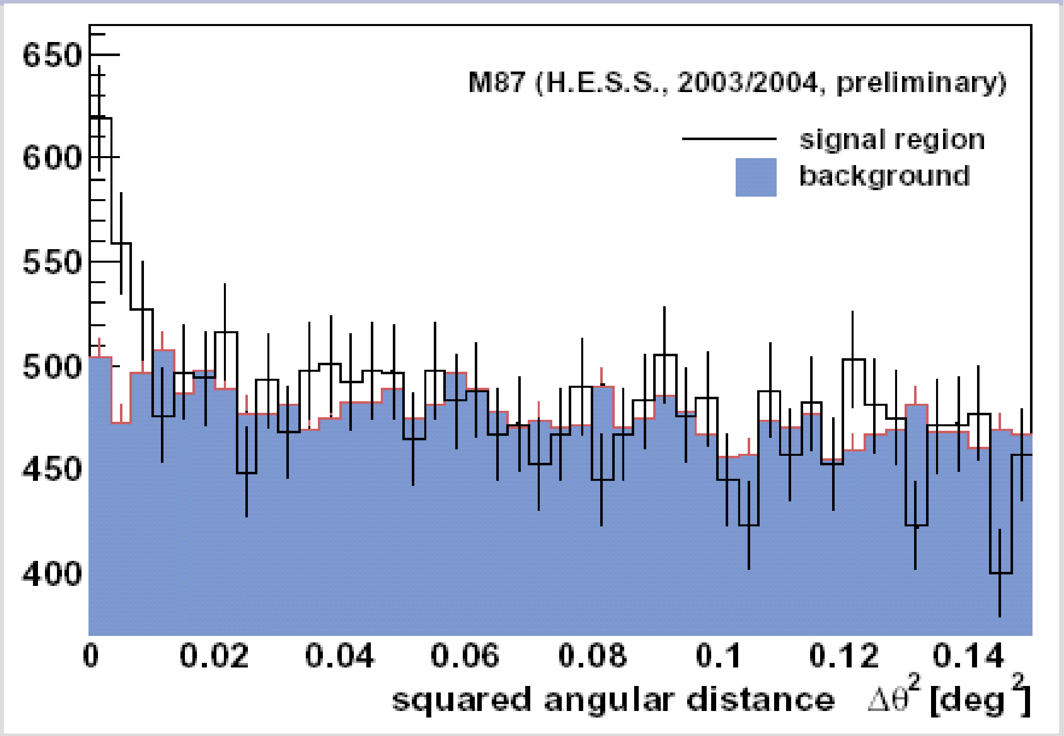
Quiescent states require long observing times

Source detection through triggers on flares.

Monitoring instrument required (ATOM) telescope moves to Namibia right now

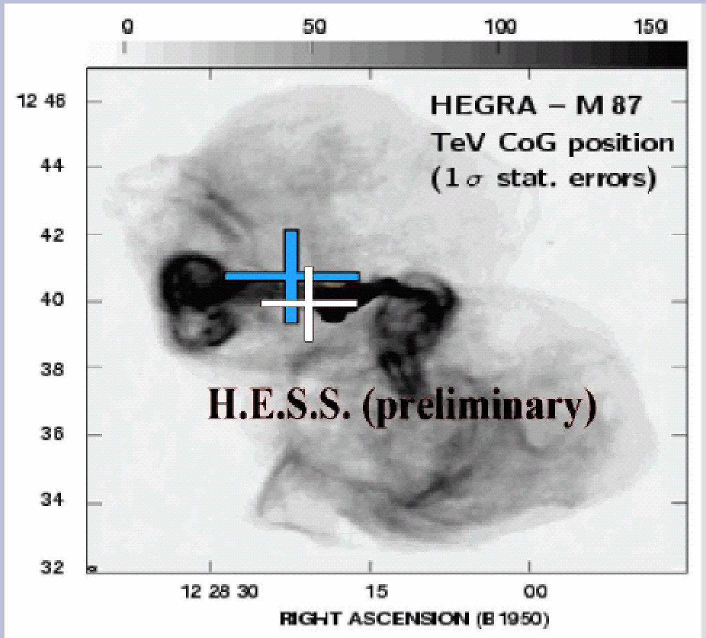
Misdirected Blazars: M87

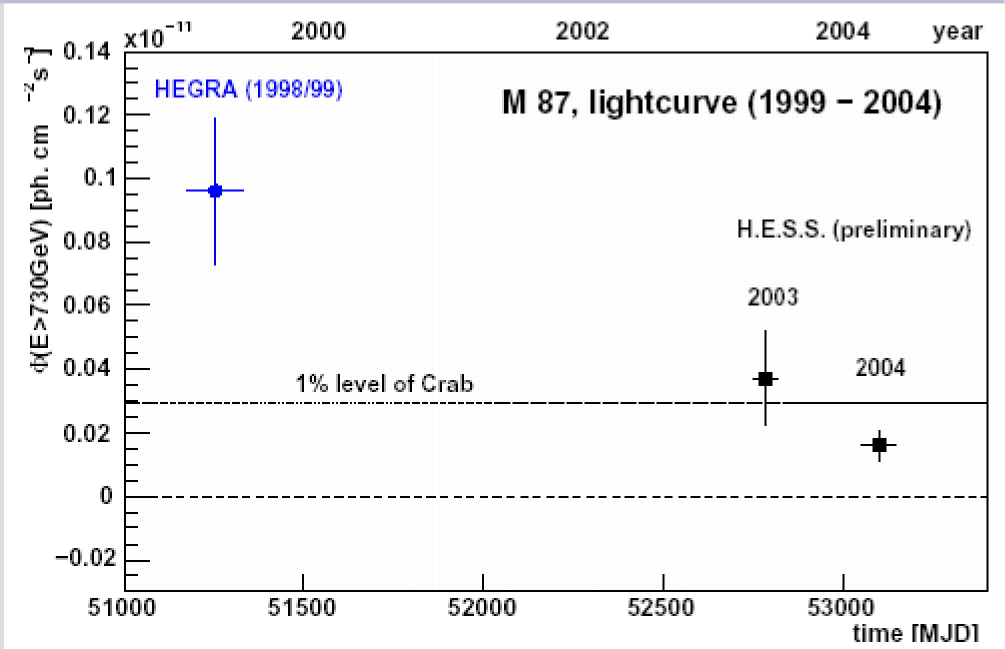




M87: A Blazar seen off-axis?
Detection by HEGRA, upper limits from Whipple
Confirmation (at lower fluxes) from H.E.S.S.

Misdirected Blazars: M87





H.E.S.S. confirmation co-spatial, consistent with PSF.

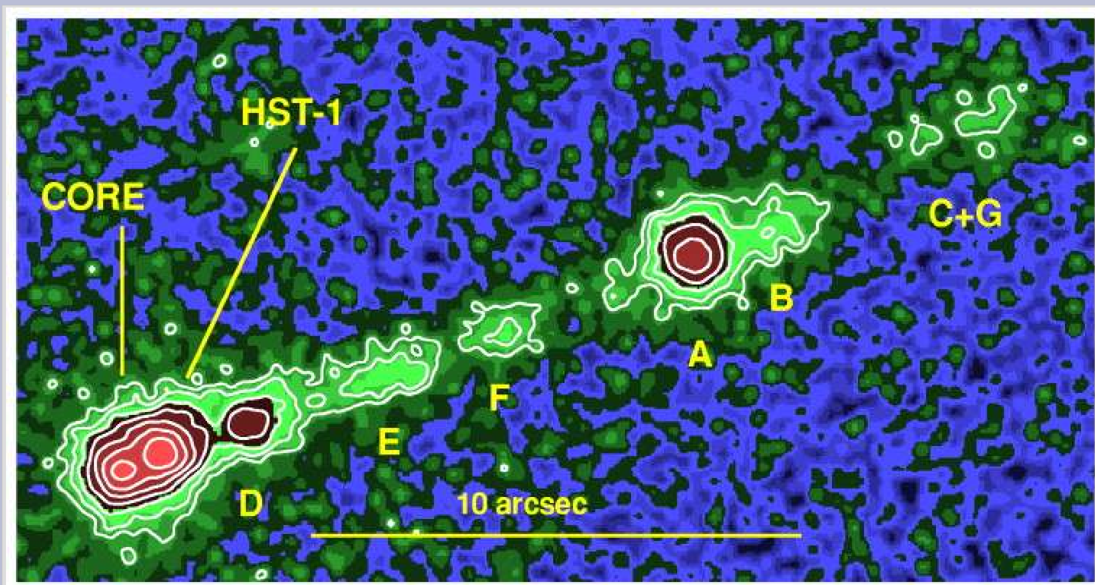
Nucleus, inner jet as potential sites.

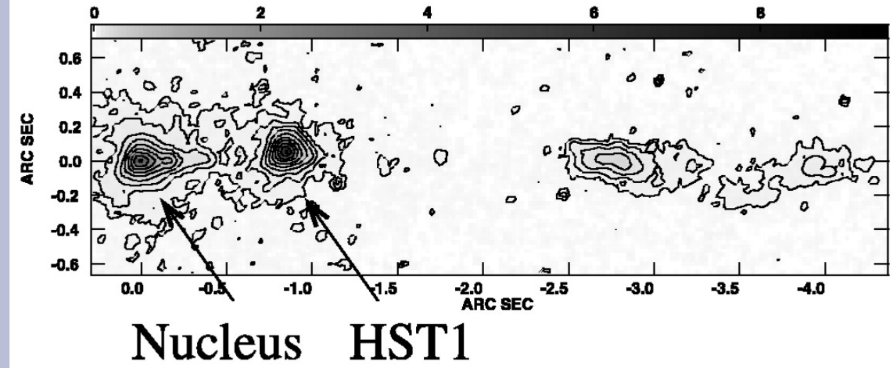
Confirming FRI as TeV sources.

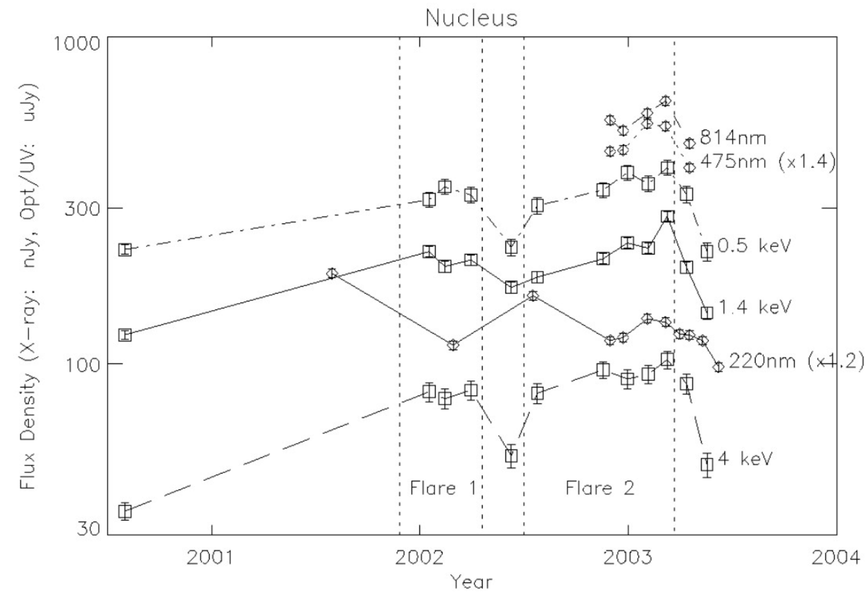
Variability? (Consistency with Whipple)

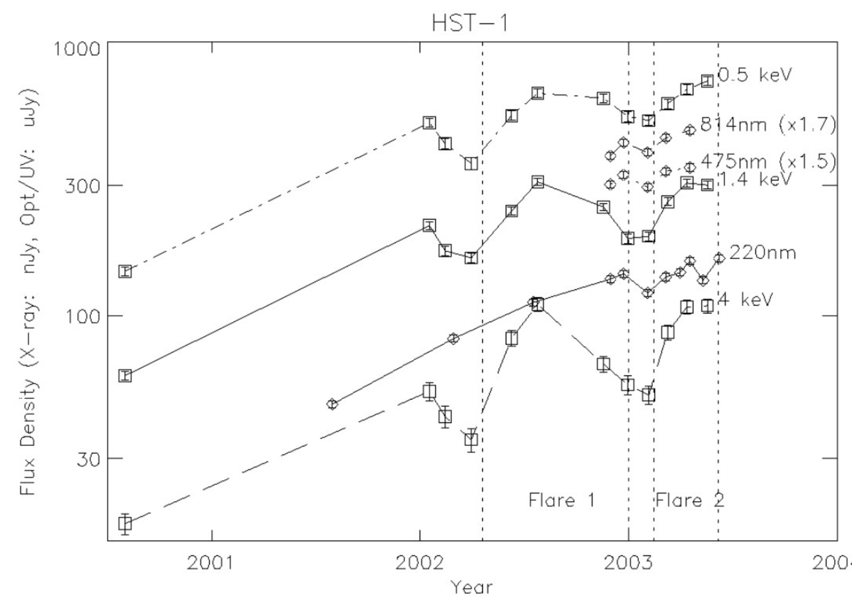
Pro: variability in knots Con: Nucleus is constant

Knot 1 or not knot 1?









Temporal sampling insufficient (up to now) to search correlations

Maximum energy of particle acceleration in extended jets

TeV opacity of the universe

Above the pair-creation threshold, photons get attenuated by cosmic radiation fields of low energy (CMB, CIB).

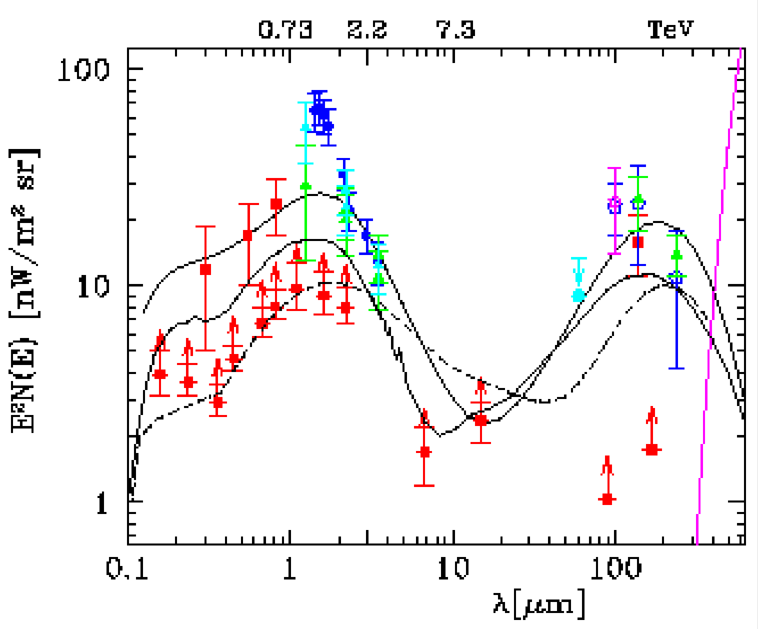
TeV photons interact with near-IR photons, which are :

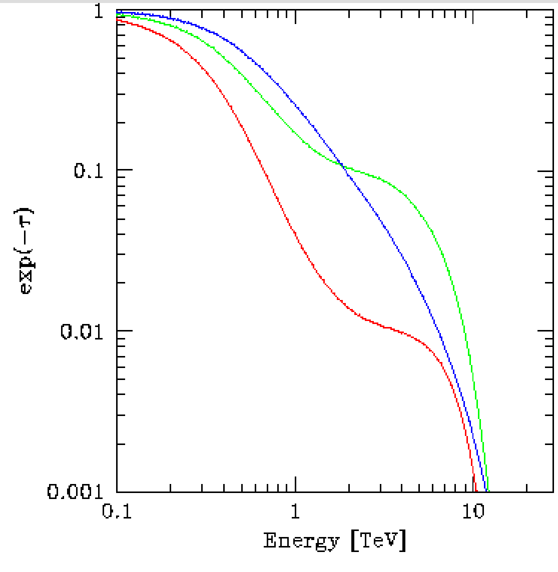
1) hard to measure directly (foreground),
2) extremely interesting (calorimeter of all fusion-generated photons in cosmic history).

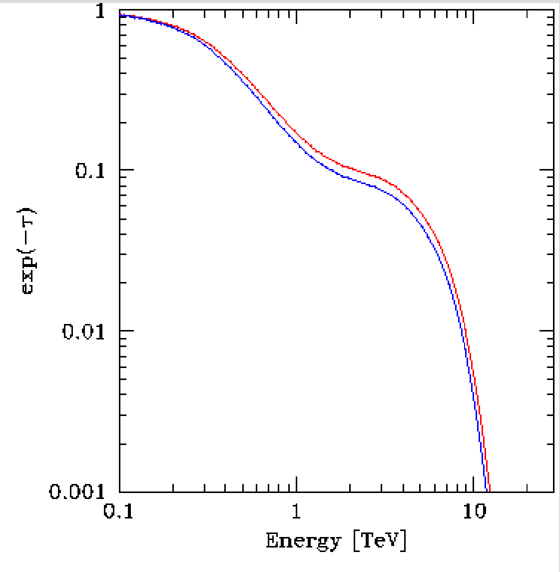
TeV opacity of the universe

Empirical Measurements of CIB:

taken from Hauser & Dwek, ARAA, 2001 updated (Costamante et al., in 2004)







Effect of absorption: Extinction (E, z, SFH)

(Costamante et al., 2004)

TeV opacity of the universe

observed TeV spectrum
depends on

emitted TeV spectrum	(evolving) IR background	cosmological parameters

determine any two and solve for the third.

HESS observations favor low CIB model (Primack, 2004). The accessible universe is large. Tracing sources of different redshifts permits derivation of CIB evolution.

Summary

increased sensitivity and fov, hence improved efficiency and dynamic range results in new classes of sources.
Blazar TeV studies profit (spectra, timing, dynamic range)

Time-resolved spectroscopy (very short timescales) – Mkn 421 Variability in cut-off energy ?

PKS 2155-304: Low states, quiescent flux?
Short time-scales, Textbook-SSC does not fit

New Blazars (e.g. PKS 2005-489)

New classes (M87 i.e. FRI, GC, XRB)

Outlook

Several additional AGN discovered already
- More simultaneous SEDs
- New Blazar physics
- New constraints on optical/IR background

Blazar detections via flare alerts (ATOM)

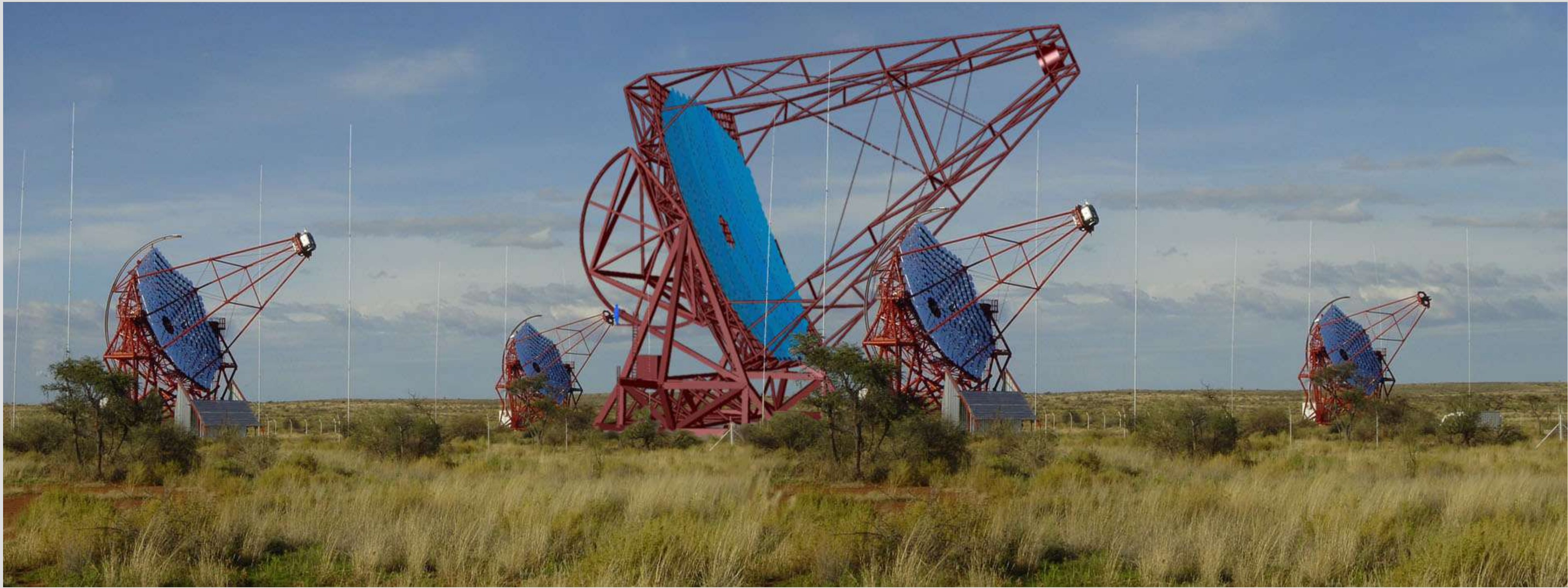
Low CIB absorption: Larger distances

Upgrades: HESS II

HESS II

An additional large (30 m diameter equivalent) telescope in the centre of the array

Aim: more light (lower energies)



5th ENIGMA meeting
13-17th June, Bornmuehle

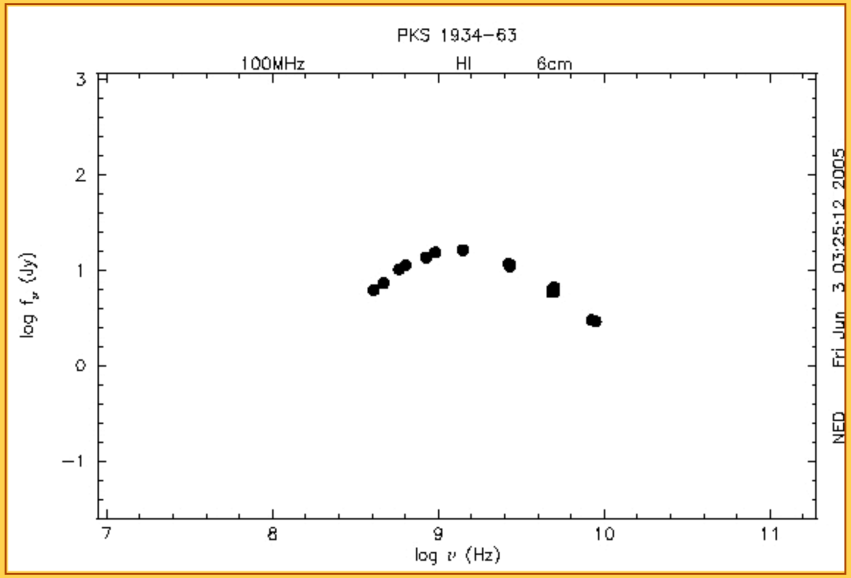
X-ray properties of GPS/CSS sources

Elisa Ferrero
Landessternwarte Heidelberg

GPS/CSS sources

✦ Obs. definition:

Convex radio spectra with peak at ~ few GHz (GPS) and below ~ 500 MHz (CSS)



✦ Properties:

Contained within ~1 kpc (GPS) and ~20 kpc (CSS)

Radio powerful ($L_{1.4\ GHz}$~10^{32} erg s^{-1})

Steep spectrum (α > 0.5) above peak

Variety of radio morphologies: double-lobed, core-jet, …

Low fractional polarization (less than ~1% at 6 cm)

Low variability (< 20%)

Turn-over: synchrotron self-absorption or free-free absorption

Two scenarios: young radio sources or “frustrated” sources

X-ray observations of GPS/CSS sources

Useful for:

– Determining class properties

– Constraining absorption properties

– Studying X-ray morphologies (*Chandra*)

– Identifying emission mechanisms

X-ray results on GPS/CSS sources

- ✶ RASS detection rate for GPS/CSS quasars ~3 times lower than for radio-loud quasars (Baker et al. 1995)

- ✶ Spectra: power laws with $\Gamma \approx 1.2\text{-}2.0$ (Siemiginowska et al. 2003, *Chandra*, 14 sources);

  broken power law (3C 48, Chandra, Worrall et al. 2004);

  Compton-reflection dominated (Mkn 668, XMM, Guainazzi et al. 2004)

- ✶ X-ray absorption ($N_H \sim 10^{21}\text{-}10^{22}$ cm^{-2}) common in GPS/CSS quasars (O' Dea et al. 2000, Guainazzi et al. 2000, Siemiginowska et al. 2003)

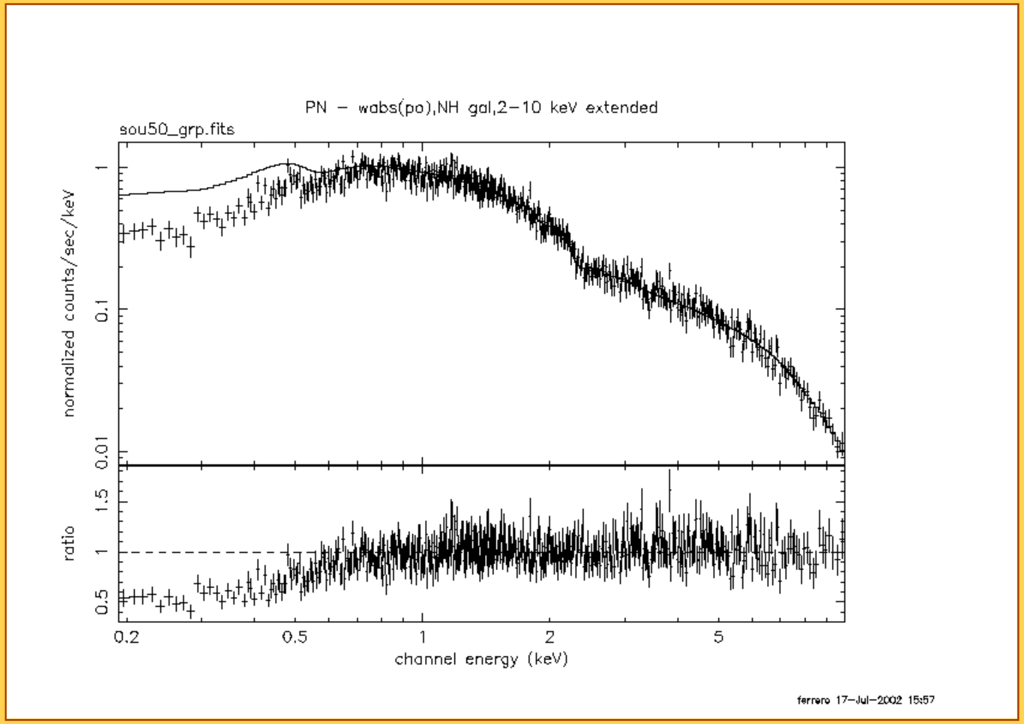
- ✶ X-ray jets extending for ~ 300 kpc: PKS 1127-145, B2 0738+313 (Siemiginowska et al. 2003)

- ✶ Emission mechanisms: synchrotron, SSC, IC scattering off CMB

High-z and GPS quasars

Study of 2 radio-loud and 2 radio-quiet quasars at z>2 with XMM
(Ferrero & Brinkmann 2003)

PKS 2126-158: GPS quasar, z=3.27, ~23 ks obs.



Power law (2 - 10 keV):

Γ=1.47±0.02

Excess absorption:

$N_{H,z}$=1.4x10^{22} cm^{-2}

X-ray absorption in high-z radio-loud quasars associated with GPS quasars?

XMM proposal (AO4)

Sample of 6 GPS quasars, z > 1, 20 ks obs.

Co-Is: S. Wagner (LSW, Heidelberg), M. Gliozzi (George Mason University, USA)
I. Papadakis (University of Crete)

2 sources accepted for obs.: [HB89] 0552+398, PKS 0237-23

[HB 89] 0552+398 observed on April 1st, 2005 ⟶ preliminary results here

PKS 0237-23 scheduled for January 2006

PKS 2004-447

The most radio-loud ($1700 < R_L < 6300$) NLSy1 galaxy, also classified as GPS

Multiwavelength observation:

– XMM observation: April 2004, 40 ks, PI L. Gallo (MPE, Garching)

– Radio and optical obs.:

ATNF, Parkes, broad band spectroscopy (D. Lewis)
University of Tasmania 25m, 5GHz (S. Ellingsen)

Siding Spring 2.4m, spectra/phot. (A. Oshlak, M. Whiting)
University of Tasmania 1m, phot. (J. Greenhill)

Goals:

X-ray spectrum: GPS or NLSy1?

SED

[HB89] 0552+398

- ✦ Optical id. with 18th mag. low polarization (< 1%) QSO, z=2.365
- ✦ Pronounced turn-over at ~5 GHz

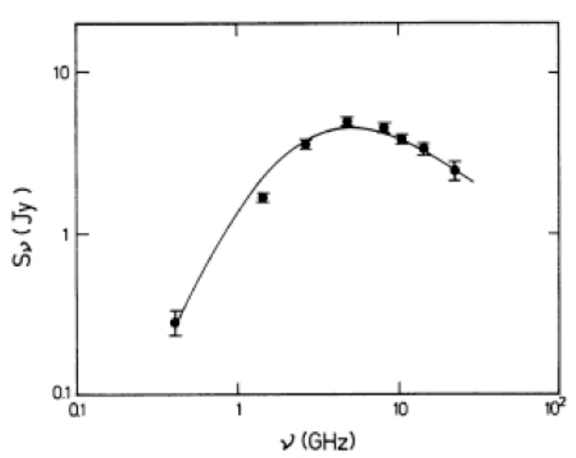


Fig. 4. Radio continuum spectrum of DA 193. The observed flux densities are from Table 2. The curve was derived from the present *VLBI* observations, as described in the text

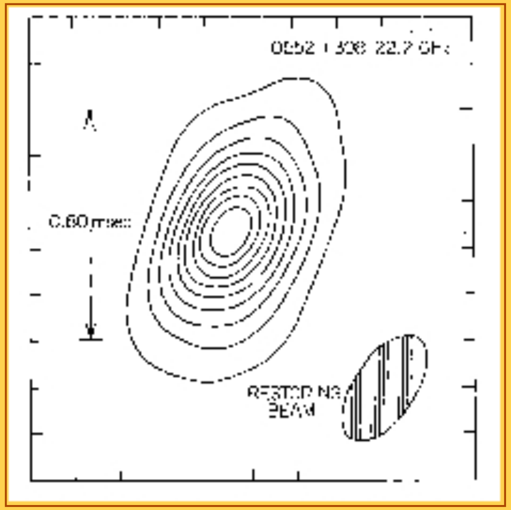
Schilizzi & Shaver (1981)

$\alpha_{thick} \approx 5/2, \quad \alpha_{thin} = 0.91$

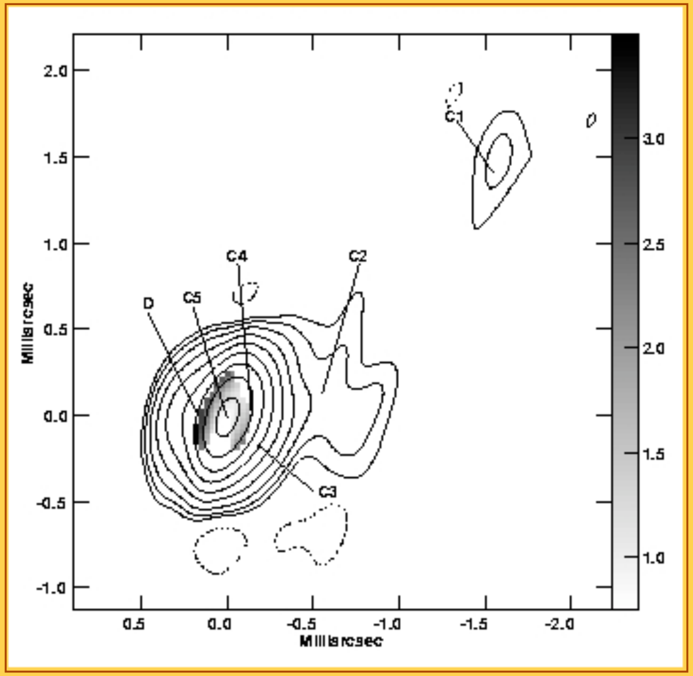
➡ resembling theoretical ideal homogeneous synchrotron source

[HB89] 0552+398 - *cont*

- Extensively studied with VLBI since 1980s
- Radio structure: one of the most compact (<3 pc), 2 components (core+halo, core+jet)



(22.2 GHz, Fey et al. 1985)



(43 GHz, Lister et al. 1998)

[HB89] 0552+398 - *cont.*

- Superluminal motion: β_{app} = 1.1 (1981-1995), β_{app} = 4.5 (1995-1997) (Wang et al. 2001)
- Doppler boosting ($\delta \approx$ 6-8), small viewing angle ($\theta \sim$ 5-8°) (Wang et al. 2001)
- Variability of ~ 20% over a period of a few years (Altschuler & Wardle 1976)
- Particle energy dominates over magnetic field energy (Spangler et al. 1993)
- Broad (FWHM = 2450 km s^{-1}) Hα line (Rokaki et al. 2003)
- Potential counterpart of EGRET source (Thompson et al. 1995), disclaimed by Mattox et al. (1997)

XMM observation of [HB89] 0552+398

Date: April 1st, 2005

Duration: 20 ks

Instruments: PN, MOS1, MOS2 (full frame + medium filter), RGS1, RGS2 (spectroscopy mode), OM (UVM2, ~230 nm)

Data processed with XMMSAS v. 6.1.0

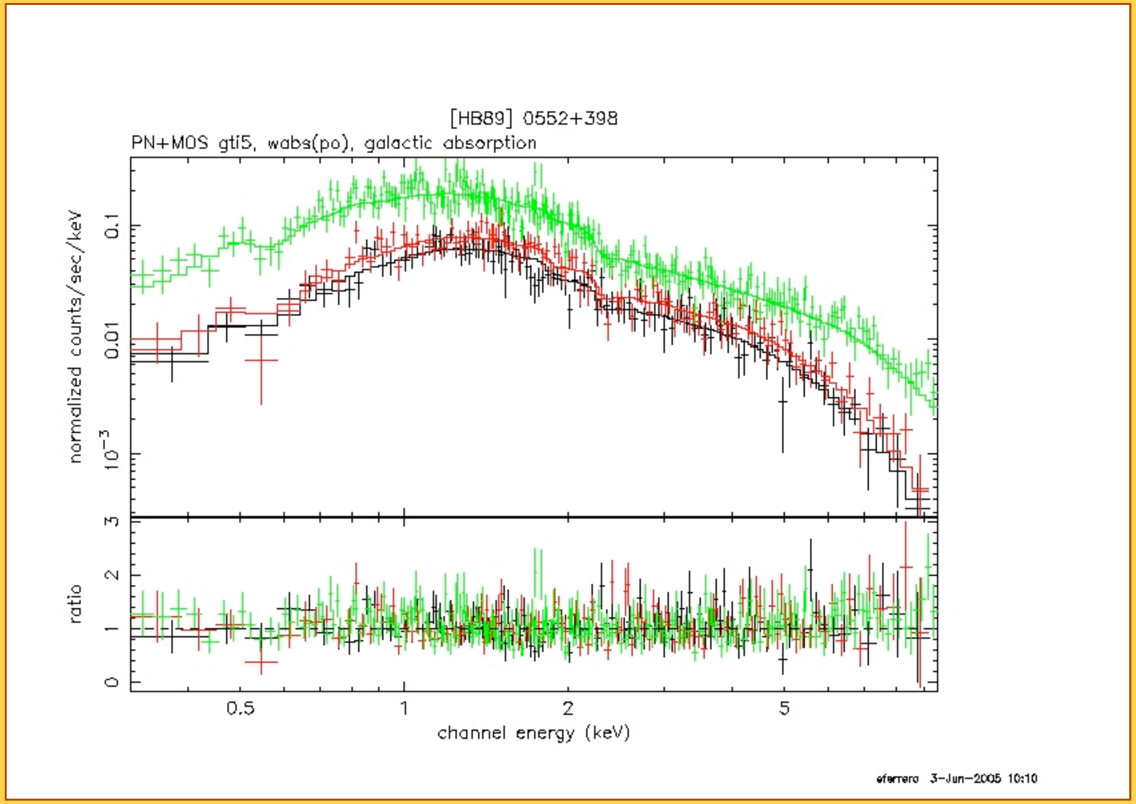
Filtering intervals of high background : eff. exposure ~ 14 ks

Spectral analysis of PN + MOS data with XSPEC

To be done: RGS, OM

Spectral analysis 1

PN + MOS 1 + MOS 2
Power law + galactic absorption



$N_H = 3.03 \times 10^{21}\ cm^{-2}$

$\Gamma = 1.64 \pm 0.03$

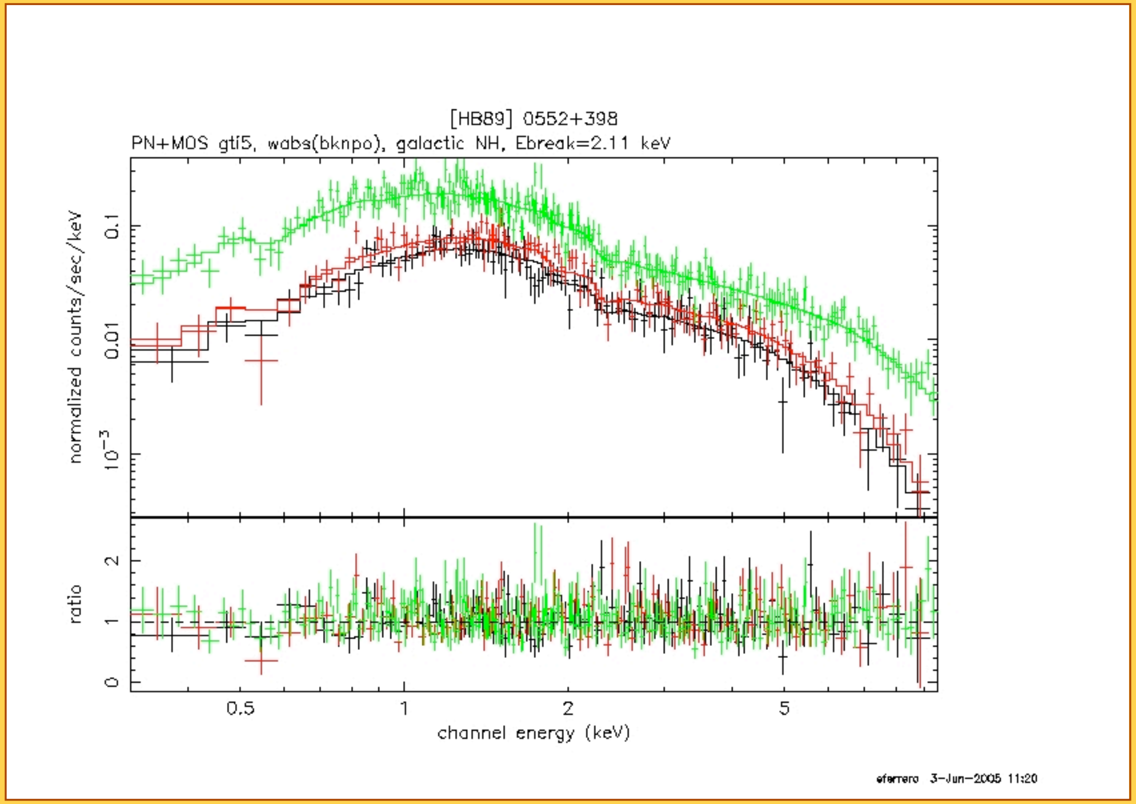
$\chi^2_\nu = 1.05$, d.o.f. = 492

$F_{0.3\text{-}10\ keV} = (2.45 \pm 0.08) \times 10^{-12}$ erg s^{-1} cm^{-2}

$L_{0.3\text{-}10\ keV} = (6.28 \pm 0.22) \times 10^{46}$ erg s^{-1}

Spectral analysis 2

PN + MOS1 + MOS2
Broken power law + galactic absorption



Γ_1 = 1.77±0.06

E_{break} = 2.11 keV

Γ_2 = 1.51±0.05

χ^2_ν = 1.01, d.o.f. = 491

$F_{0.3\text{-}10\ keV}$ = $(2.57 \pm 0.09) \times 10^{-12}$ erg s^{-1} cm^{-2}

$L_{0.3\text{-}10\ keV}$ = $(6.56 \pm 0.25) \times 10^{46}$ erg s^{-1}

Summary of preliminary results

✦ Best fit: broken power law ⟶ two components, what are they?

✦ Flux variations:

$F_{0.1\text{-}2.4\ keV} = (2.95 \pm 0.21) \times 10^{-12}$ erg s^{-1} cm^{-2} (RASS, Brinkmann et al. 1997)

$F_{0.1\text{-}2.4\ keV} = 1.51 \times 10^{-12}$ erg s^{-1} cm^{-2} (1993 ROSAT-PSPC obs., Bloom et al. 1999)

$F_{0.1\text{-}2.4\ keV} = (1.53 \pm 0.07) \times 10^{-12}$ erg s^{-1} cm^{-2} (XMM, 2005)

✦ Spectral variability: $\Gamma = 1.53 \pm 0.45$ Brinkmann et al. (1997)

$\alpha = 0.09(+0.36,-0.16)$ Bloom et al. (1999)

$\Gamma = 1.77 \pm 0.06$, $E<2$ keV present work

✦ Absorption in excess of galactic value not required ⟶ SSA and youth model

Host galaxies of CSS radio sources

5th ENIGMA meeting
June 13-17
Bornmühle, Germany

Mirko Tröller
Metsähovi Radio Observatory

in collab. with
Merja Tornikoski, Metsähovi
Esko Valtaoja, Tuorla Observatory

Outline

- Introduction
- The Sample
- Data Analysis
- Results
- Summary

Compact steep spectrum sources

Properties:

- Compact, small, high luminous radio sources
- steep spectra
- characteristic peakfreq. dependent of size

Aim of the work:

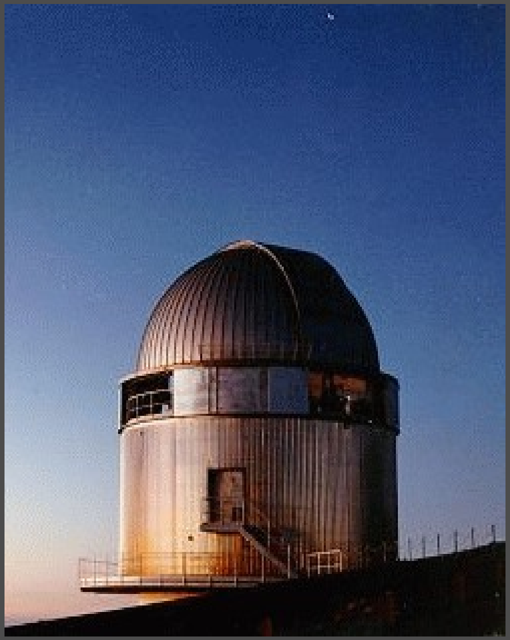
- what are the hosts
- study the environment (interaction, cluster,...)
- probe the evolution scenarios (frustrated vs. young)

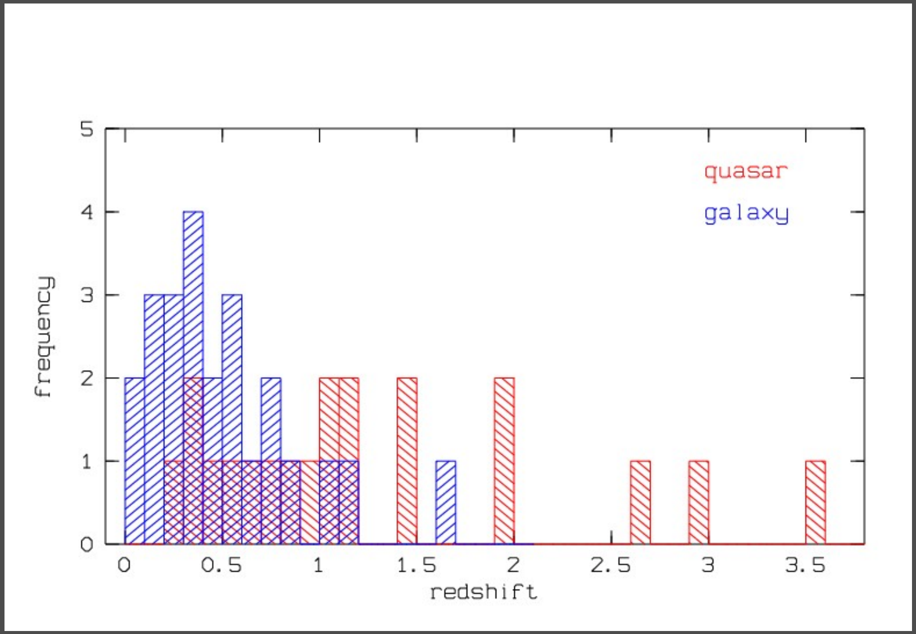
The sample

Complete sample of 44 CSS
  24 galaxies, 20 QSOs

broad-band images in R and V
  t_{int} = 600-1800 sec

observed at the NOT



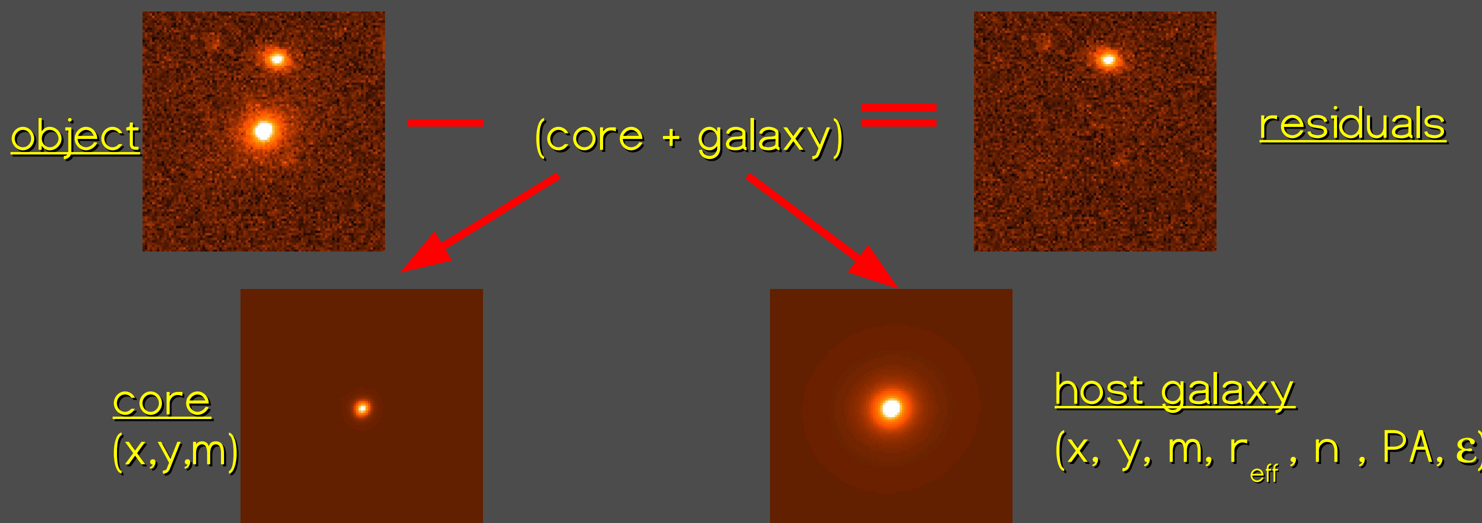


QSOs tend to be at higher redshift, only 3 galaxies z>1

Analysis / fit parameter

2-dim. surface-brightness analysis

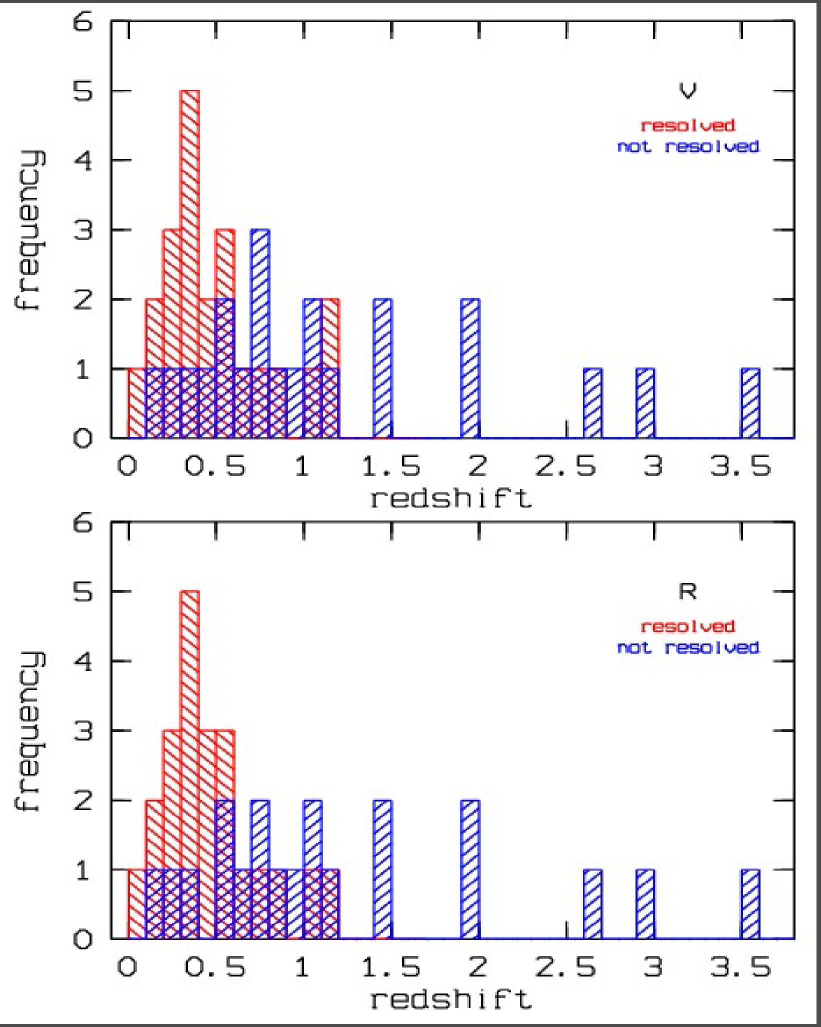
two-component-model : core + galaxy



Model A : core + galaxy
Model B : galaxy only

Mirko Tröller
Metsähovi Radio Observatory

Resolved hosts



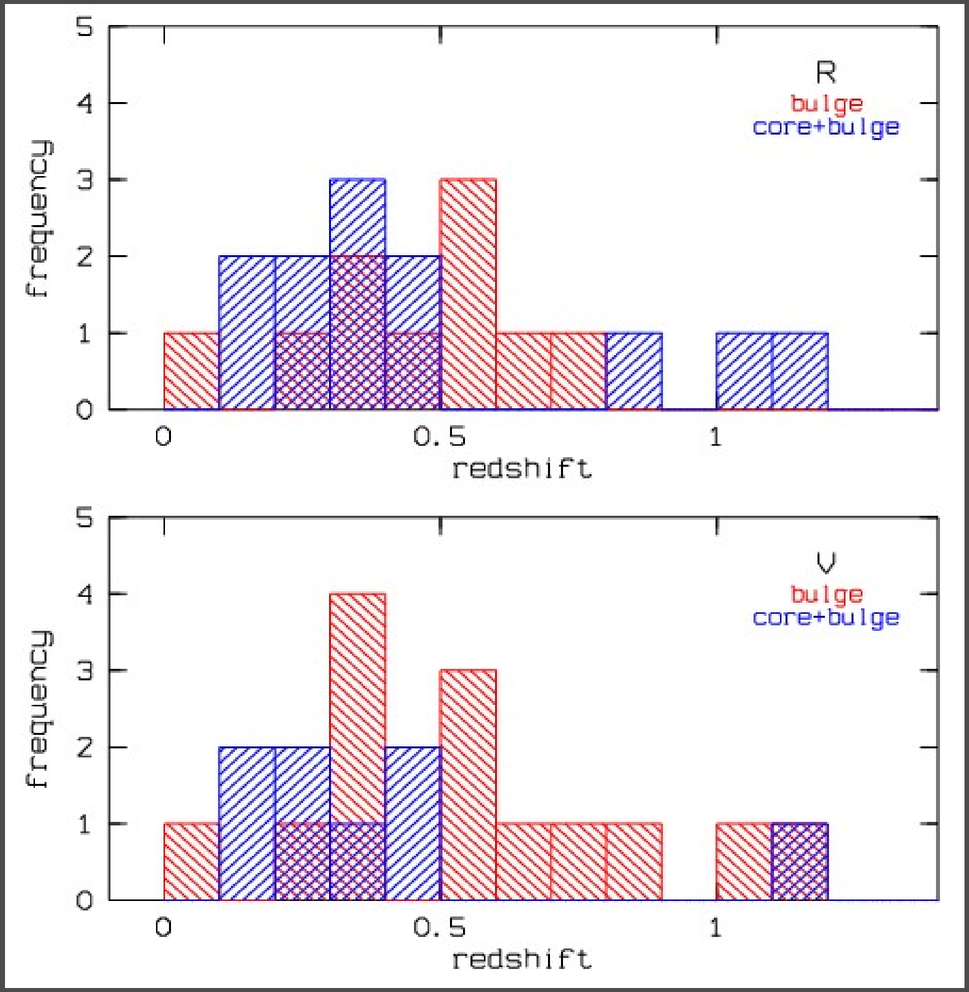
V:

23/44 hosts resolved
17/24 galaxies
6/20 quasars
$\langle z \rangle = 0.54$, $z_{max} = 1.14$

R:

23/44 hosts resolved
18/24 galaxies
5/20 quasars
$\langle z \rangle = 0.51$, $z_{max} = 1.13$

Best model

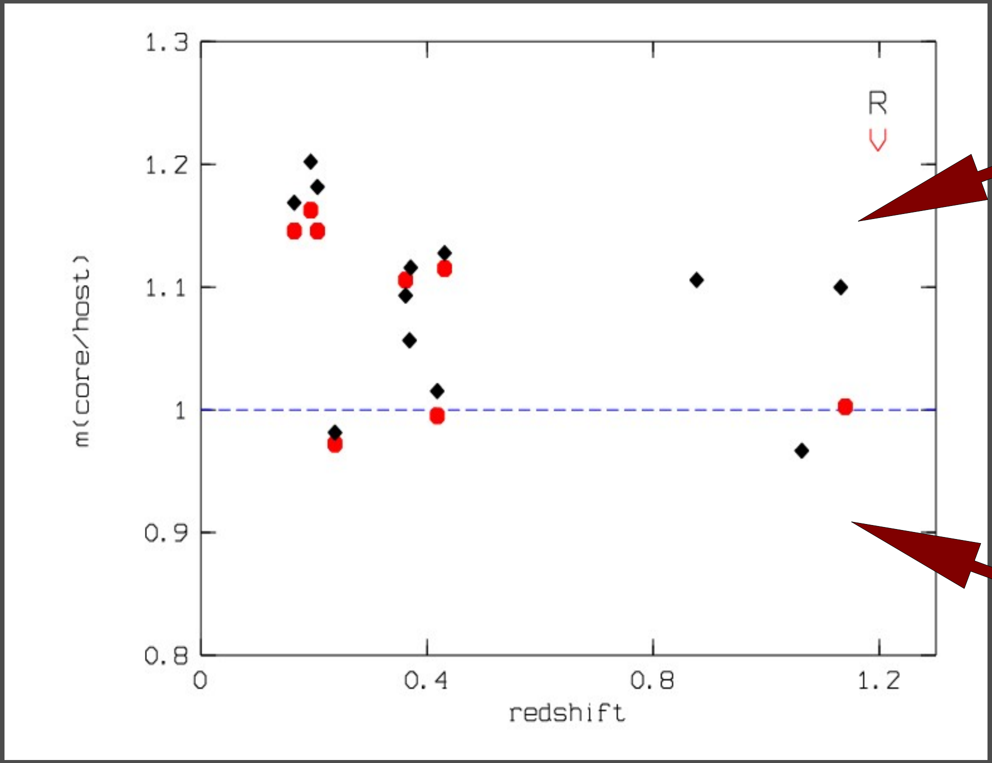


R:
11 galaxy
12 core+galaxy

V:
14 galaxy
9 core+galaxy

AGN/Galaxy - brightness

model core+bulge

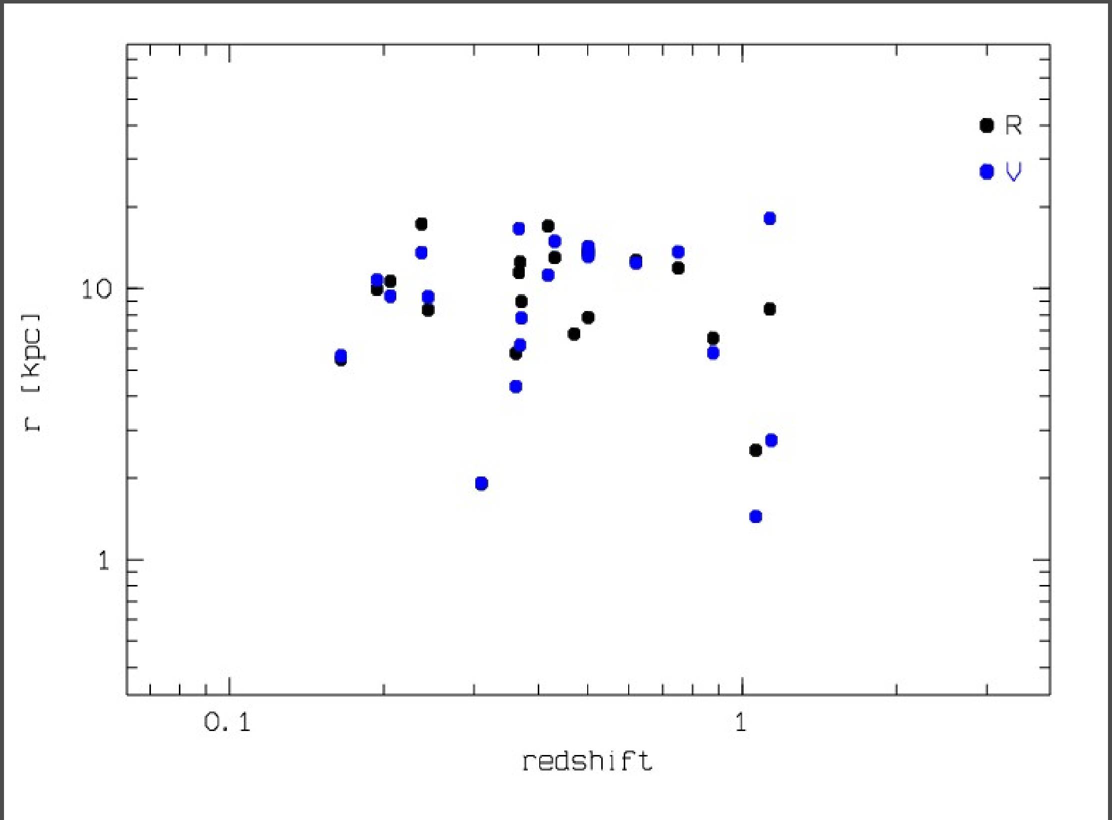


bright galaxy
faint AGN

faint galaxy
bright AGN

→ more "fainter" AGN components in CSS sources (in R and V)

Size



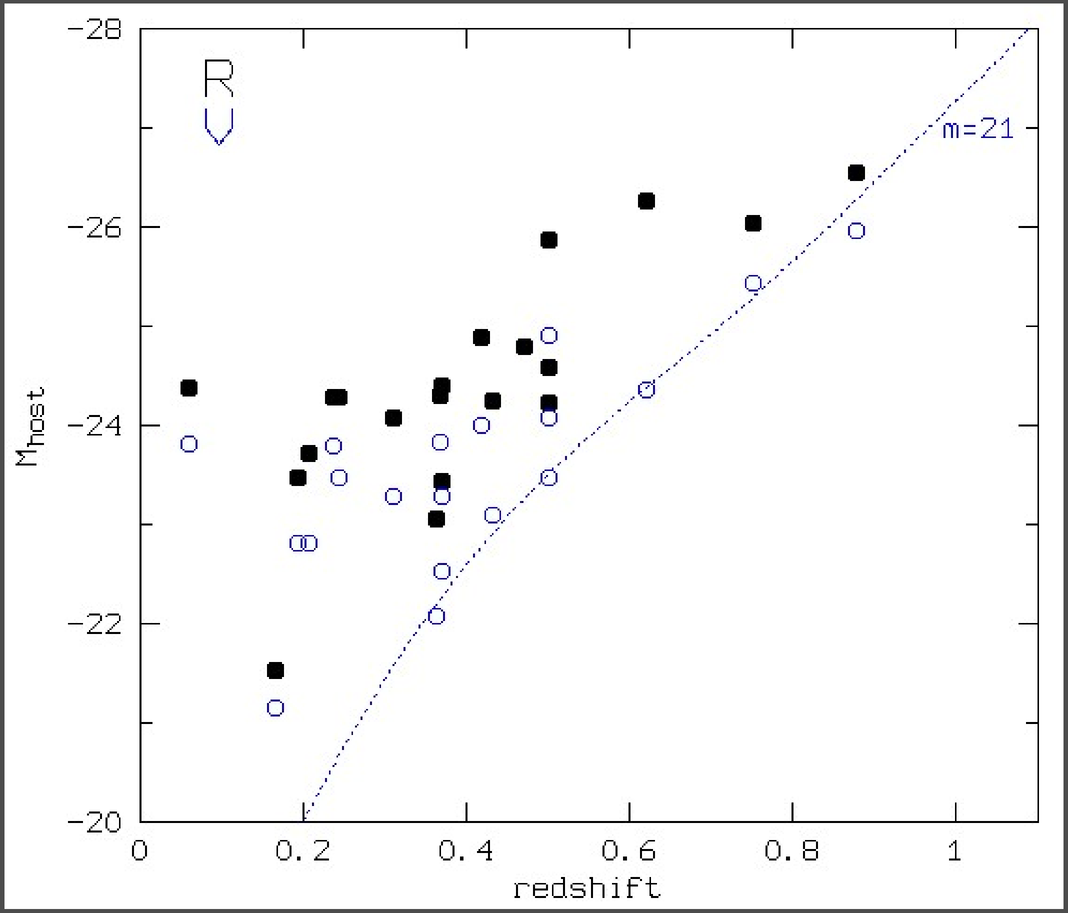
R:
$\langle r_{eff} \rangle = 11.0$kpc

V:
$\langle r_{eff} \rangle = 11.1$kpc

Radii are independent of redshift

Hosts are large $\langle r_{eff} \rangle = 11$kpc

Abs. brightness



V: $\langle M \rangle = -23.6$

$M_{max} = -26.0$

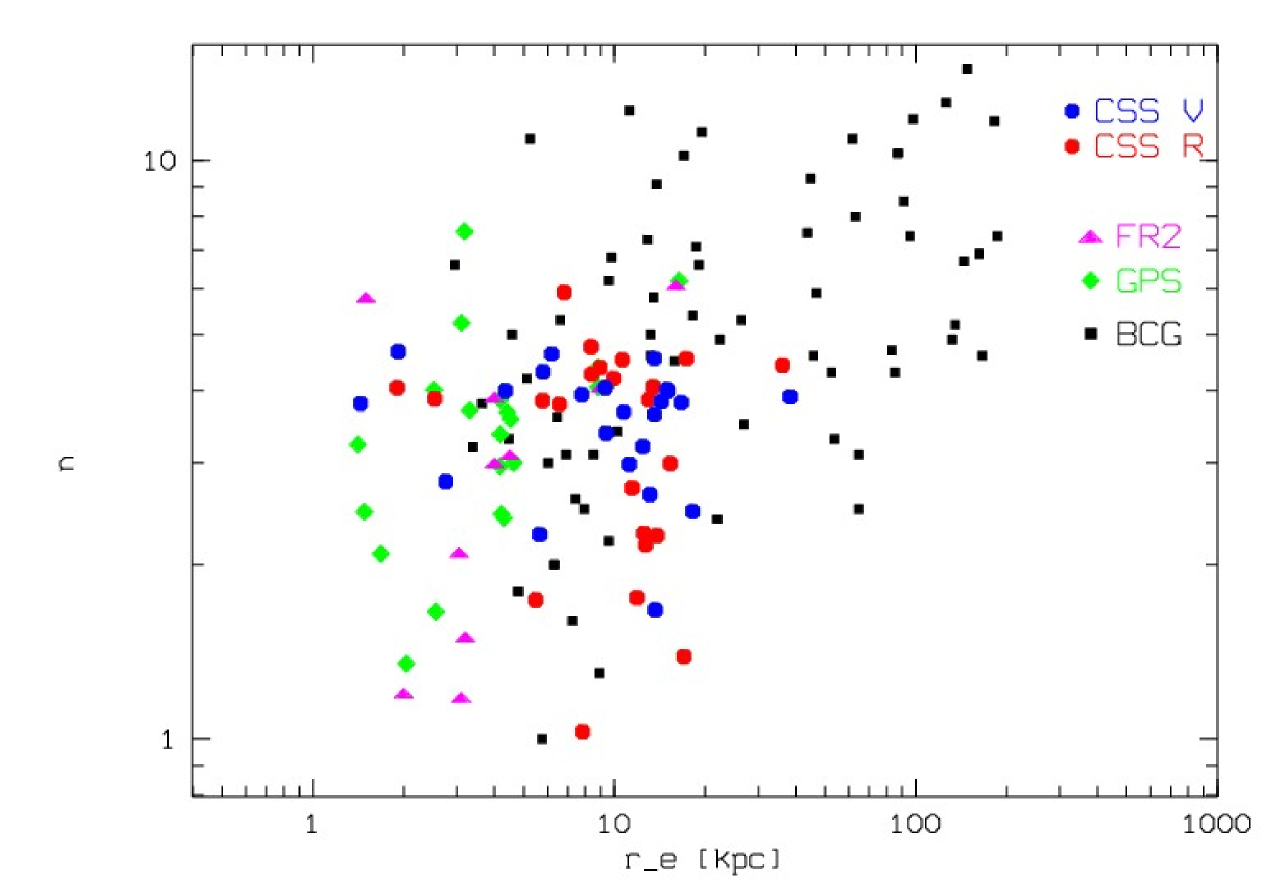
$M_{min} = -21.1$

R: $\langle M \rangle = -24.4$

$M_{max} = -26.5$

$M_{min} = -21.5$

Type



(deVries2000, Graham1996, Caon1993)

surface-brightness

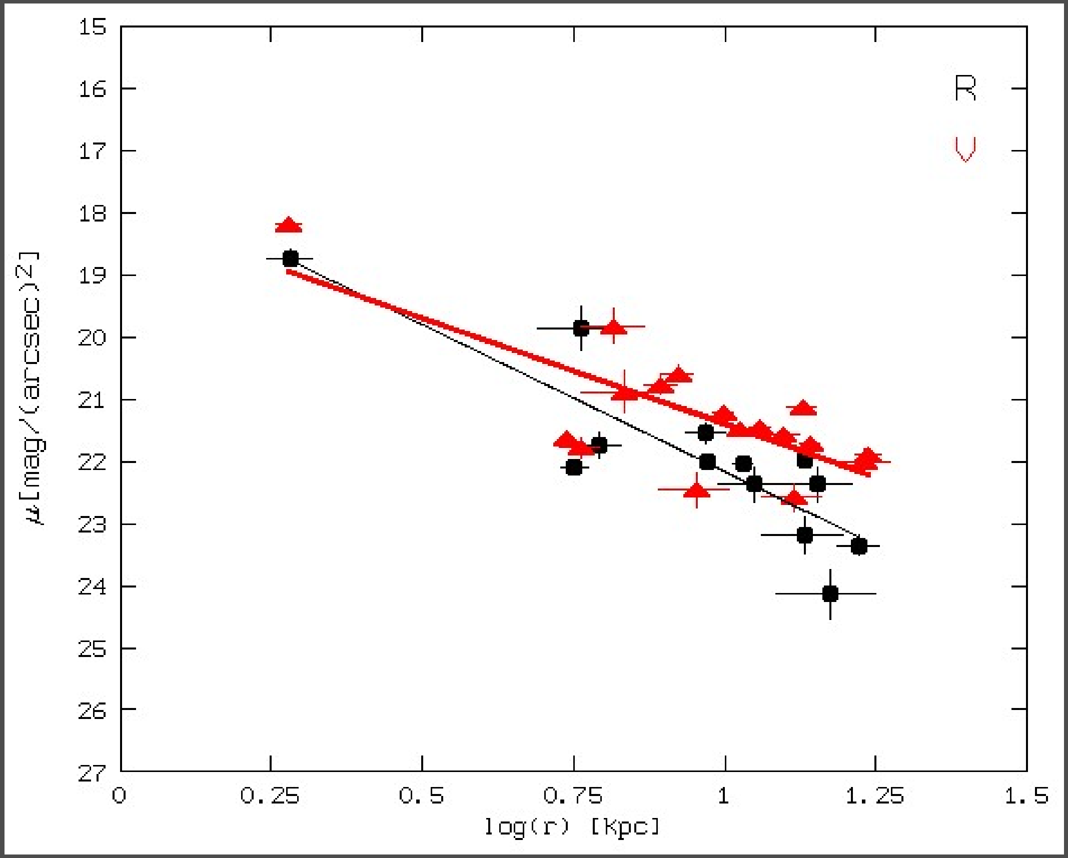
$$\mu(r) \propto \left(\frac{r}{r_e}\right)^{1/n}$$

n=4 de Vaucouleurs
n=1 spiral

CSS hosts
$\langle n \rangle_V = 3.6$
$\langle n \rangle_R = 3.4$

CSS hosts are similar to GPS and FR2

Kormendy relation



$$\mu_e \propto k \log(r_e)$$

R-band: k=3.4±0.6
V-band: k=4.7±0.6

Lit.:
non-BCG: k=4.5
BCG/FR1: k=3.1
GPS/CSS/FR2: k=4.0-5.2

Slope suggests similarity to GPS/FR2 rather than to FR1/BCG

Summary

- CSS sources are bulge dominated elliptical galaxies with a weak and often absent nuclear component (in R and V)

- Hosts are large and bright ellipticals

  $<M_R>=-24.4$, $<r_{eff}>=11.0$ kpc

  $<M_V>=-23.6$, $<r_{eff}>=11.1$ kpc

- **~20/44** objects have close companions **(<5")** and show evidence of a poor cluster environment

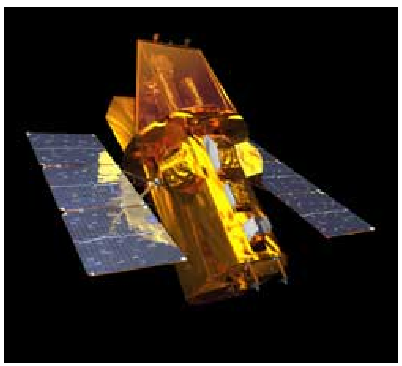
- Host type is similar to GPS and FR2 not BCG

  -> supports the GPS-CSS-FR2 sequence, youth scenario

Mirko Tröller
Metsähovi Radio Observatory

Thanks for your attention

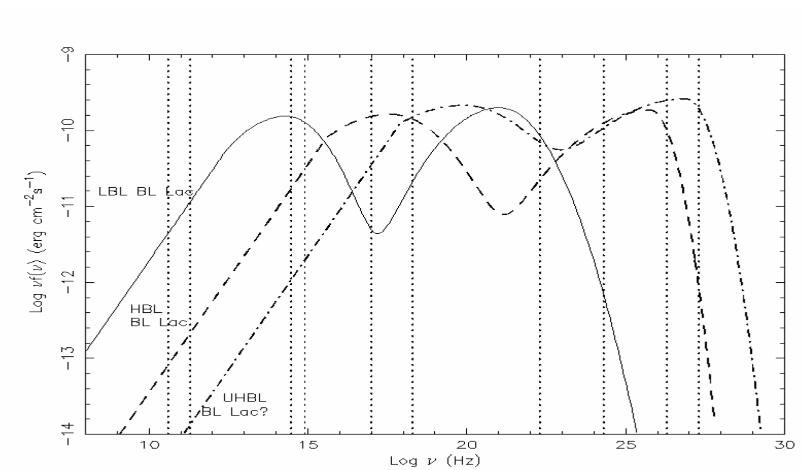
Multi-frequency Study of SWIFT Blazars



Lars Fuhrmann,

G. Tosti, N. Marchili, A. Cucchiara
Perugia University

P. Giommi et al. , ASI



ENIGMA meeting, June 2005

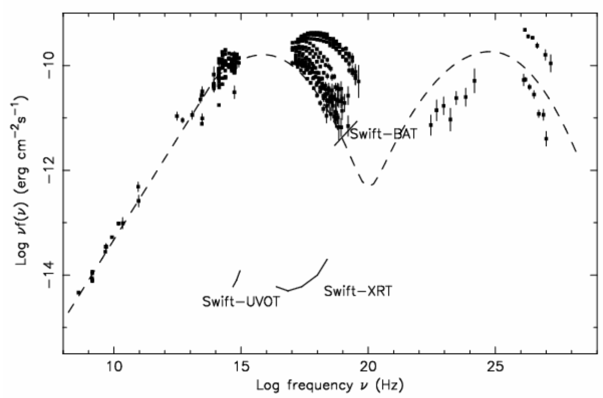
Overview

- SWIFT observations of blazars: a broad band approach
- OJ287 with Effelsberg during the XMM pointing
- Seasonal Cycles in “classical“ IDV sources:
  a short update for 0954+658! (task 2)

SWIFT Blazar project

Collaboration with P. Giommi, ASI; E. Massaro, A. Tramacere Univ. of Rome

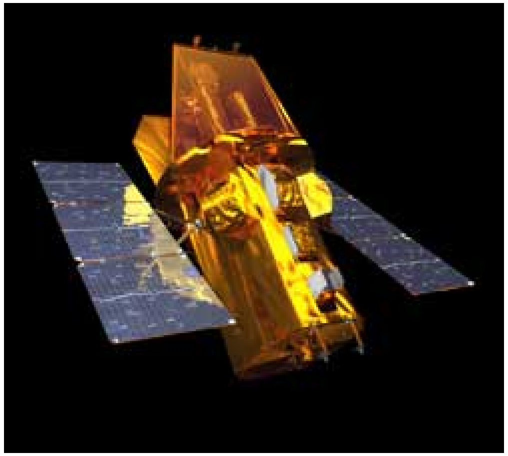
MKN421



- start: April 05 with SWIFT and REM
- 2 blazar samples: 34 well known blazars
  18 WMAP blazars
- aim: 1) study of broad band spectral dynamics, constrain spectral models, test of SSC-models etc.

  2) complete X-ray measurements of WMAP blazars, broad band properties of microwave blazars

SWIFT



- start: Nov. 2004
- multi-wavelength observatory:

Burst Alert Telescope (BAT):

15 - 150 keV

X-ray Telescope (XRT):

0.3 - 10 keV

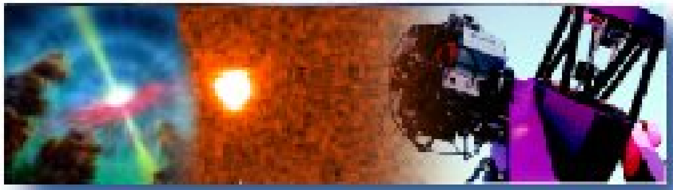
UV/Optical Telescope (UVOT):

170 - 650 nm

→ **SWIFT broad band studies**

REM: optical/IR observations

- Rapid Eye Monitor at la Silla
- 60cm fully robotic
- REMIR: J, H, K bands
- ROSS: I, R, V

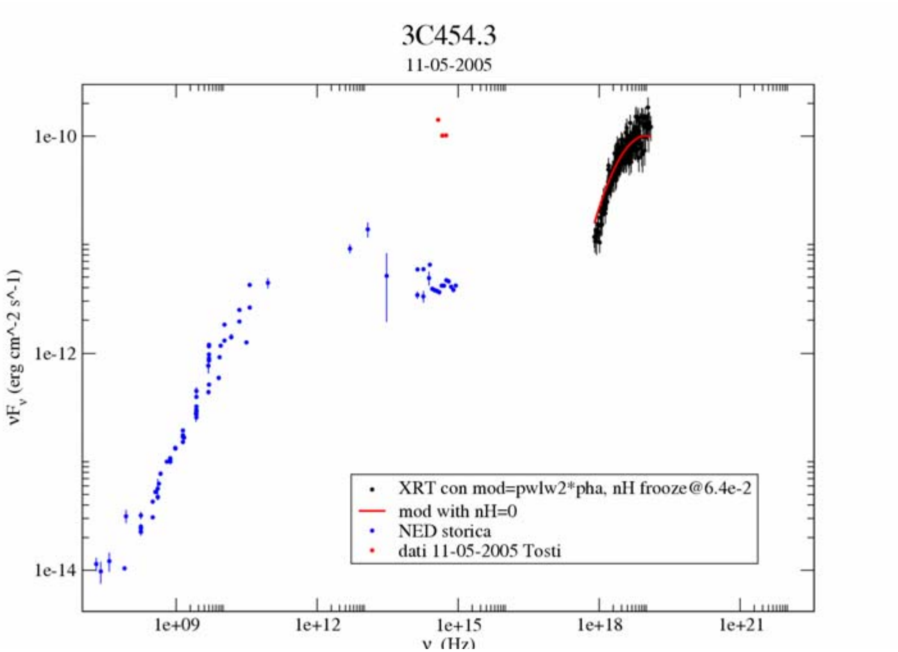


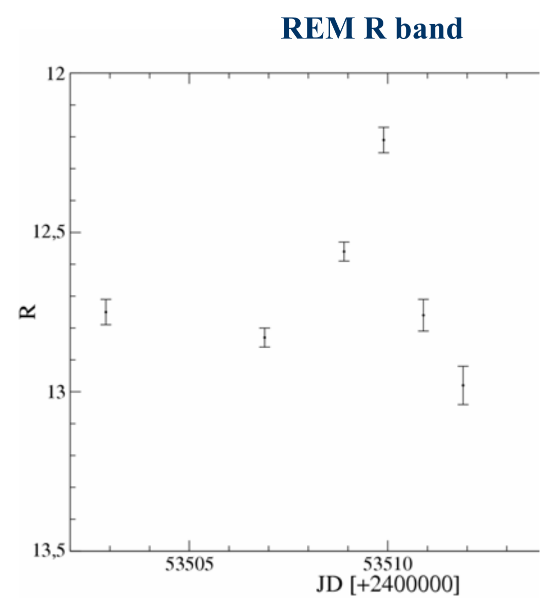
PKS0208-512	PKS1313-333
PKS0215+015	1Jy1406-076
AO0235+164	1Jy1424-418
BZBJ0325-1646	1Jy1548+056
1H0323+022	1ES1553+113
WGAJ0447.9-032	S21848+28
BZBJ0550-3216	PKS2005-489
1Jy0805-077	PKS2155-304
OJ287	PKS2209+236
1H1100-230	1Jy2227-088
PKS1206-238	CTA102
1Jy1213-172	3C454.3
1H1219+301	1Jy2255-282
ON231	1Jy2333-528
3C273	PKS2355-534
3C279	1H2354-315

total: 32

First results:

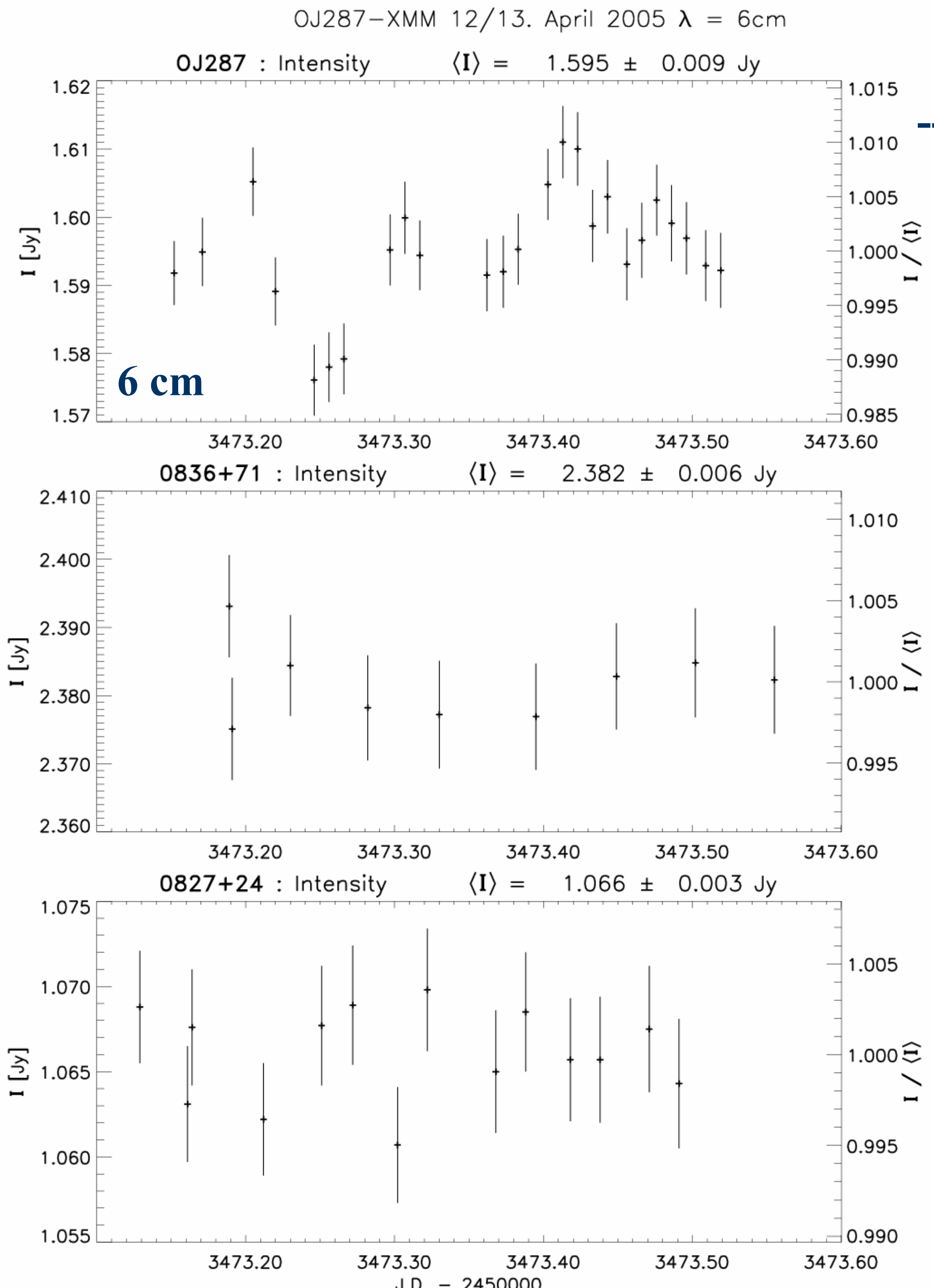
- SWIFT: 18 out of 52 sources observed so far (6 several times)
- REM: 22 observed
- future: include radio bands (Effelsberg, Noto)



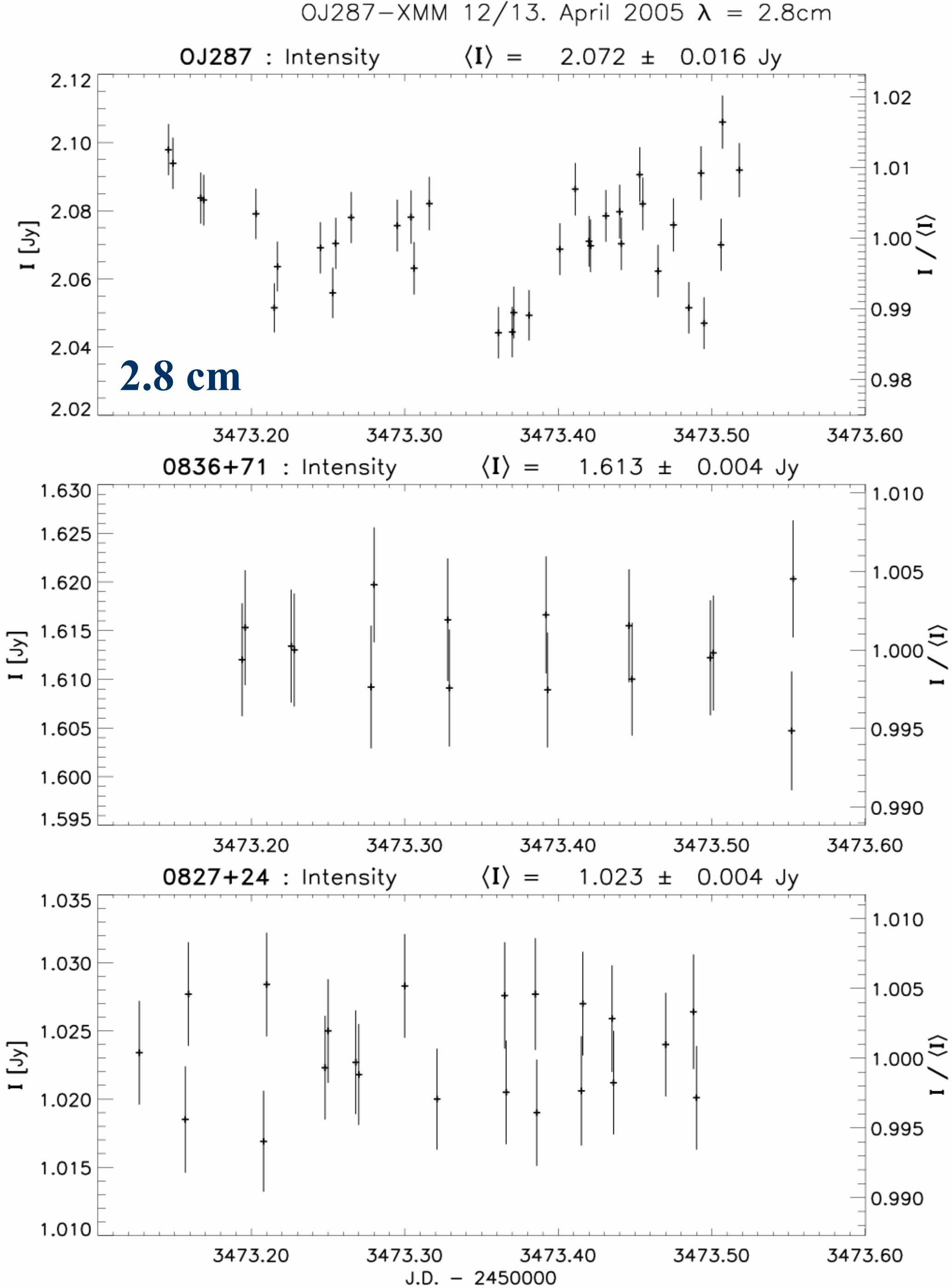


OJ287: Effelsberg at 5 and 10 GHz

- core campaign (XMM-pointing): simultaneous IDV observations on 12/13.04.05: 15.00 – 01.00 UT
- 6 and 2.8 cm
- 1 scan per ~ 20 min
- same duty cycle for sec. calibrators
- tau-, gain-correction, time-dependent correction

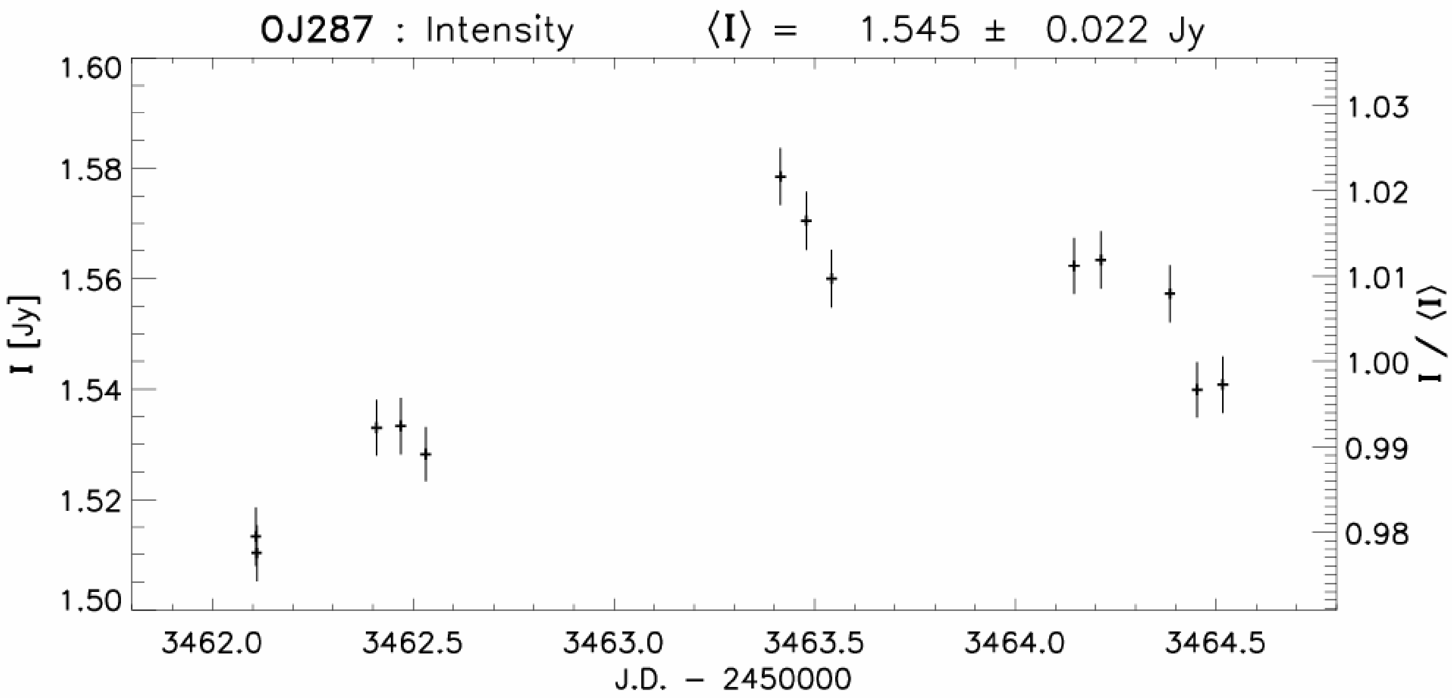


<S>[Jy]	m[%]	Y[%]	χ^2	χ^2_{red}
1.595	0.54	1.41	67.636	2.818
2.382	0.22	0.00	4.304	0.538
1.066	0.25	0.00	8.423	0.648



<S>[Jy]	m[%]	Y[%]	χ^2	χ^2_{red}
2.072	0.76	2.01	154.238	4.407
1.613	0.25	0.00	7.152	0.477
1.023	0.34	0.00	18.205	0.867

OJ287: 01-04.04.05 @ 6 cm:



A Seasonal Cycle in 0954+658 ? (task 2)

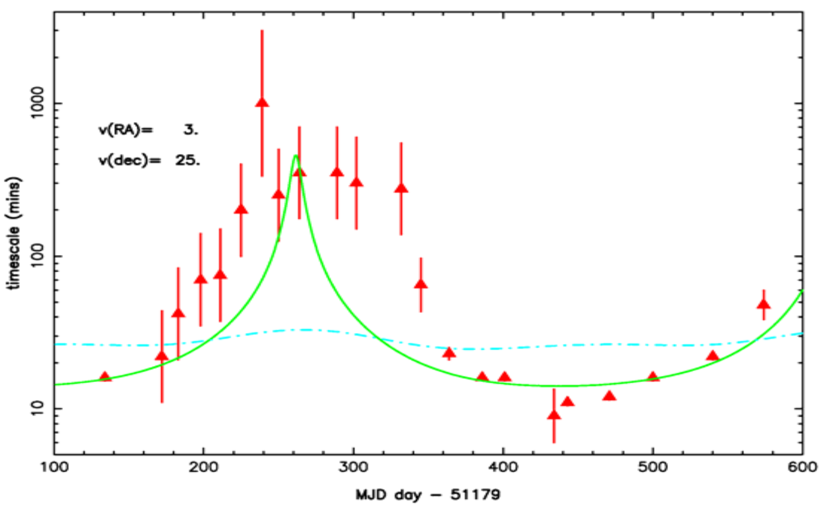
- collaboration with the Bonn team
- radio IDV: intrinsic or extrinsic or both?
- new IDV type (?): “extreme“ IDV sources with $\Delta S \sim 300\%$ and $t_{IDV} \sim 0.5$ hrs: PKS 0405-385, PKS 1257-326 and J1819+3845
- seasonal cycles in the variability time scales and time delay measurements: interstellar scintillation

- new phenomenon in IDV studies
  Dennett-Thorpe & de Bruyn (2000, 2003):

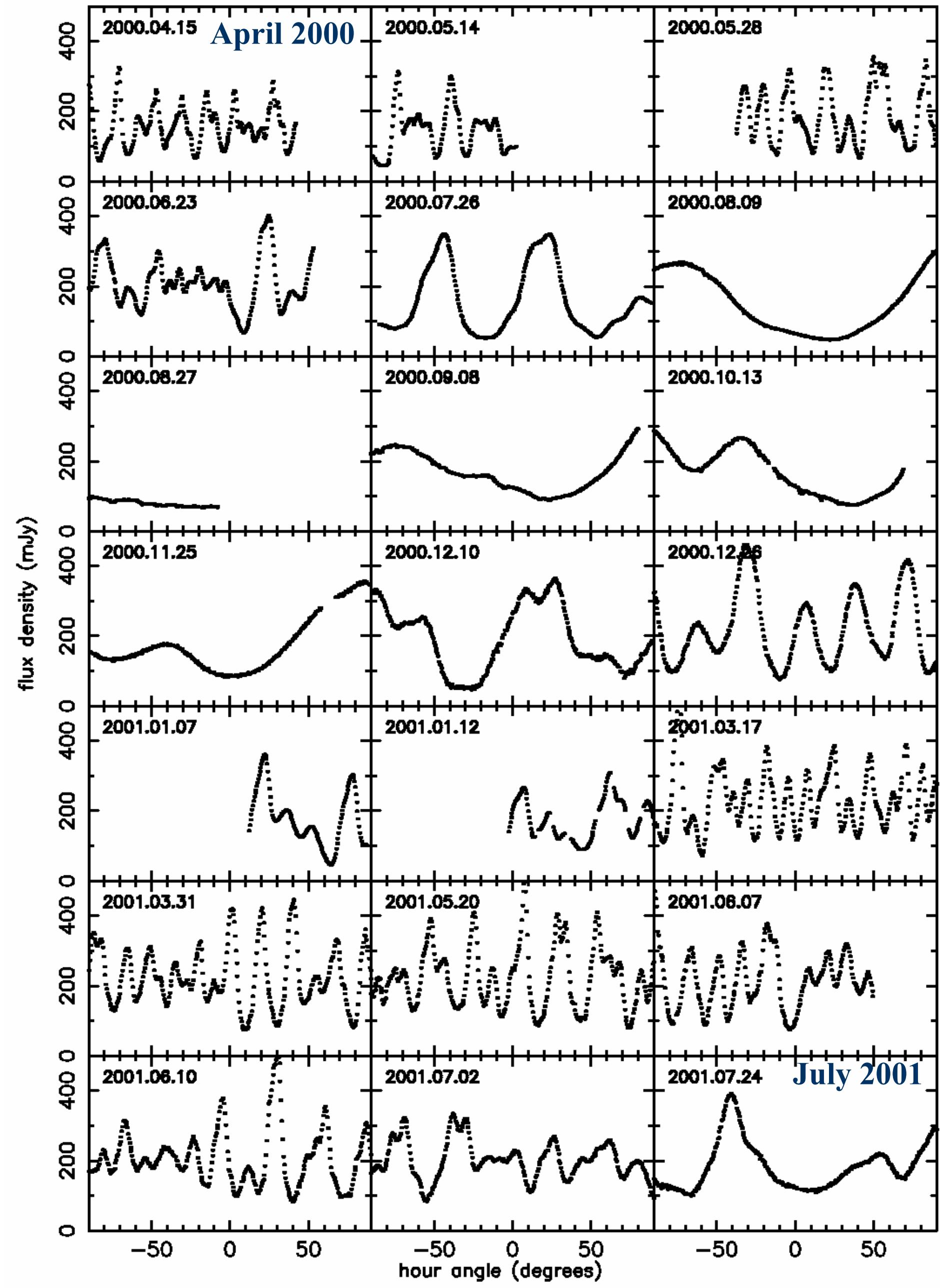
➔ seasonal cycle in the extreme IDV source J1819+3845

- relative velocity v changes as earth evolves around Sun
- $t_{ISS} = s_0 / v$, spacial scale $s_0 \sim D \cdot \theta_S$

J1819+3845

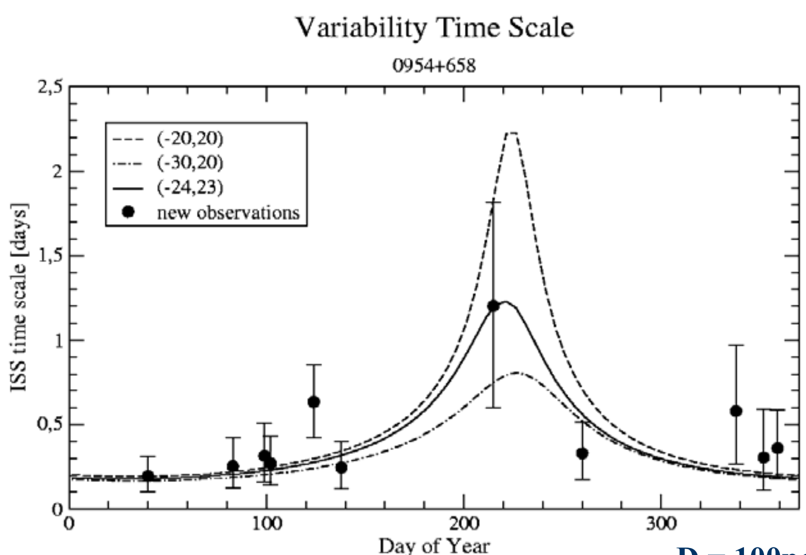


Westerbork 5 GHz

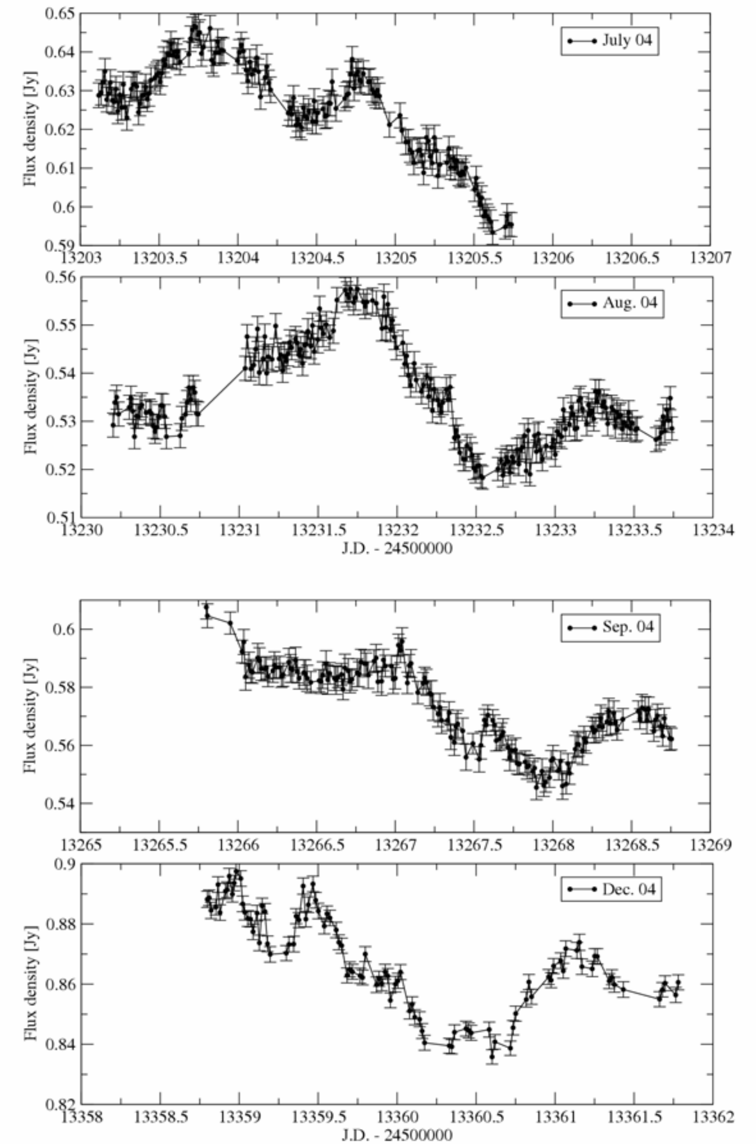


Seasonal Cycles in “classical“ IDV sources

- **Effelsberg IDV monitoring at 5 GHz since 2000: 0954+658 new candidate**

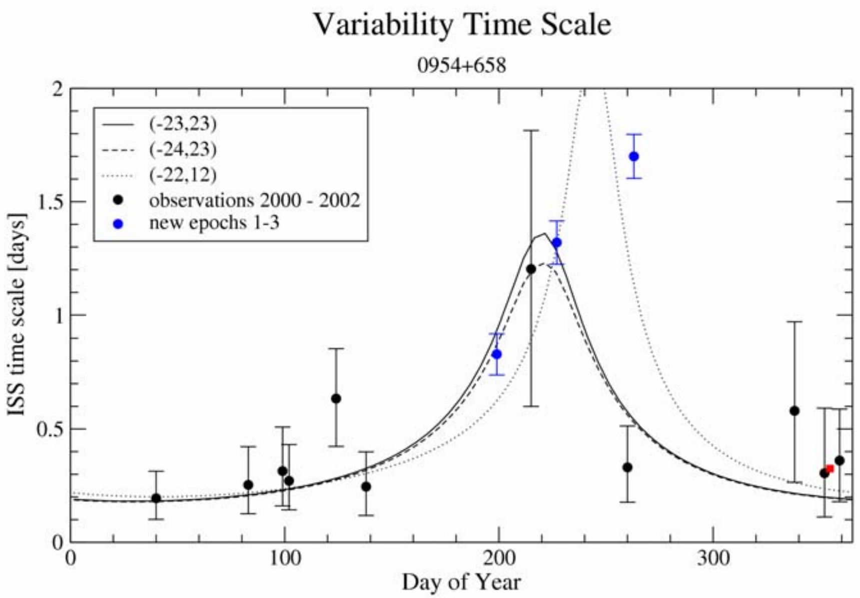


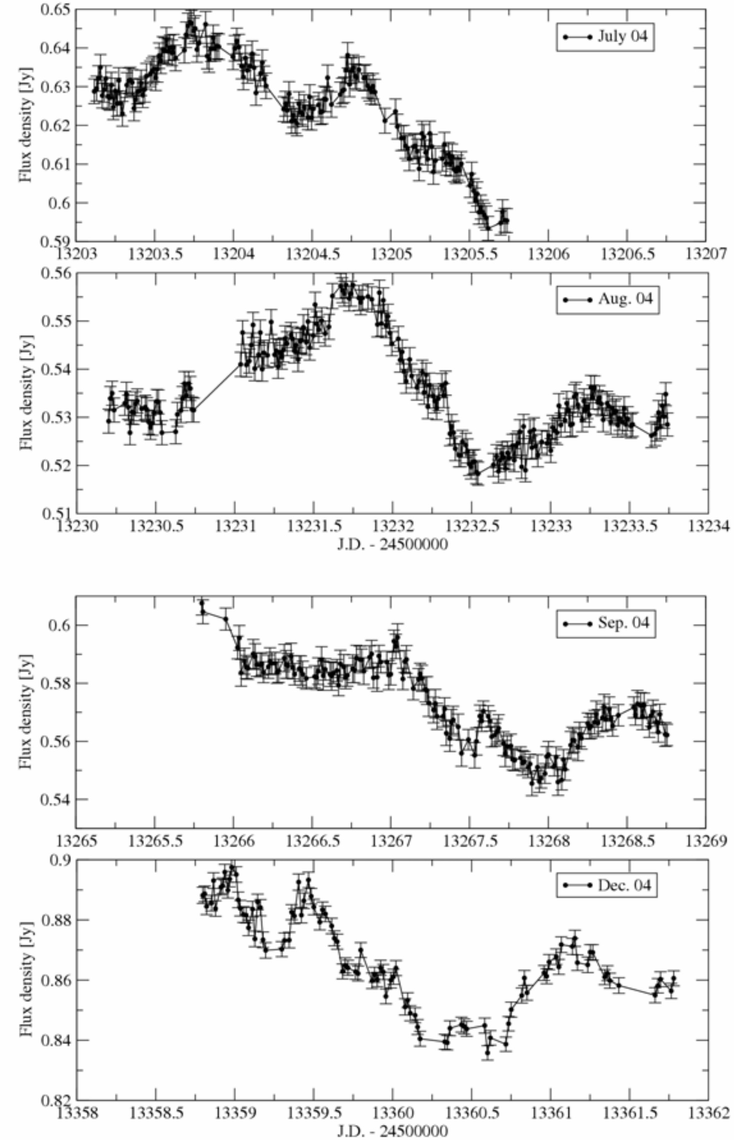
D = 100pc
θ = 70 μas



- **4 new epochs between July and December 04**

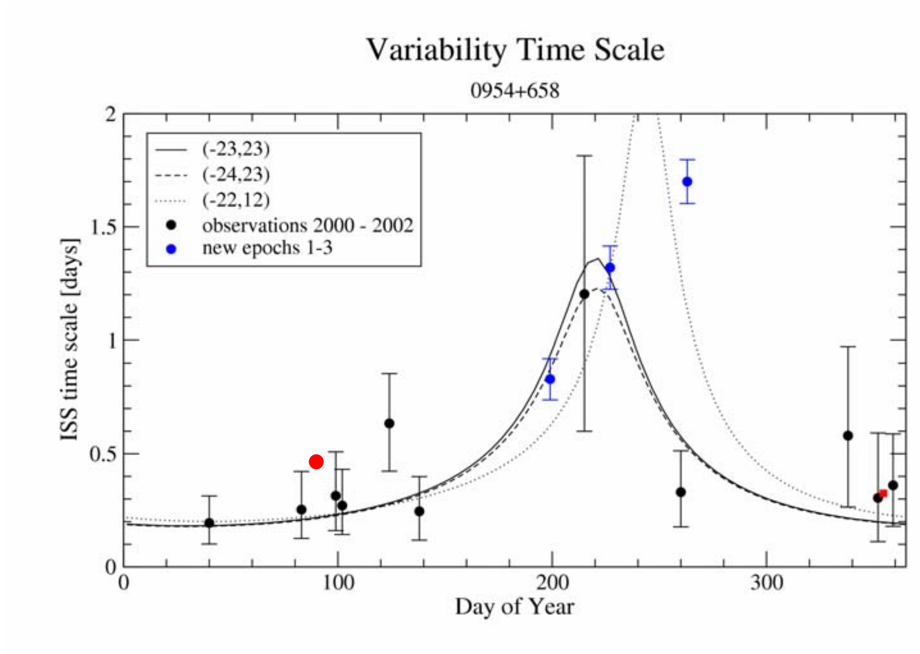
Seasonal Cycles in “classical“ IDV sources

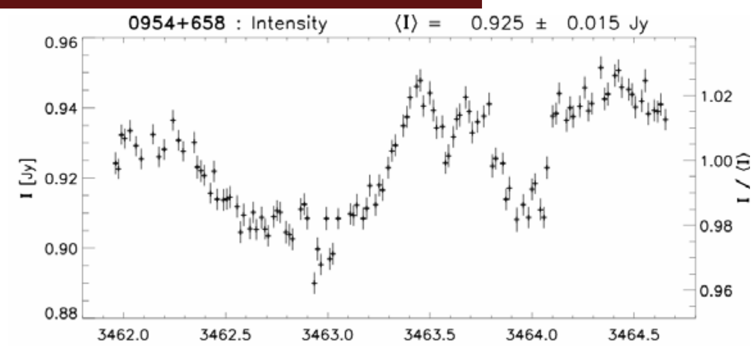


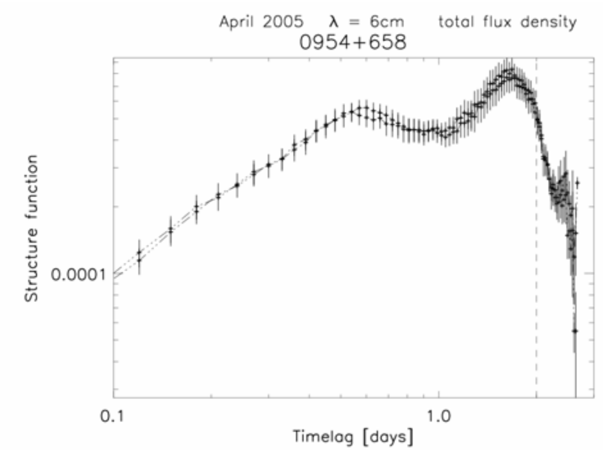


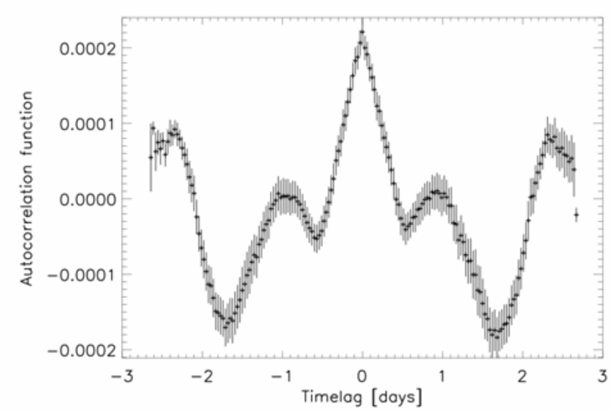
- temporal analysis: 0.83, 1.32, 1.7 and 0.34 days
- new epochs are needed!!!

Seasonal Cycles in “classical“ IDV sources









- new epoch in April 2005
- temporal analysis: 0.5 days

INTEGRAL-multifreqency observations of S5 0716+71: first results of the core campaign

Luisa Ostorero

(Landessternwarte Heidelberg)

on behalf of the S5 0716+71 ENIGMA-WEBT collaboration

Outline

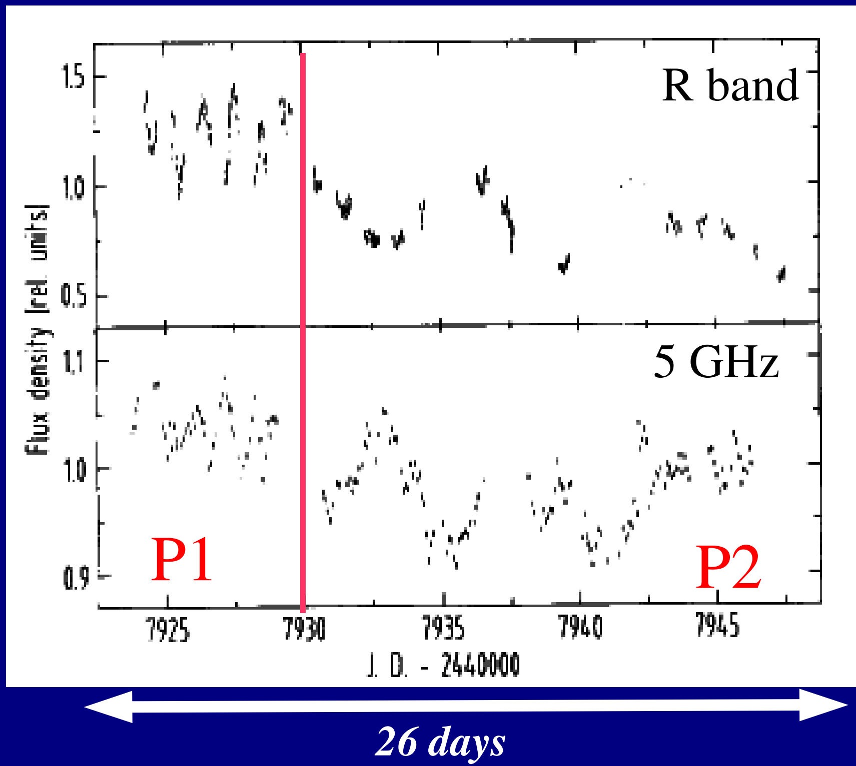
- Scientific motivation
- Short summary of the campaign
- Data analysis: - Optical
  - Radio
  - INTEGRAL
- First results
- Conclusions

Scientific motivation

Scientific motivation

0716+714

- Well-known, bright blazar (R ~ 14.8 – 12.5)
- Redshift unknown: z>0.3
  (Schalinski et al. 1992, Stickel et al. 1993, Wagner et al. 1996)
- Optical and radio intra-day variability (IDV) exhibited at every epoch in the past
  (Wagner et al. 1990, Quirrenbach et al. 1991)
- First source in which radio/optical IDV correlation was claimed: IDV likely intrinsic
  (Quirrenbach et al. 1991, Wagner et al. 1996)



Simultaneous change of variability mode
fast (P1) → slow (P2)

P1: Radio spectrum flatter when F_R higher

from Quirrenbach et al. 1991

Scientific motivation

- If IDV intrinsic:

→Constraint on the size of the emitting region

$$D < c \cdot \Delta t_{obs} \cdot (1+z)^{-1}$$

→High photon densities and brightness temperatures required

$$T_b \propto \frac{d_L^{\,2} \cdot F_\nu}{\nu^2 \cdot \Delta t^2_{obs} \cdot (1+z)^4} \div (10^{17}\text{-}10^{18})\ \mathrm{K} >> \sim 10^{12}\ \mathrm{K}$$

d_L = *luminosity distance*
F_ν = *flux*
ν = *frequency*
z = *redshift*

$T_{IC} \sim 10^{12}$ K : inverse-Compton limit (Kellermann & Pauliny-Toth 1969)

$$T_b \sim \delta^3 \, T_b'$$

→ high Doppler factors ($\delta \sim 100$) required to lower T_b to 10^{12} K
VLBI observations: $\delta \sim 20\text{-}30$ (Bach et al. 2005)

Scientific motivation

- Inverse-Compton limit on brightness temperature: $T_{IC} \sim 10^{12}$ K
  set by Inverse Compton (IC) scattering

$$\frac{L_{com}}{L_{syn}} = 0.5 \bullet (T_{12})^5 \bullet \nu \bullet \left[1 + 0.5 \bullet (T_{12})^5 \bullet \nu\right]$$

$(T_{12} = T / 10^{12}\, K)$

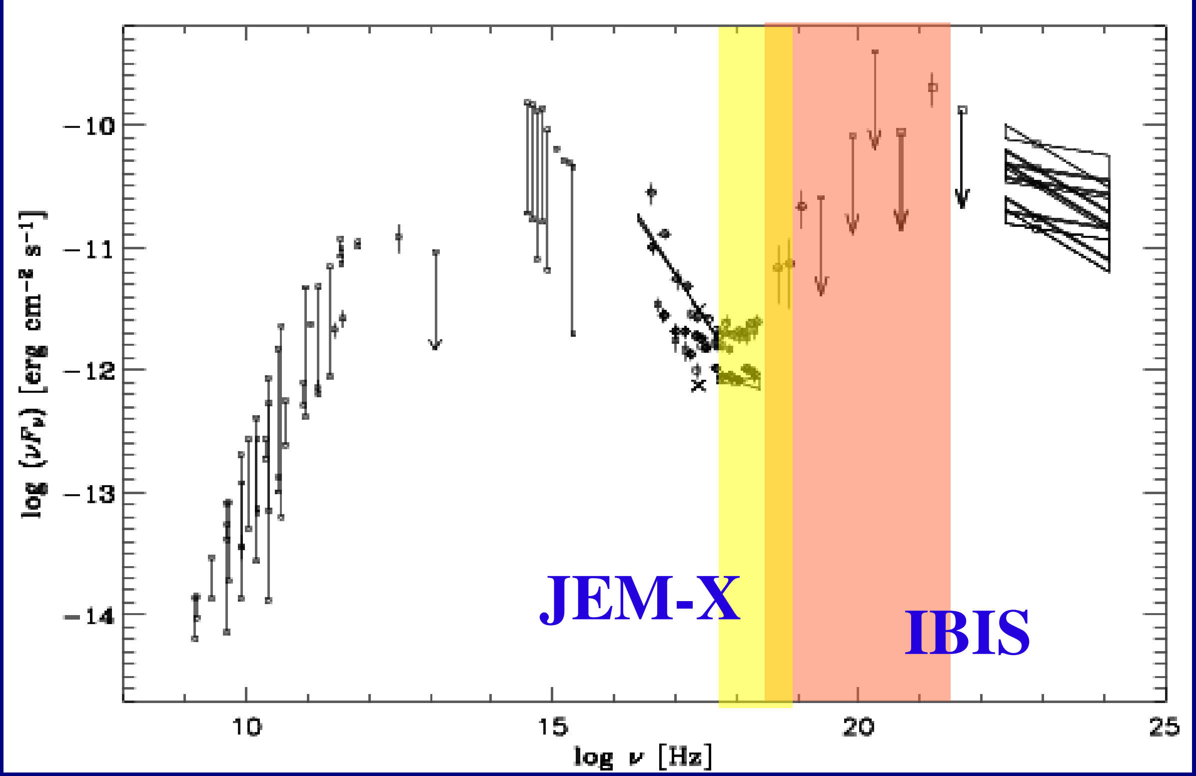
self-regulating mechanism via Inverse Compton catastrophe (KP69)

$T_b > 10^{12}$ K ➔ IC catastrophe ➔ cooling

- Aim of the campaign:
  search for radiative signatures of IC catastrophes in 0716+714

Scientific motivation

- 0716+714 SED : IC peak in the MeV energy band (INTEGRAL)



High-energy detectors onboard INTEGRAL:

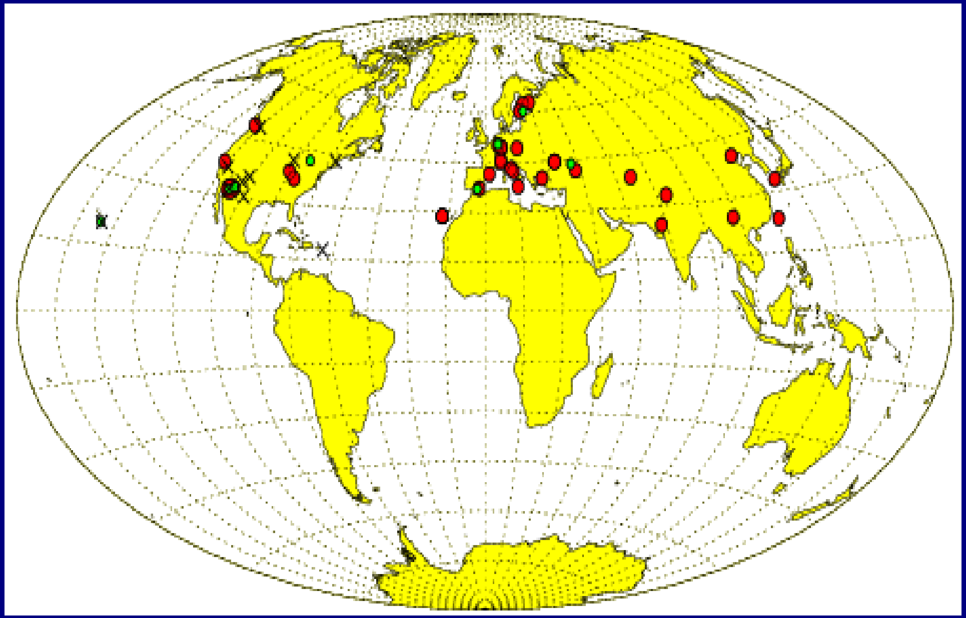
JEM-X: 3 – 35 keV
IBIS: 15 keV – 10 MeV

- 0716+714: ideal target to investigate the violation of the IC limit and its radiative signatures at many frequencies, from radio to gamma-rays.
  Flushes of ICS radiation (2nd order) expected to occur in the IBIS band (10^{18} -10^{20} Hz) after correlated radio-optical flares

Short summary of the campaign

Summary of the campaign

- INTEGRAL observation of 540 ksec in November 2003 (PI: S. Wagner)
- Simultaneous multiwavelength observations organized for a 2-week period:
    - ENIGMA observing facilities
    - Coordinated observatories and WEBT consortium



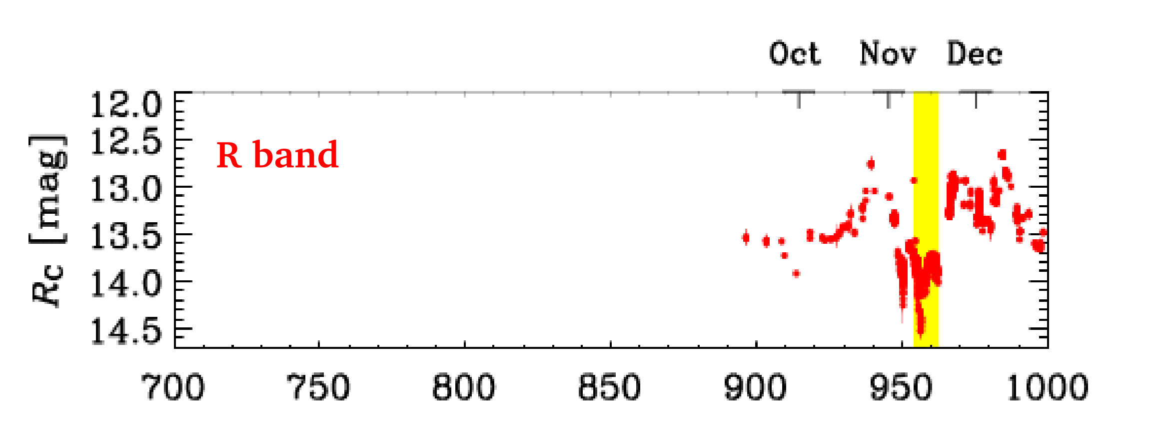
- 38 Opt/IR telescopes (28 cm–4.2 m)
- 9 Radio/mm/submm telescopes
- X VLBA antennas

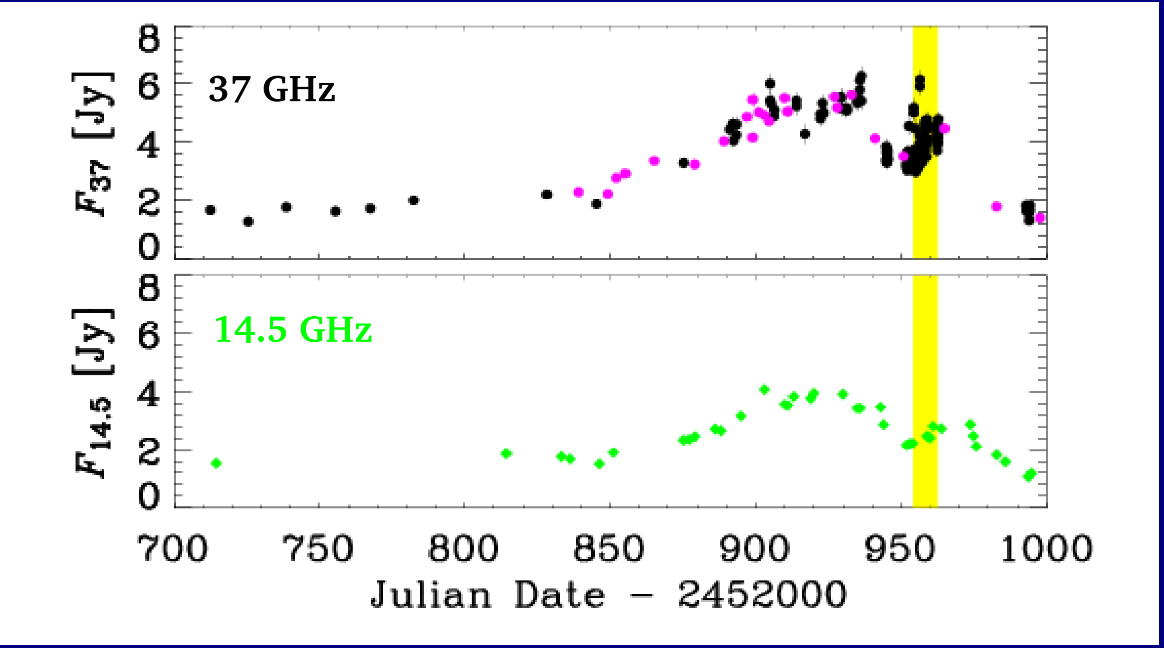
- Exceptional events recorded in the source emission: extension of the campaign till May 2004
- Result: CORE-CAMPAIGN + EXTENDED CAMPAIGN (total duration: 8 months)

Short summary of the campaign

S5 0716+71 *bright* in the optical band(R~12.8) *before and after* the INTEGRAL pointing, but *faint during* the pointing (R~13.6-14.2)

S5 0716+71 *very bright* in the radio band during the INTEGRAL pointing, although already in the declining phase of a big outburst





INTEGRAL
Nov 10-17, 2003

Short summary of the campaign

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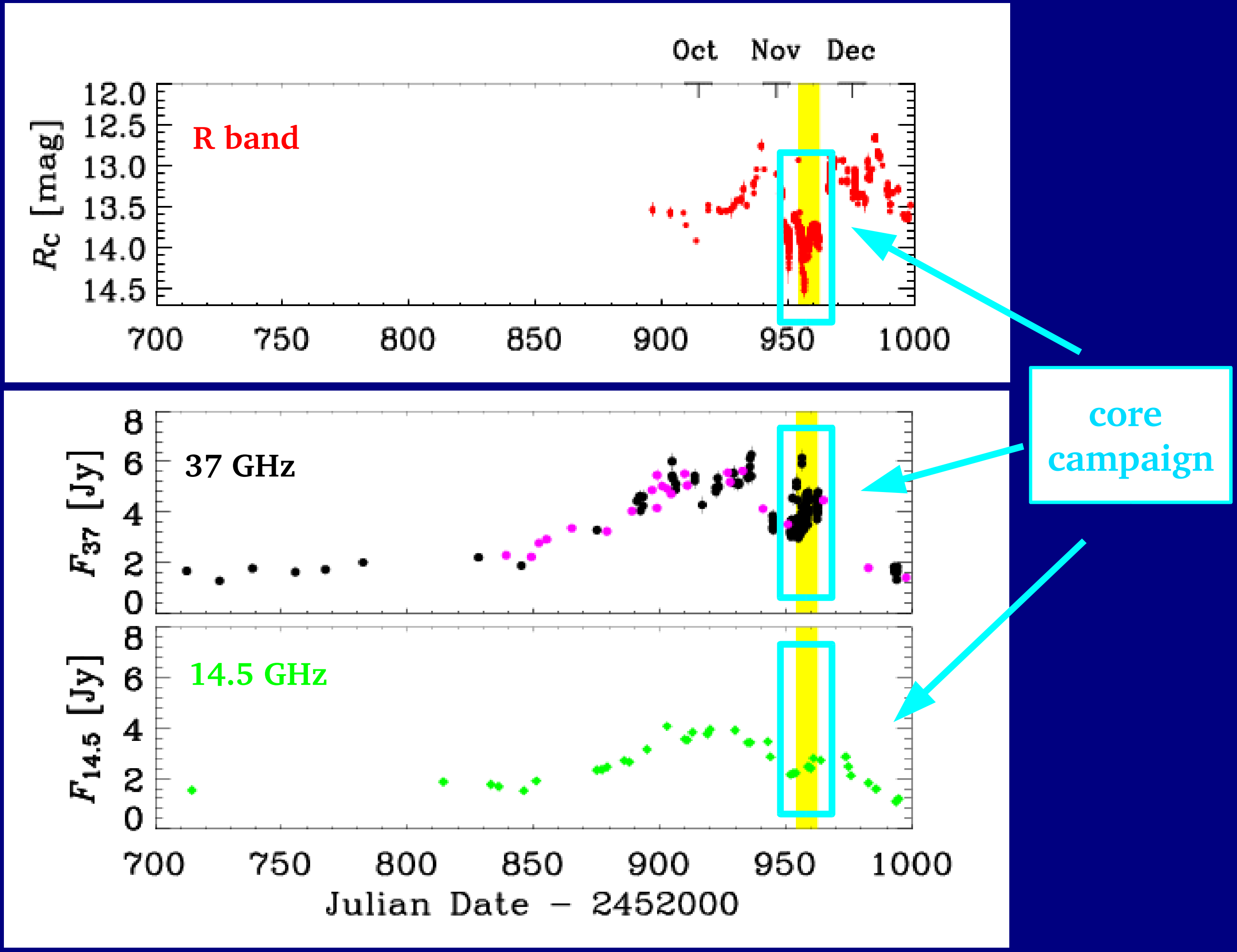


INTEGRAL
Nov 10-17, 2003

Data analysis

Data analysis

Groundbased observations

Optical data:

1) Data archiving
2) Frame photometry
3) Calibration of the data
4) Light curve assembling

Radio data:

1) Data collection
2) Comparison of light curves at different frequencies

INTEGRAL observations

JEM-X: data analysis by Elisa Ferrero (LSW Heidelberg)
IBIS/ISGRI: data analysis by Jose Gracia (University of Athens)

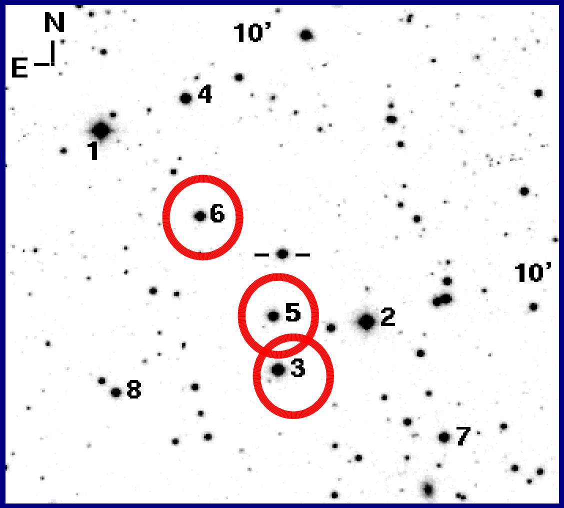
Data analysis : optical

1) <u>Frame photometry</u>

performed with a C-code of aperture photometry developed by K. Nilsson (Tuorla Observatory)
→ 47% of the frames analysed with the same procedure

2) <u>Calibration of the data</u>

with the subsets of calibration stars free of saturation common to most of the datasets (where possible), in order to minimize the inter-instrumental offsets

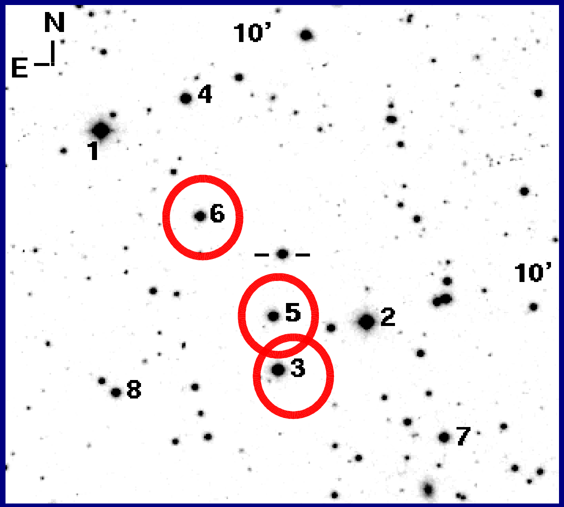


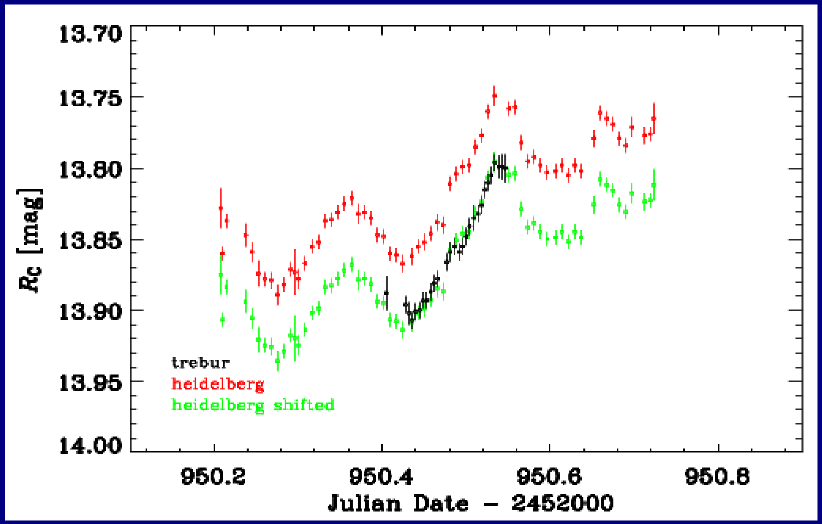
Data analysis : optical

1) Frame photometry — performed with a C-code of aperture photometry developed by K. Nilsson (Tuorla Observatory)
→ 47% of the frames analysed with the same procedure

2) Calibration of the data — with the subsets of calibration stars free of saturation common to most of the datasets (where possible), in order to minimize the inter-instrumental offsets

3) Light curve assembling — cleaning, binning, computation of the offsets among different telescopes/detectors, selection of higher-quality simultaneous data

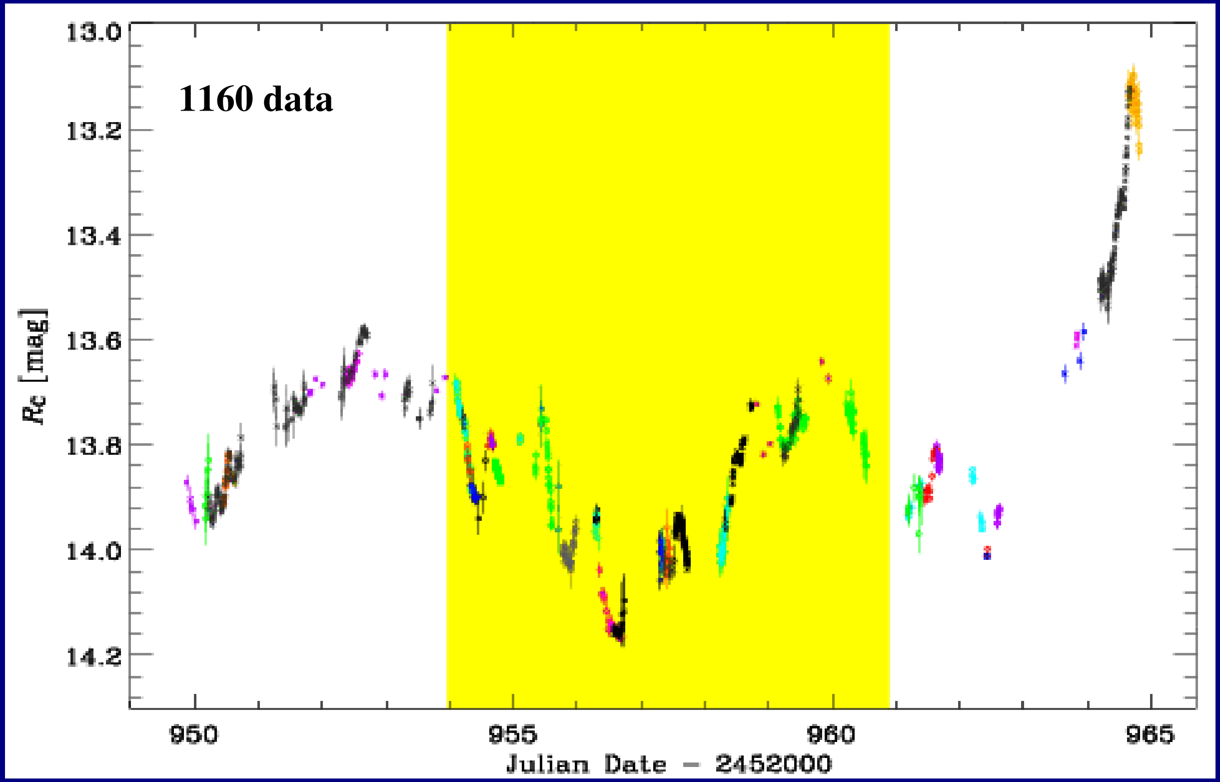




Data analysis : optical

Optical R-band light curve: November 06-20, 2003

- Lulin
- Mt. Maidanak
- Abastumani
- Crimean
- Tuorla
- MonteBoo
- Perugia
- Heidelberg
- Trebur
- Torino
- Hoher List
- Calar Alto
- KVA
- WHT
- Bell
- St. Louis
- WIYN
- Coyote Hill
- Univ. Victoria



Inter-day variability

INTEGRAL pointing

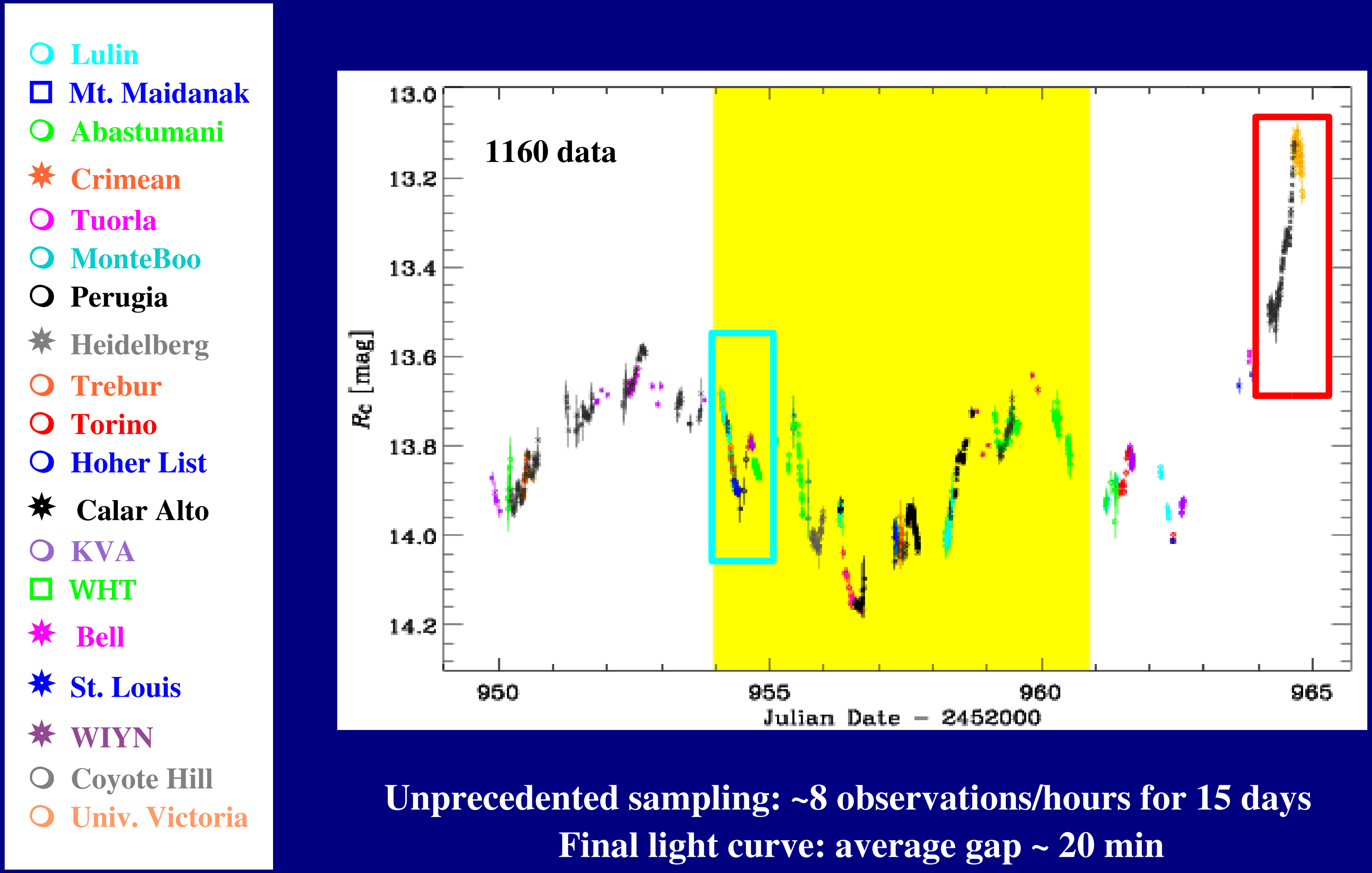
Unprecedented sampling: ~8 observations/hours for 15 days

Final light curve: average gap ~ 20 min

F_{var} ~24%

Data analysis: optical

Optical R-band light curve: November 06-20, 2003



Inter-day variability

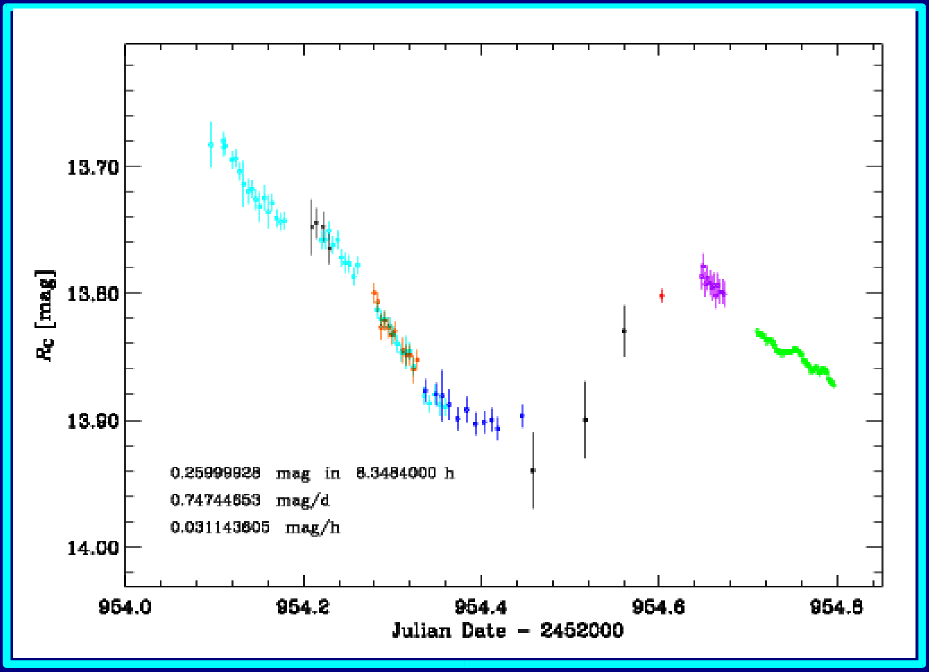
INTEGRAL pointing

Unprecedented sampling: ~8 observations/hours for 15 days

Final light curve: average gap ~ 20 min

$F_{var} \sim 24\%$

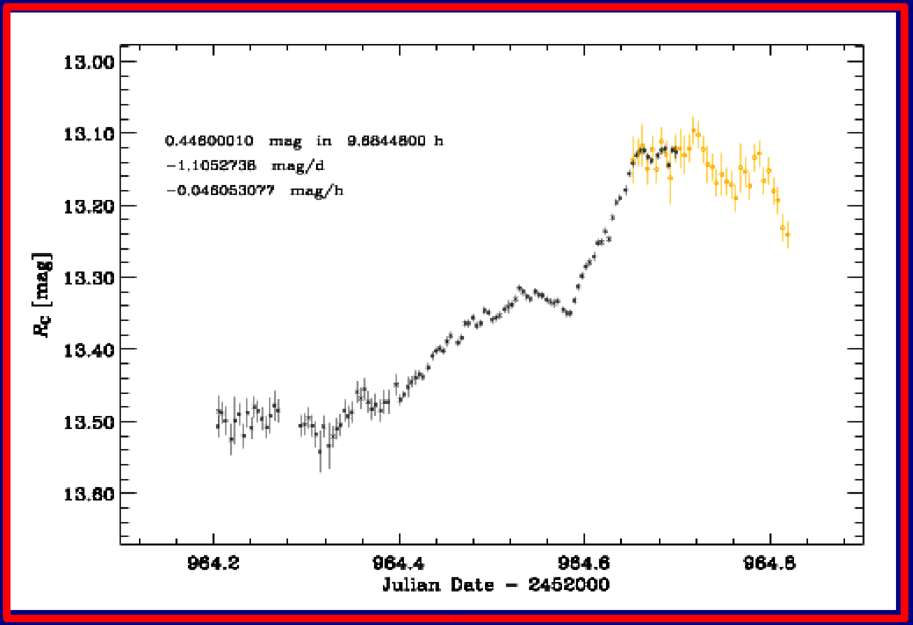
Data analysis: optical



Lulin
Trebur
Heidelberg
Hoher List
Perugia
Torino
KVA
WHT

Intra-day variability

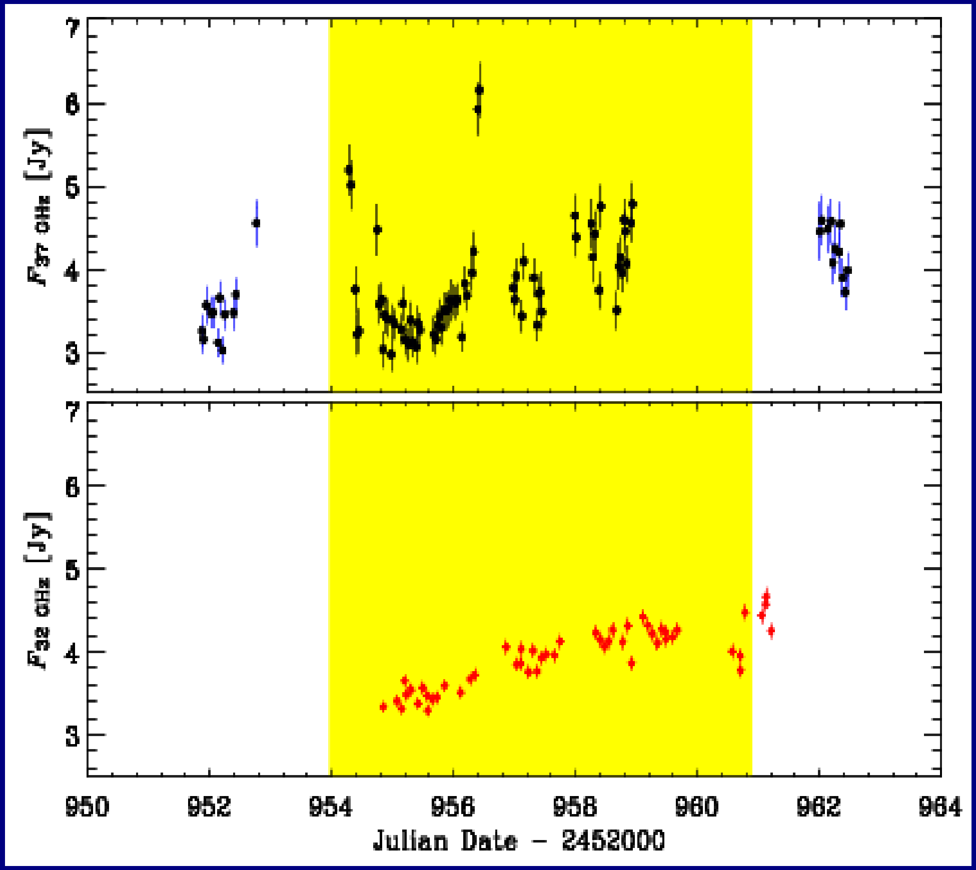
Heidelberg
Un. Victoria



Focusing on ~17 hours segments of light curve, one can see the observing task moving from East to West during the night.
However, the high declination of the source allowed superposition between observations taken at very different latitudes.

Data analysis: radio

Radio light curves at 32 and 37 GHz



INTEGRAL pointing

<u>37 GHz (Metsähovi)</u>

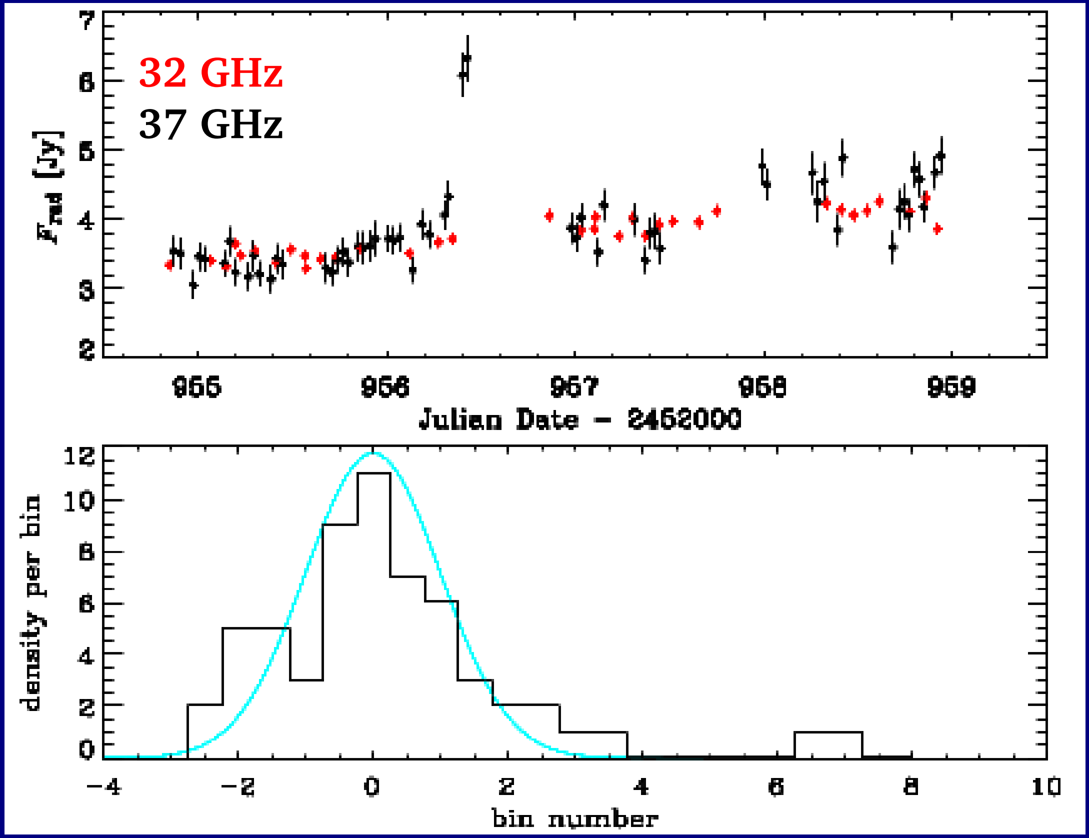
- better sampling (14 data/day)
- bigger error bars (weather)
- bigger scatter
- some “outliers”

<u>32 GHz (Effelsberg)</u>

- less good sampling (9 data/day)
- smaller error bars
- smaller scatter
- no counterpart of the 37 GHz outliers due to lack of data

Data analysis: radio

Comparison of the 32 GHz and 37 GHz
data in the overlapping period

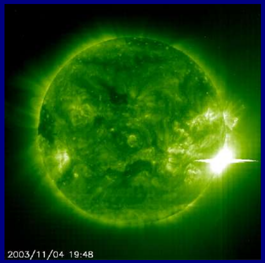


Differences between the two light curves: normally distributed (at 5% significance level)

⇓

Bigger scatter of the 37 GHz data consistent with weather effetcs

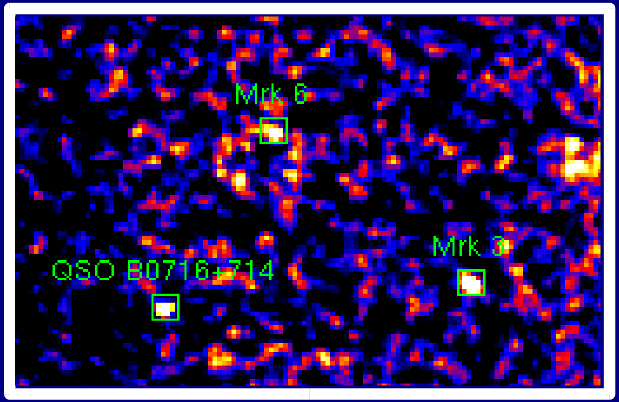
Data analysis: INTEGRAL



INTEGRAL data:
strongly affected by enhanced background due to the solar flare of Nov 04, 2003

- **JEM-X (3-35 keV)**
  - Source not detected neither at science-window (SW) level nor in the SW-mosaic
  - Upper limit: $F_x \sim 1.5 \cdot 10^{-11}$ erg/cm^2/sec from comparison of count rates at the sky position of 0716 +714 with Crab Nebula JEM-X count rate

ISGRI image by Jose Gracia

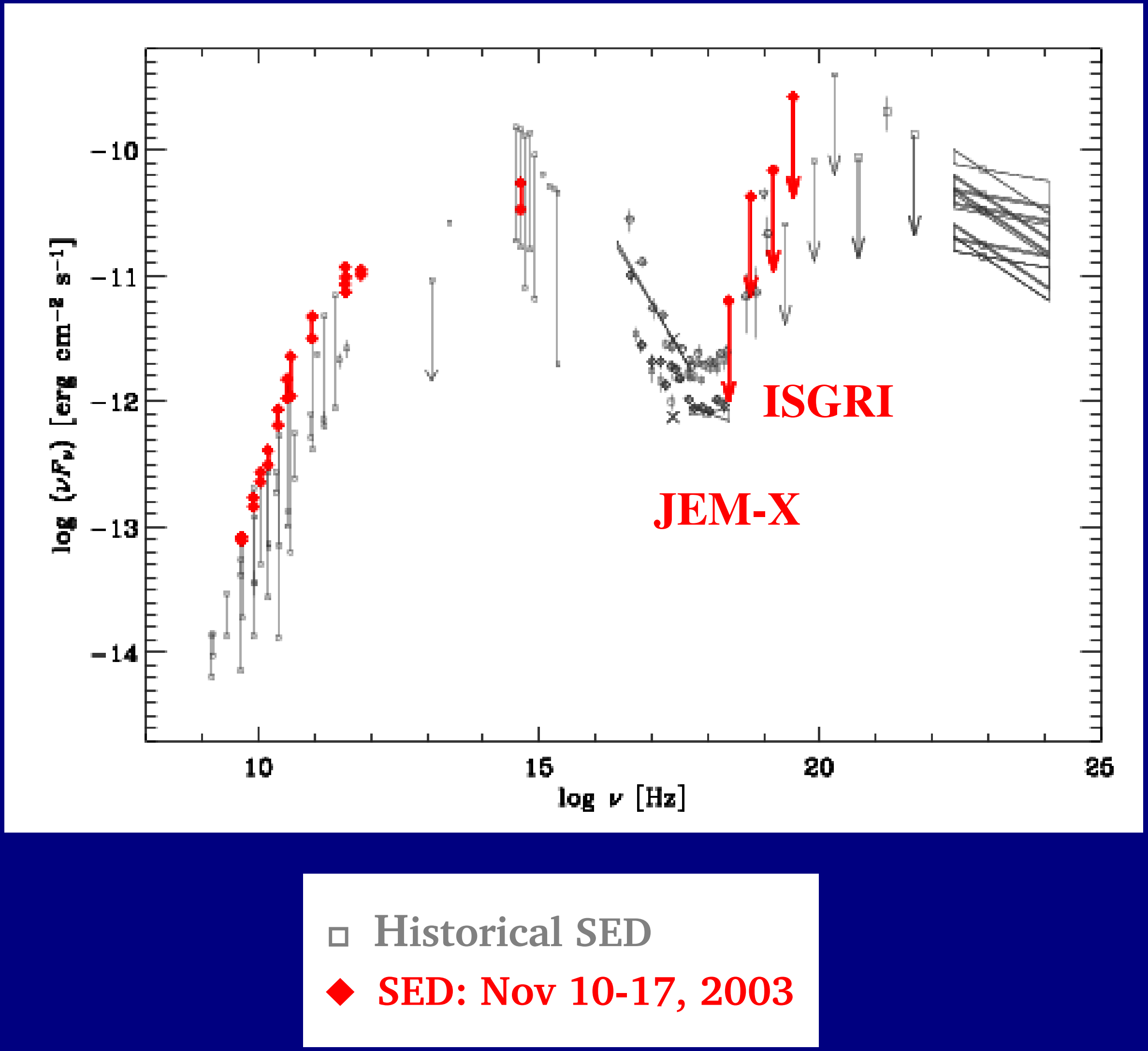


- **IBIS/ISGRI (15 keV-10 MeV)**
  - Source not detected in the mosaic of all the SWs
  - SW detections not significantly different from the background
  - Conservative upper-limit estimates in the 15-40, 40-100, and 100-200 keV sub-bands from mosaic of $>1\sigma$ detections

First results

First results

- 0716+714: SED simultaneous to the INTEGRAL pointing

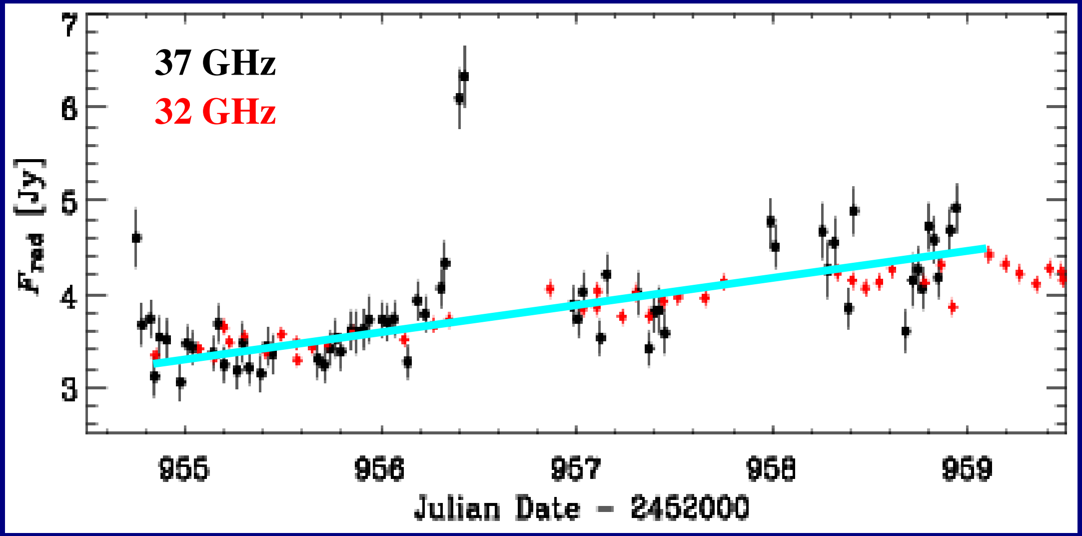


Nov. 2003 data from:

-UMRAO (4.8,8.0,14.5 GHz)
- Metsähovi (22,37 GHz)
- Effelsberg(5.0,10.7,32 GHz)
- IRAM(90,230 GHz)
- KP12m (90 GHz)
- HHT (345 GHz)
- JCMT (450, 850 μm)
- optical ENIGMA-WEBT collaboration
- INTEGRAL

First results

- Variability brightness temperatures from radio light curves - I



Radio "baselines" : $T_b \sim 6.5 \cdot 10^{14}$ K $\Rightarrow \delta \geq 8$

32 GHz IDV: $T_b \div 2.7 \cdot 10^{16}$ K $\Rightarrow \delta \geq 30$

37 GHz IDV: $T_b \div 5.4 \cdot 10^{17}$ K $\Rightarrow \delta \geq 80$

$T_b \div 2.5 \cdot 10^{18}$ K (outliers) $\Rightarrow \delta \geq 130$

If Doppler boosting invoked: $\delta \geq (T_b/10^{12}\mathrm{K})^{1/3}$ required

First results

- Variability brightness temperatures from radio light curves - II

Doppler factors derived from proper motion of VLBI components:
$\delta \sim 20\text{-}30$ (Bach et al. 2005)

- ➢ can account for:
  - the T_b derived from the inter-day variability at 32 and 37 GHz
  - the T_b derived from the IDV at 32 GHz

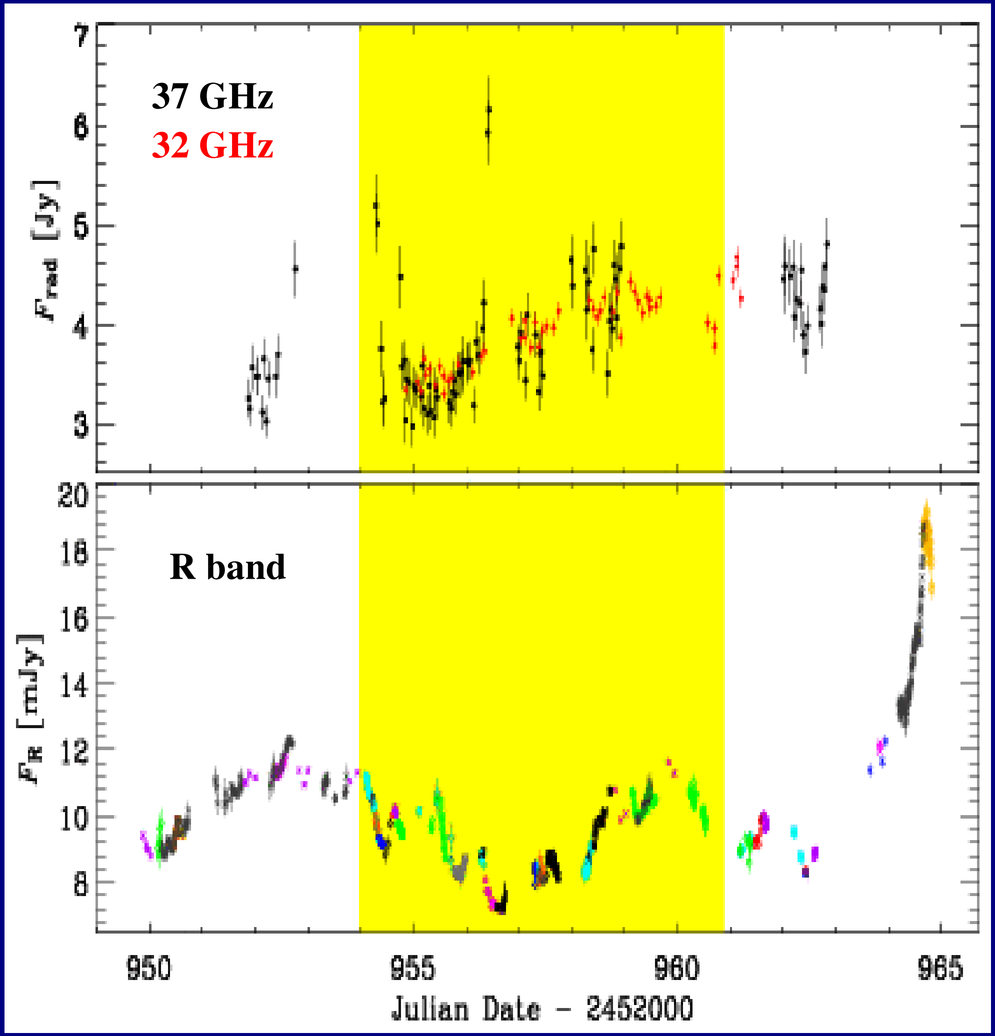
- ➢ are too low to explain the T_b derived from the 37 GHz IDV

However:
- 3σ IDV features at 37 GHz might originate from the bigger scatter (bad weather ?)

although:
- the outliers might be real, suggesting IC catastrophes

First results

- Radio-optical variability



No evidence of correlation between radio and optical light curves, as it was observed in the past

⇓

The contribution of extrinsic effects to radio IDV cannot be ruled out

⇓

The observed T_b might not be representative of the source photon density

⇓

The non-detection by INTEGRAL is likely due to non-occurrence of IC catastrophes

Conclusions

- 0716+714 core-campaign results

  - <u>Optical</u>
    - monitoring with exceptional sampling
    - inter-day and intra-day variability: usual

  - <u>Radio</u>
    - inter-day variability: Tb'$\leq 10^{12}$ K ↔ $\delta \geq 8$ → agreement with observations
    - 32 GHz IDV: Tb'$\leq 10^{12}$ K ↔ $\delta \geq 30$ → agreement with observations
    - 37 GHz IDV: Tb'$\leq 10^{12}$ K ↔ $\delta \geq 80$ → IC catastrophe?

  - No evidence of radio-optical correlation
    → non-negligible extrinsic contribution to the observed radio IDV

  - <u>INTEGRAL</u>: source not detected
    - upper limit by JEM-X (3-35 keV)
    - upper limits by IBIS/ISGRI (15-200 keV)

  - No multi-λ signatures of inverse-Compton catastrophes occurring in the source during the core-campaign

The broad band flux density monitoring of 0716+714 -

A revised analysis of the radio data

T.P. Krichbaum on behalf of the observing teams

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A. Witzel, J.A. Zensus

Partners:

many participants in this workshop, plus

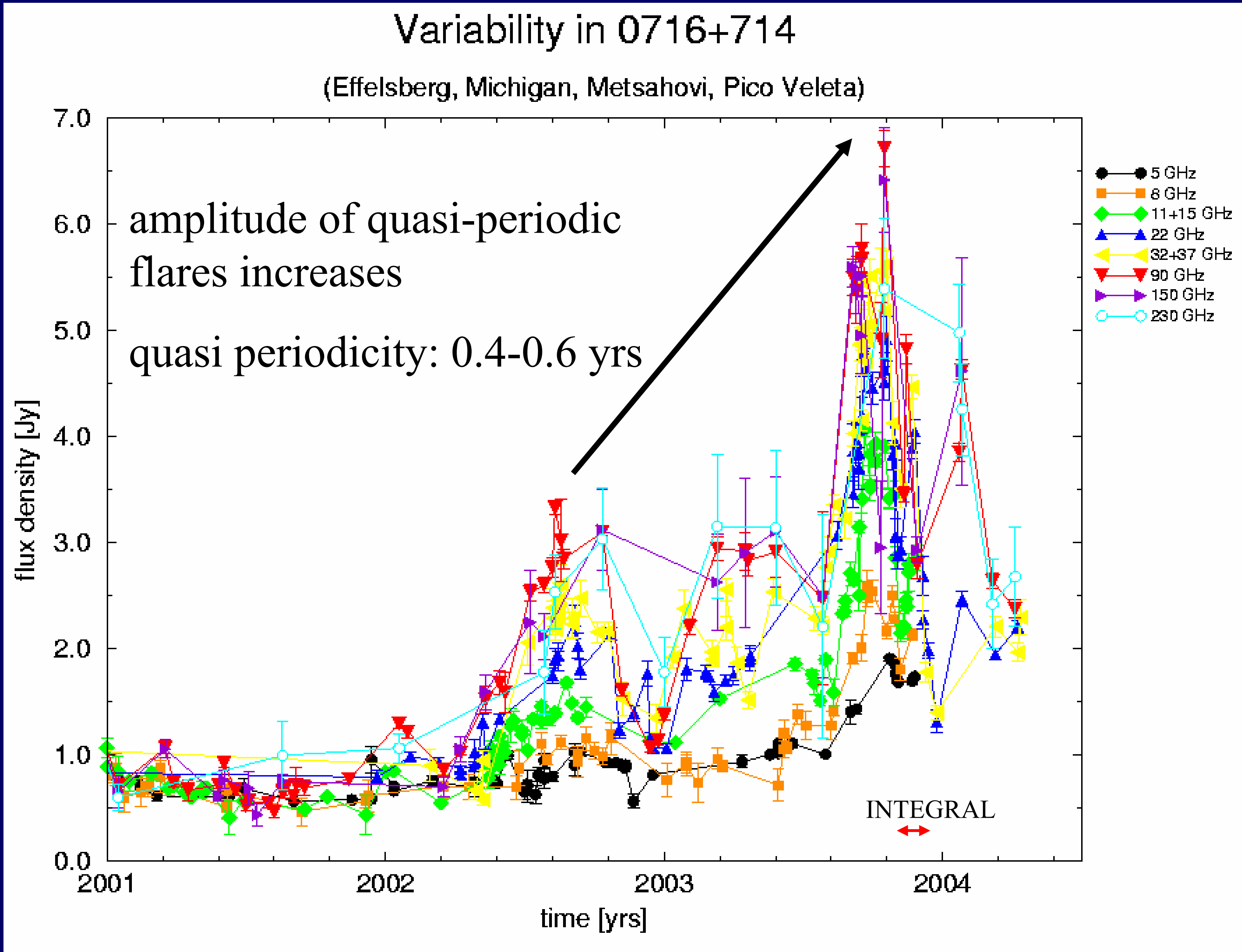
S. Wagner, et al.

H. Ungerechts, H. Wiesemeyer, C. Thum, M. Grewing (IRAM)

A. Apponi, B. Vila-Vilaro, P. Strittmatter, L. Ziurys (Steward Obs.)

R. Strom (ASTRON)

B.W. Sohn (KVN)


Variability in 0716+714
(Effelsberg, Michigan, Metsahovi, Pico Veleta)
amplitude of quasi-periodic flares increases
quasi periodicity: 0.4-0.6 yrs
flux density [Jy]
time [yrs]
INTEGRAL
5 GHz
8 GHz
11+15 GHz
22 GHz
32+37 GHz
90 GHz
150 GHz
230 GHz
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
2001
2002
2003
2004

Participating observatories

Radio:

Effelsberg (5 GHz I+P, 10.5 GHz I+P, 32 GHz I),

Michigan (5, 8, 15 GHz, I+P) ,

Westerbork (1.4 & 2.2 GHz, I),

Metsähovi (22 & 37 GHz, I)

VLBA (6 x 8 hrs, 1.6 - 43 GHz, dual pol.)

Millimeter:

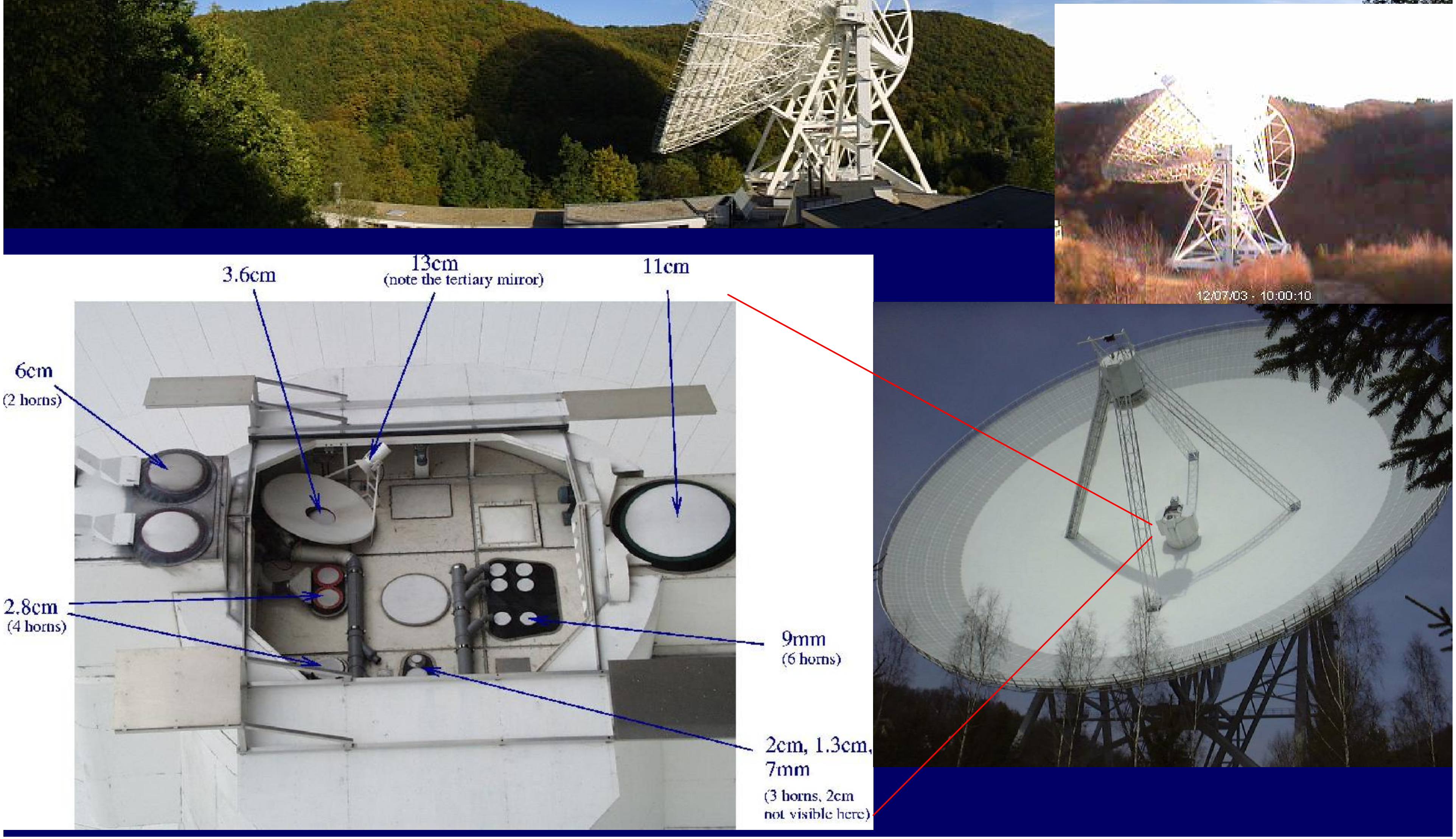
Pico Veleta (90 & 230 GHz), Kitt Peak (90 GHz),

Heinrich-Hertz (345 GHz), JCMT (850 μm, 450 μm)

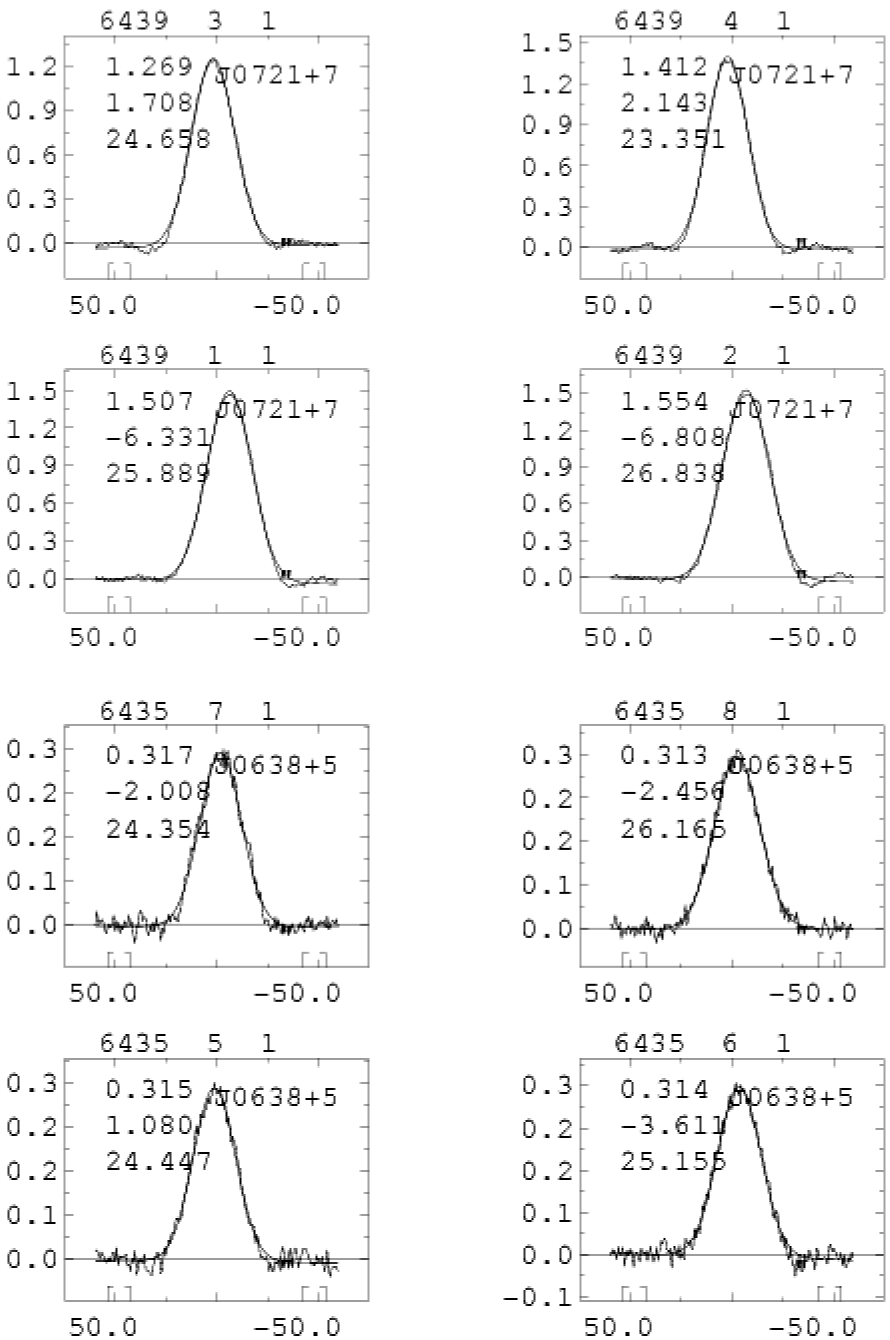
Optical: WEBT (many optical telescopes)

High Energies: INTEGRAL (optical, X – ray, γ – ray)

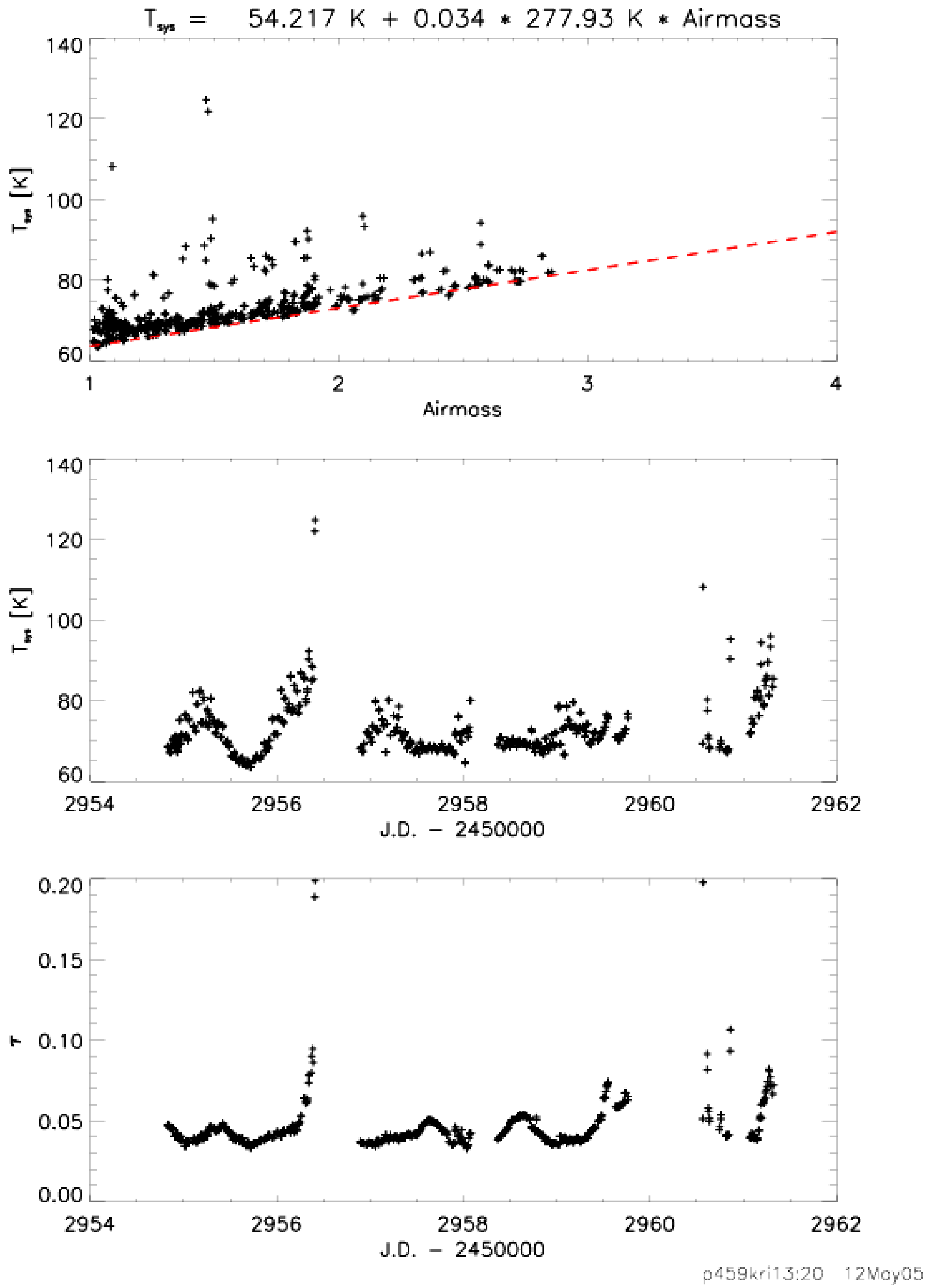
The 100m radio telescope of the MPIfR in Effelsberg

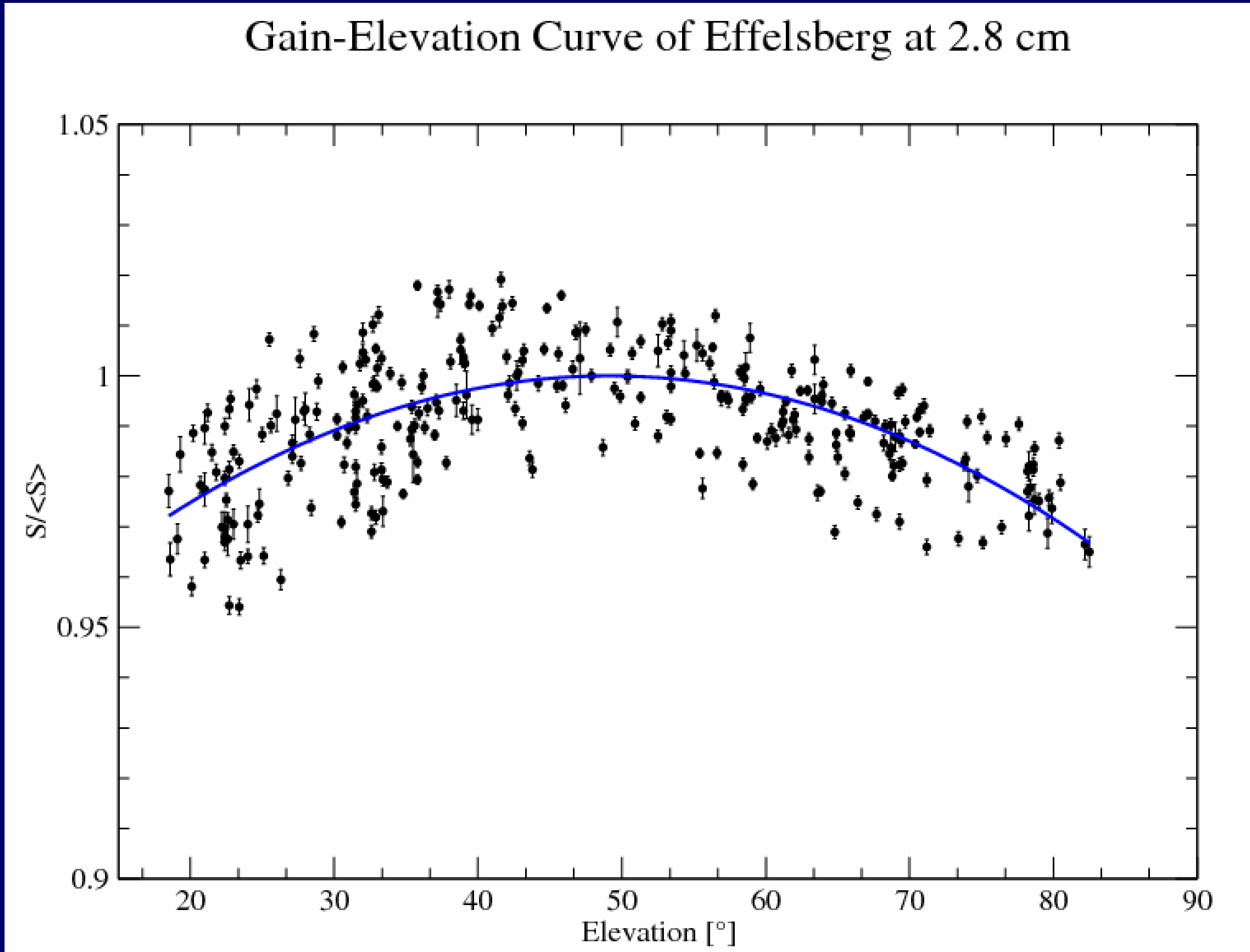


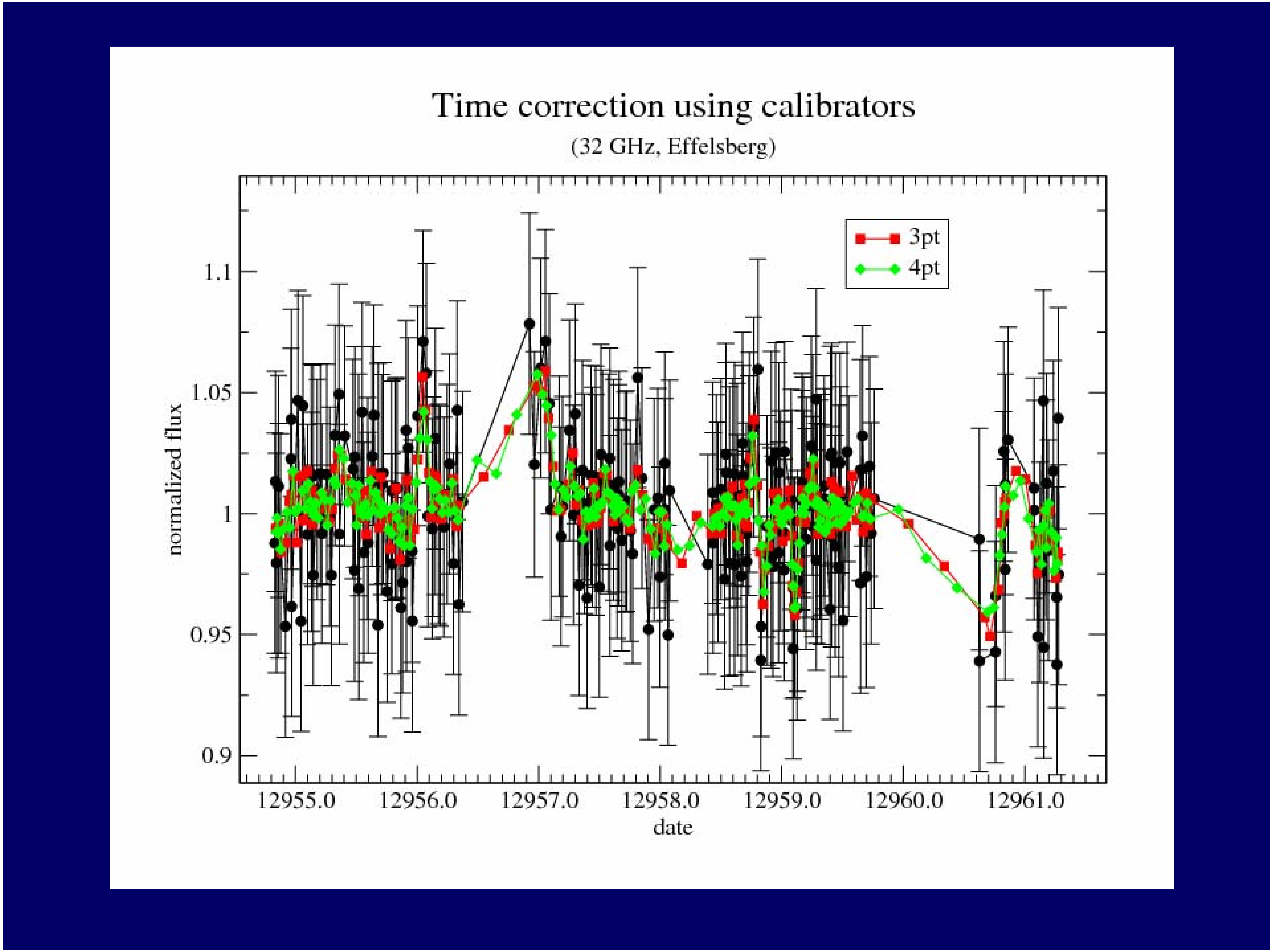
Example of cross-scans in Az/El for 2 sources observed at 9mm with the Effelsberg 100 m RT.

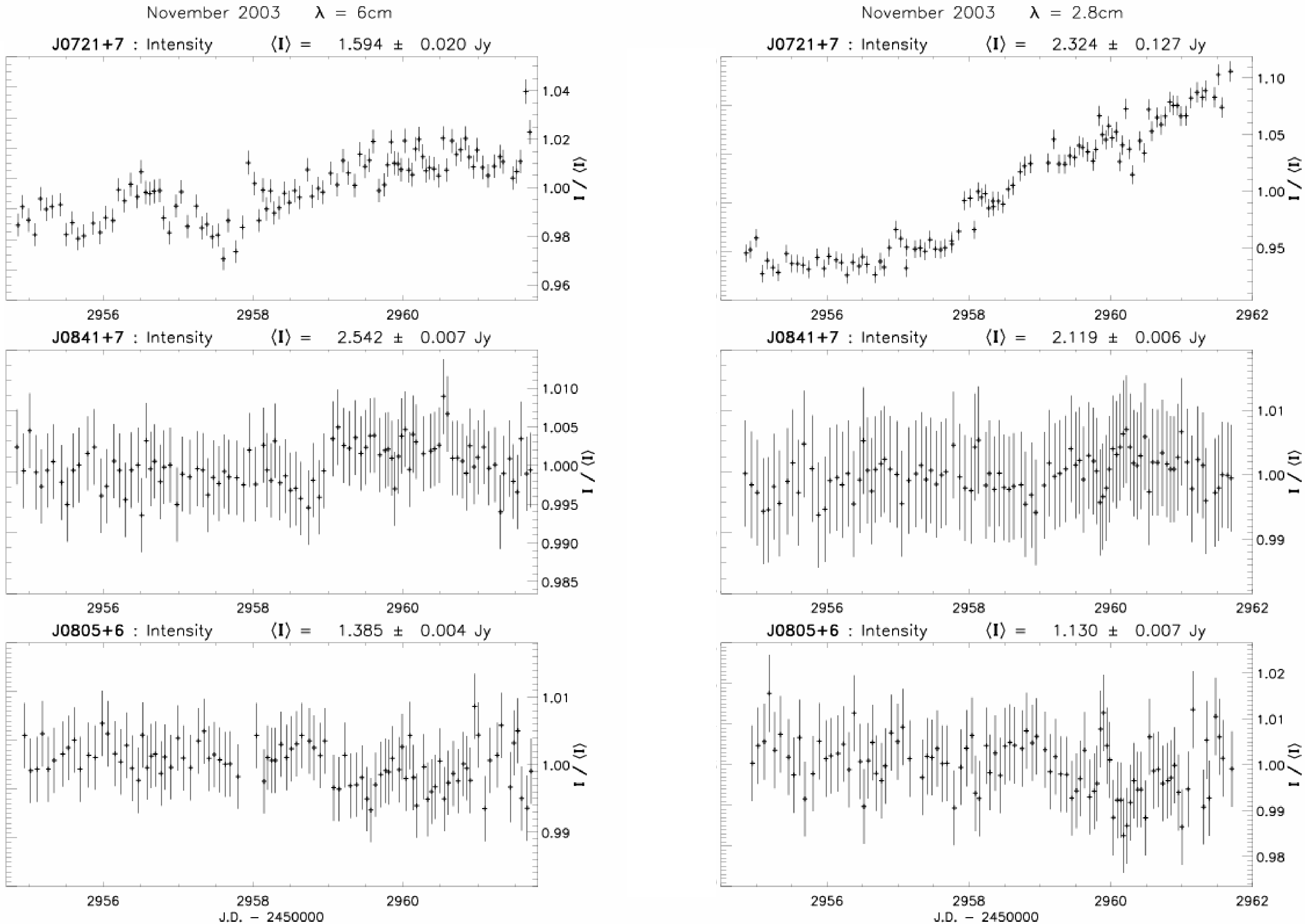


Example for the atmospheric opacity correction (i.e. at 9mm)

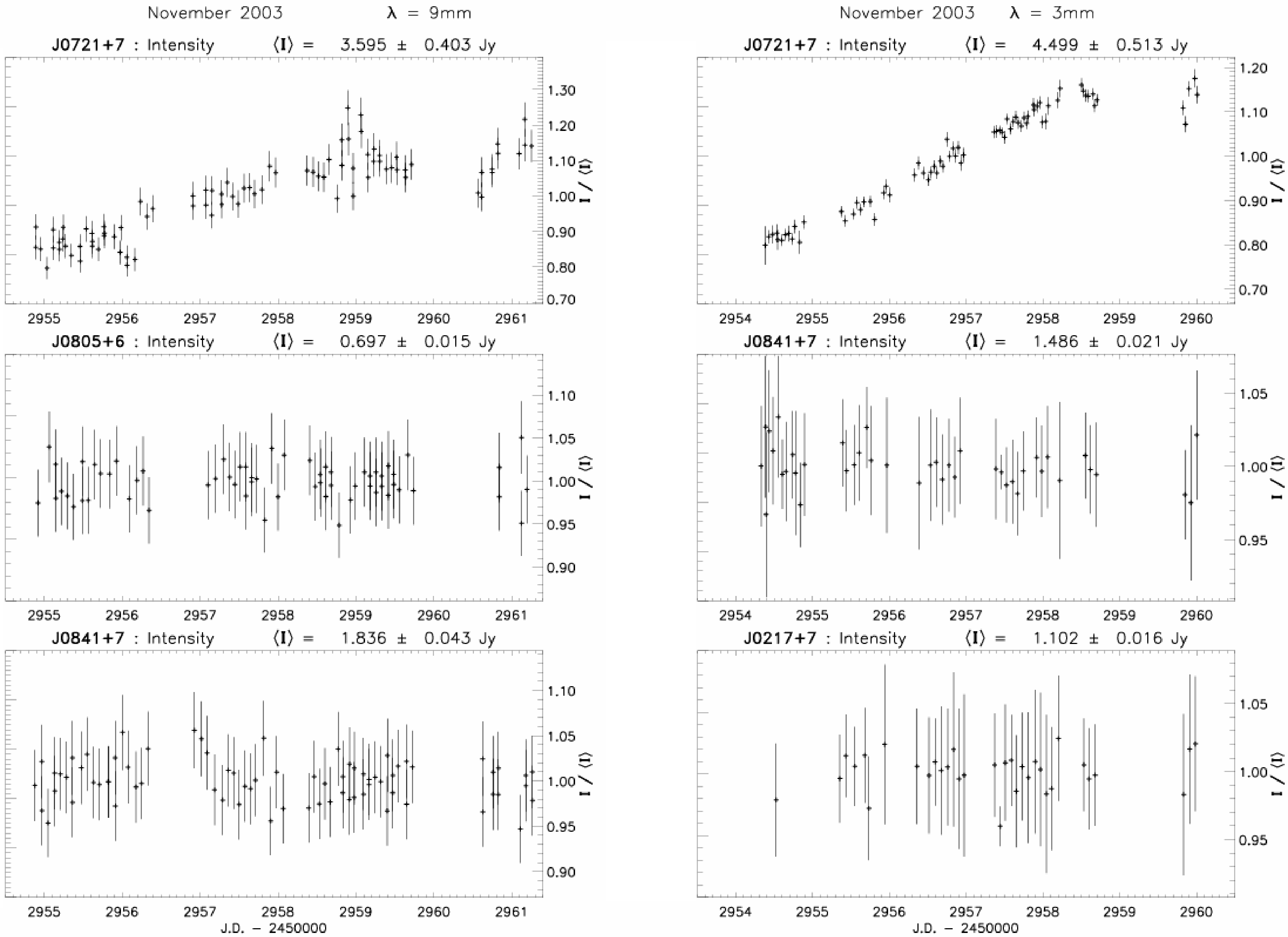



Gain-Elevation Curve of Effelsberg at 2.8 cm
1.05
1
0.95
0.9
S/<S>
20
30
40
50
60
70
80
90
Elevation [°]

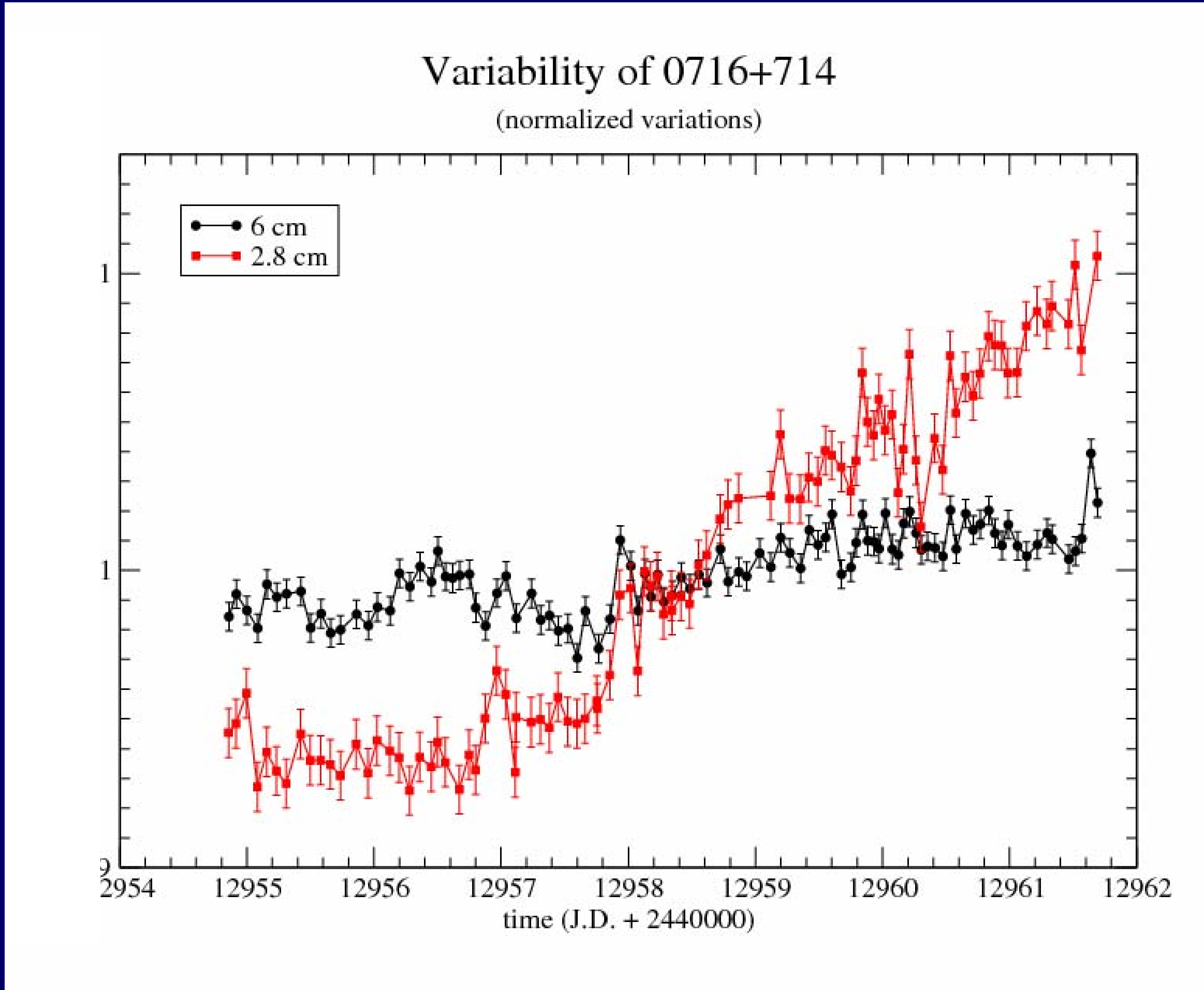

Time correction using calibrators
(32 GHz, Effelsberg)
3pt
4pt
normalized flux
date
1.1
1.05
1
0.95
0.9
12955.0
12956.0
12957.0
12958.0
12959.0
12960.0
12961.0

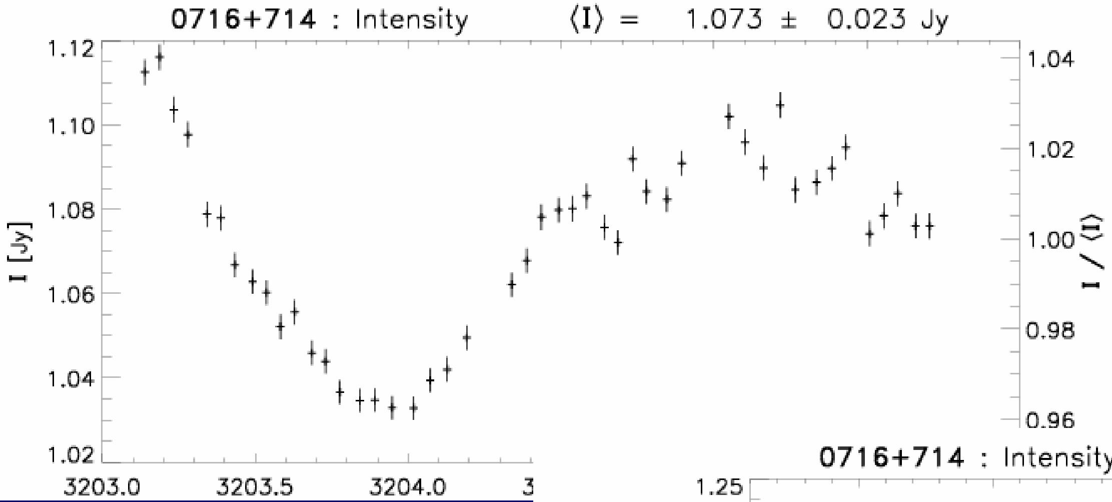


November 2003 λ = 6cm
November 2003 λ = 2.8cm
J0721+7 : Intensity ⟨I⟩ = 1.594 ± 0.020 Jy
J0721+7 : Intensity ⟨I⟩ = 2.324 ± 0.127 Jy
J0841+7 : Intensity ⟨I⟩ = 2.542 ± 0.007 Jy
J0841+7 : Intensity ⟨I⟩ = 2.119 ± 0.006 Jy
J0805+6 : Intensity ⟨I⟩ = 1.385 ± 0.004 Jy
J0805+6 : Intensity ⟨I⟩ = 1.130 ± 0.007 Jy
I / ⟨I⟩
J.D. − 2450000
2956
2958
2960
2962



November 2003 λ = 9mm
J0721+7 : Intensity ⟨I⟩ = 3.595 ± 0.403 Jy
J0805+6 : Intensity ⟨I⟩ = 0.697 ± 0.015 Jy
J0841+7 : Intensity ⟨I⟩ = 1.836 ± 0.043 Jy
J.D. − 2450000
I / ⟨I⟩
November 2003 λ = 3mm
J0721+7 : Intensity ⟨I⟩ = 4.499 ± 0.513 Jy
J0841+7 : Intensity ⟨I⟩ = 1.486 ± 0.021 Jy
J0217+7 : Intensity ⟨I⟩ = 1.102 ± 0.016 Jy
J.D. − 2450000
I / ⟨I⟩


Variability of 0716+714
(normalized variations)
6 cm
2.8 cm
1
1
9
2954
12955
12956
12957
12958
12959
12960
12961
12962
time (J.D. + 2440000)

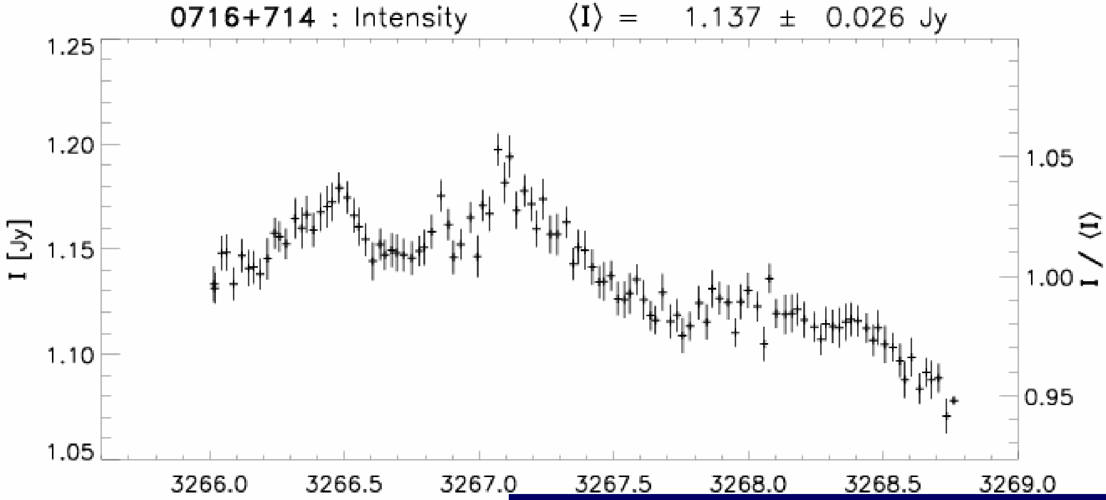


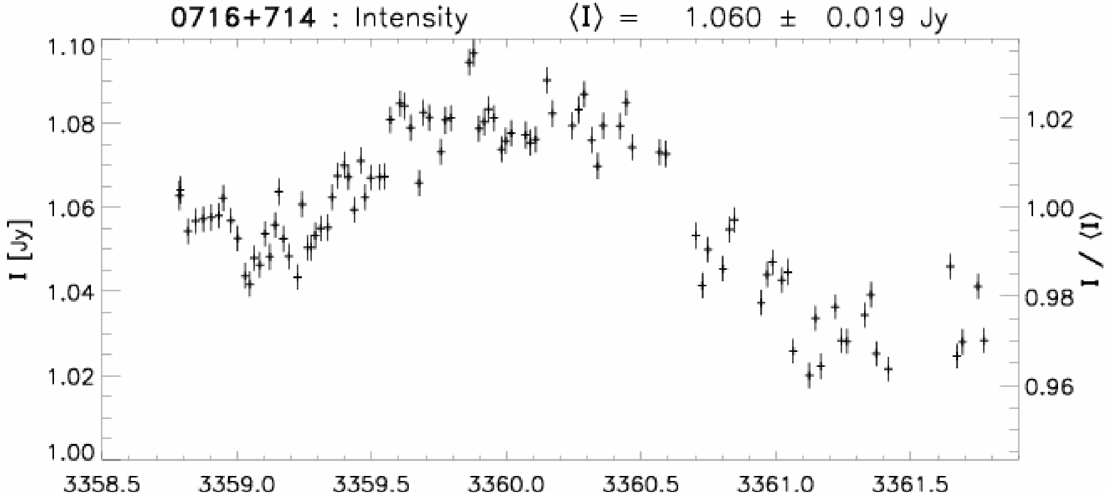
July 2004

m= 2.1 %

Sep. 2004

m= 2.3 %

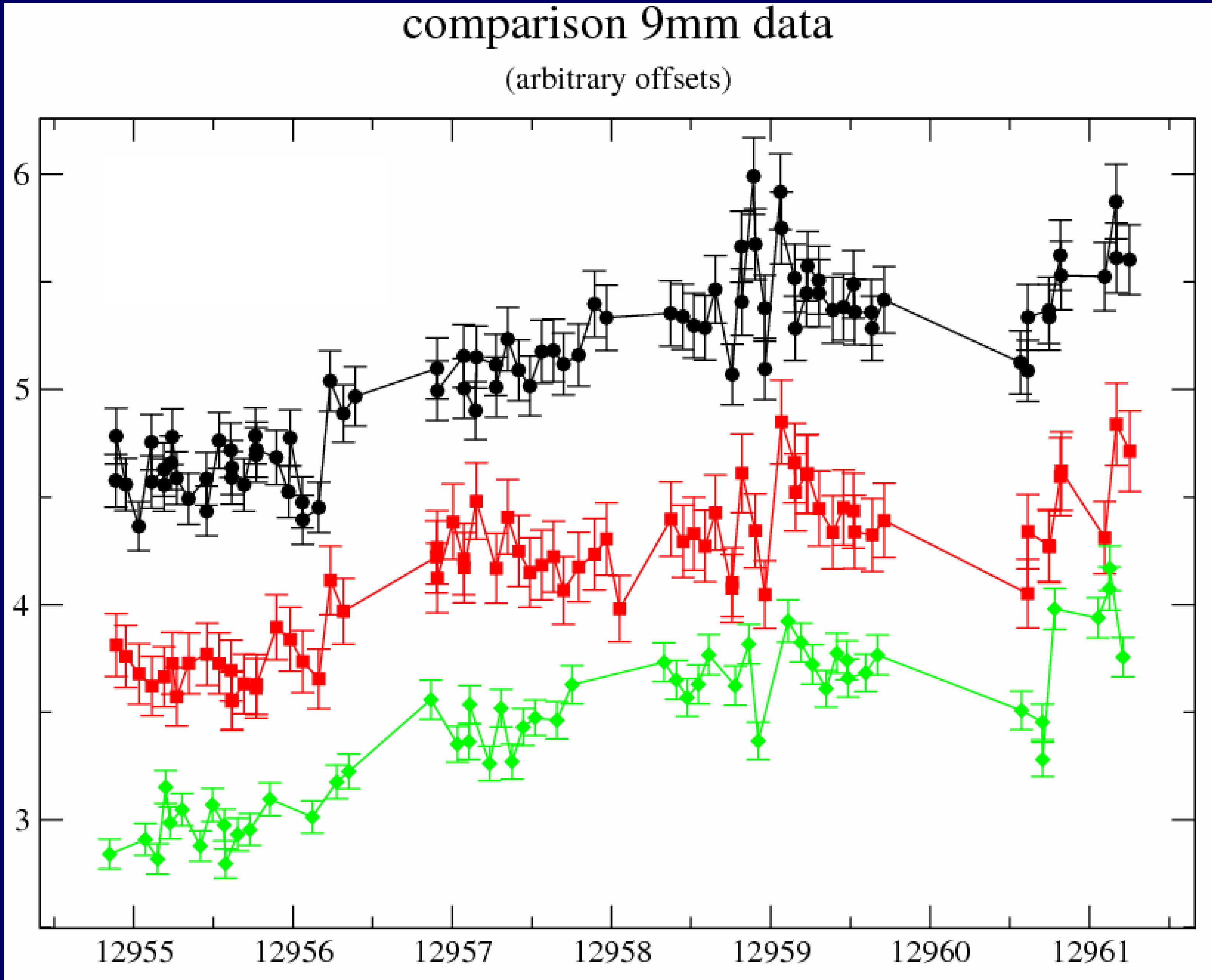




Dec. 2004

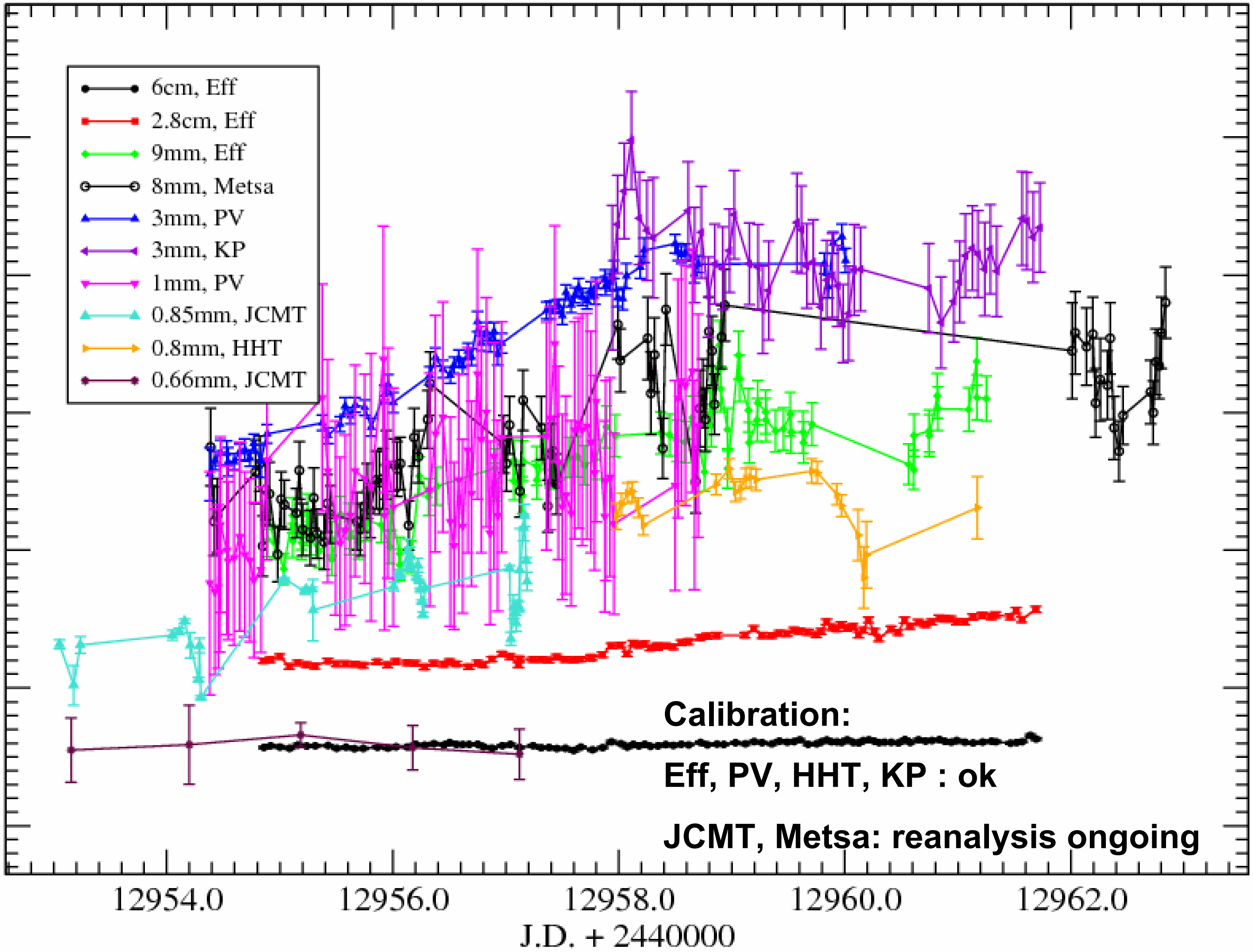
m= 1.8 %

L. Fuhrmann, et al.

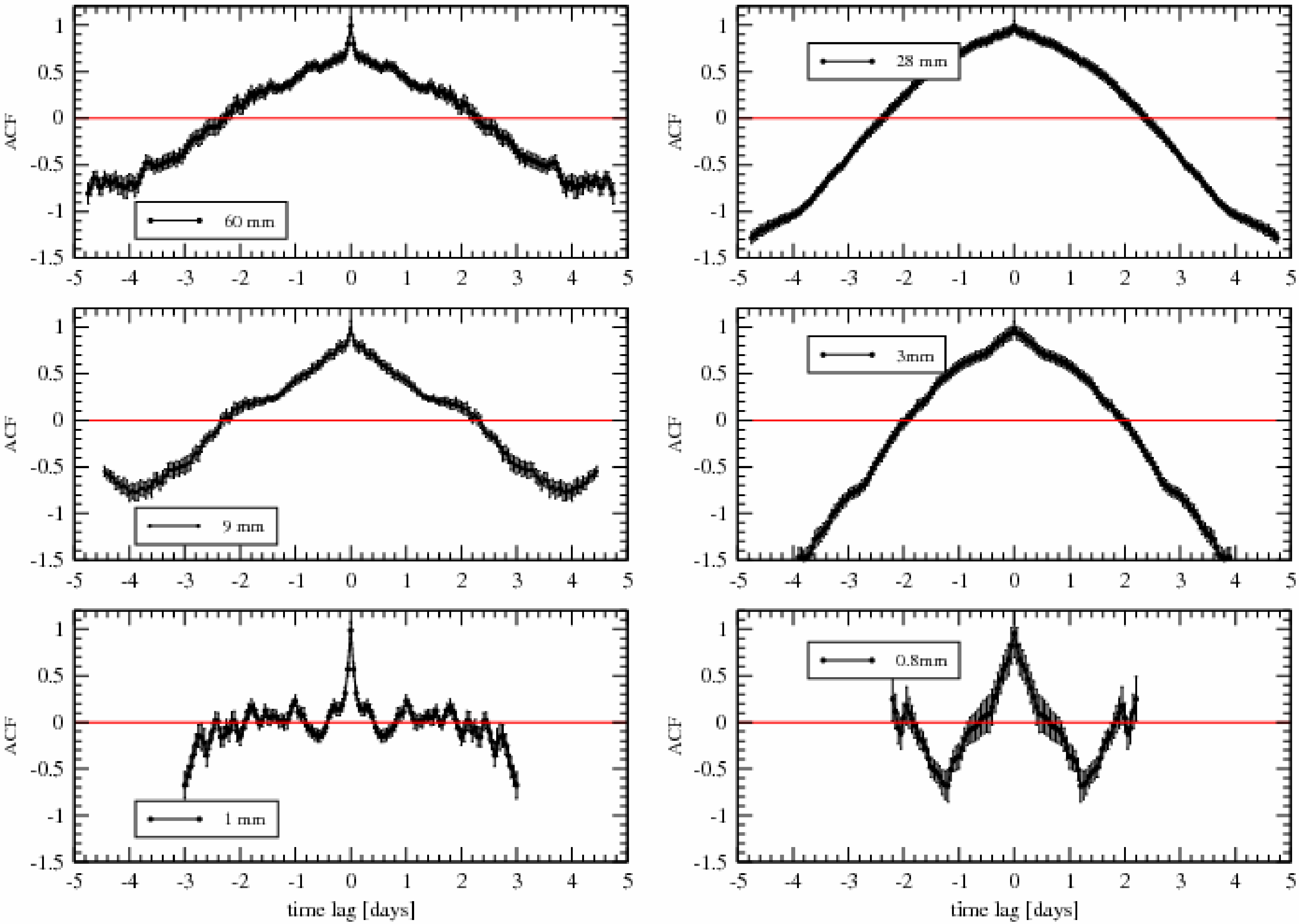

comparison 9mm data
(arbitrary offsets)
6
5
4
3
12955
12956
12957
12958
12959
12960
12961

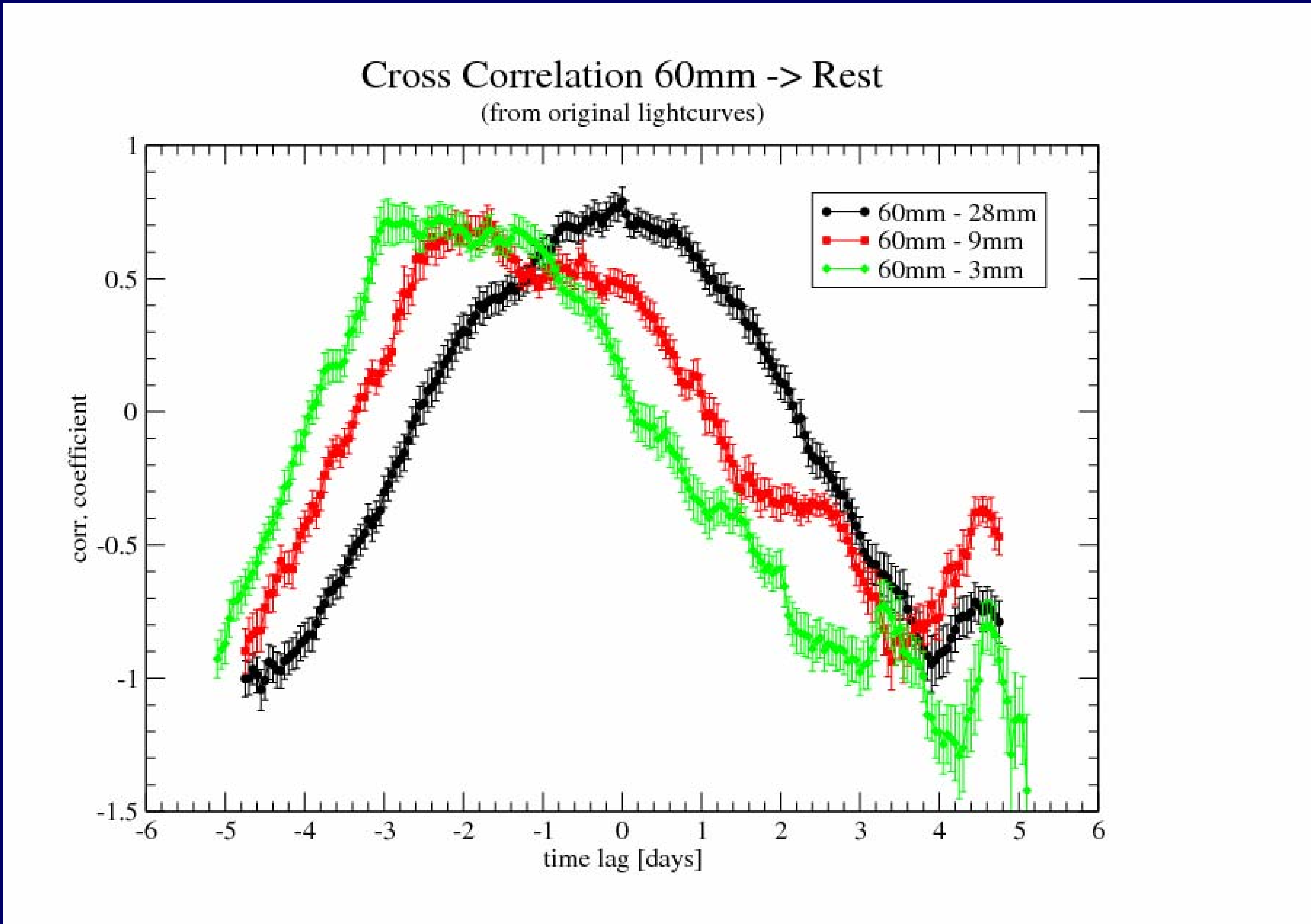
Flux Density Variability of 0716+714

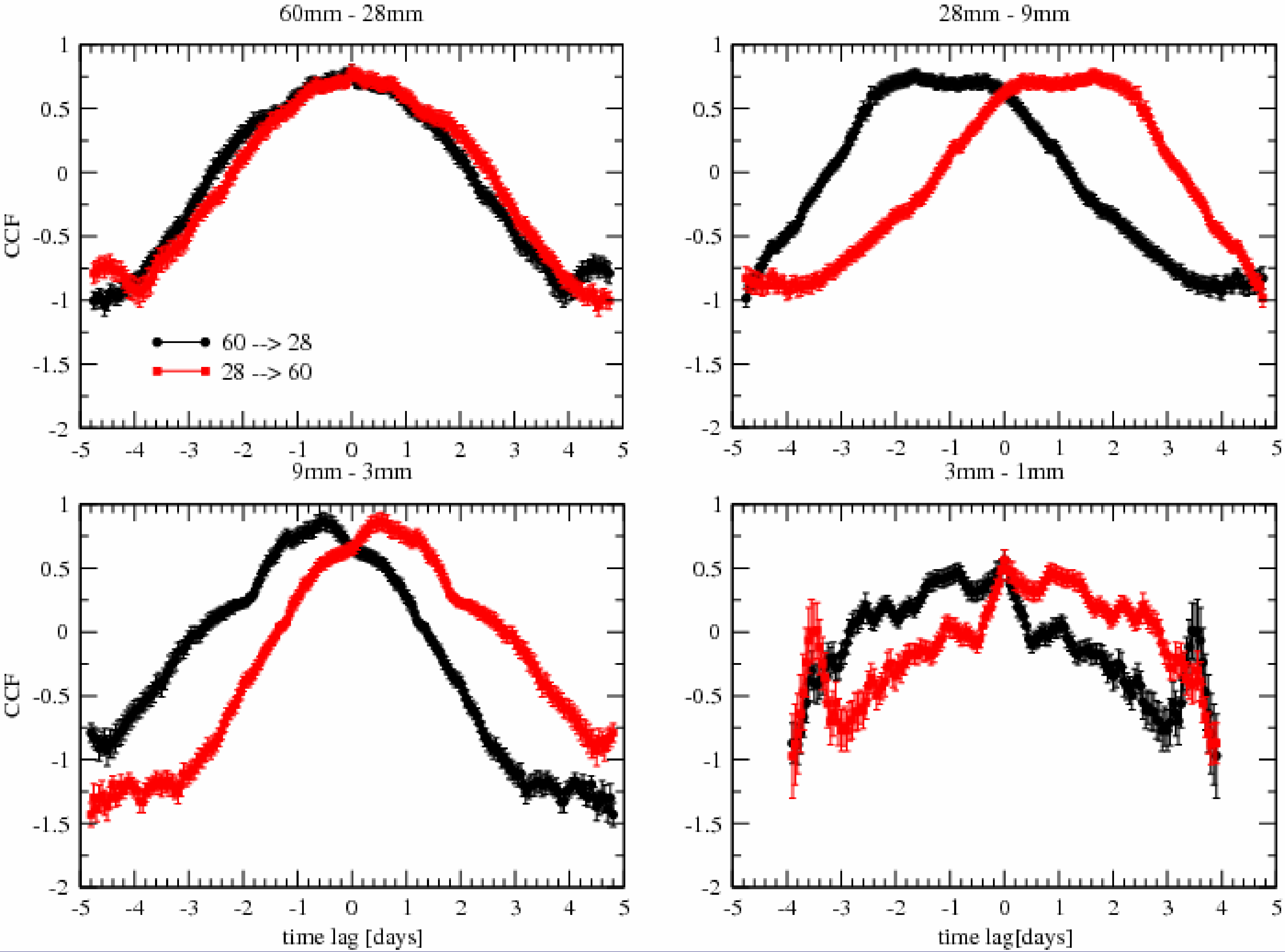
(10.-18. Nov. 2003)



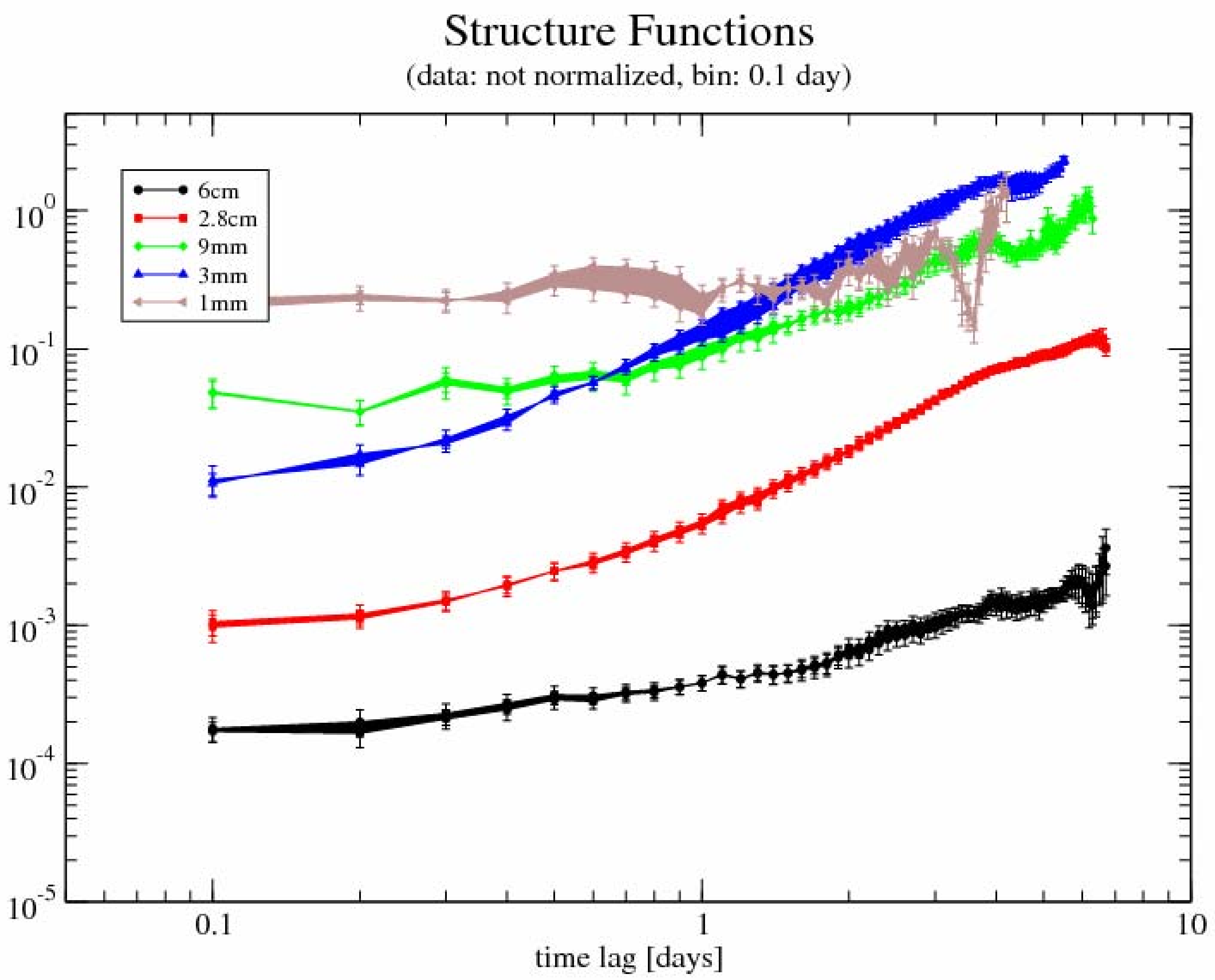
Autocorrelation Functions



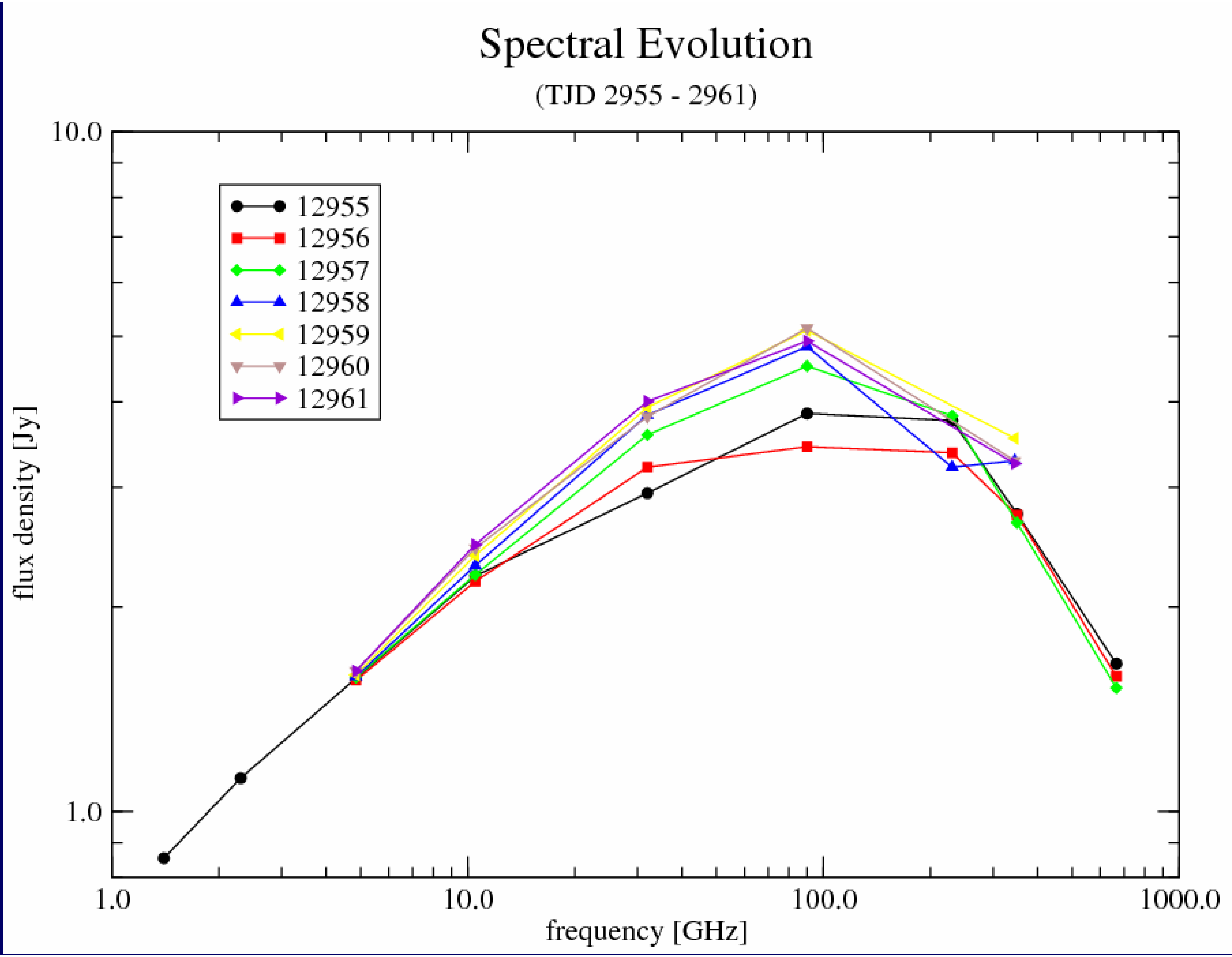

Cross Correlation 60mm -> Rest
(from original lightcurves)
60mm - 28mm
60mm - 9mm
60mm - 3mm
corr. coefficient
time lag [days]
1
0.5
0
-0.5
-1
-1.5
-6
-5
-4
-3
-2
-1
0
1
2
3
4
5
6



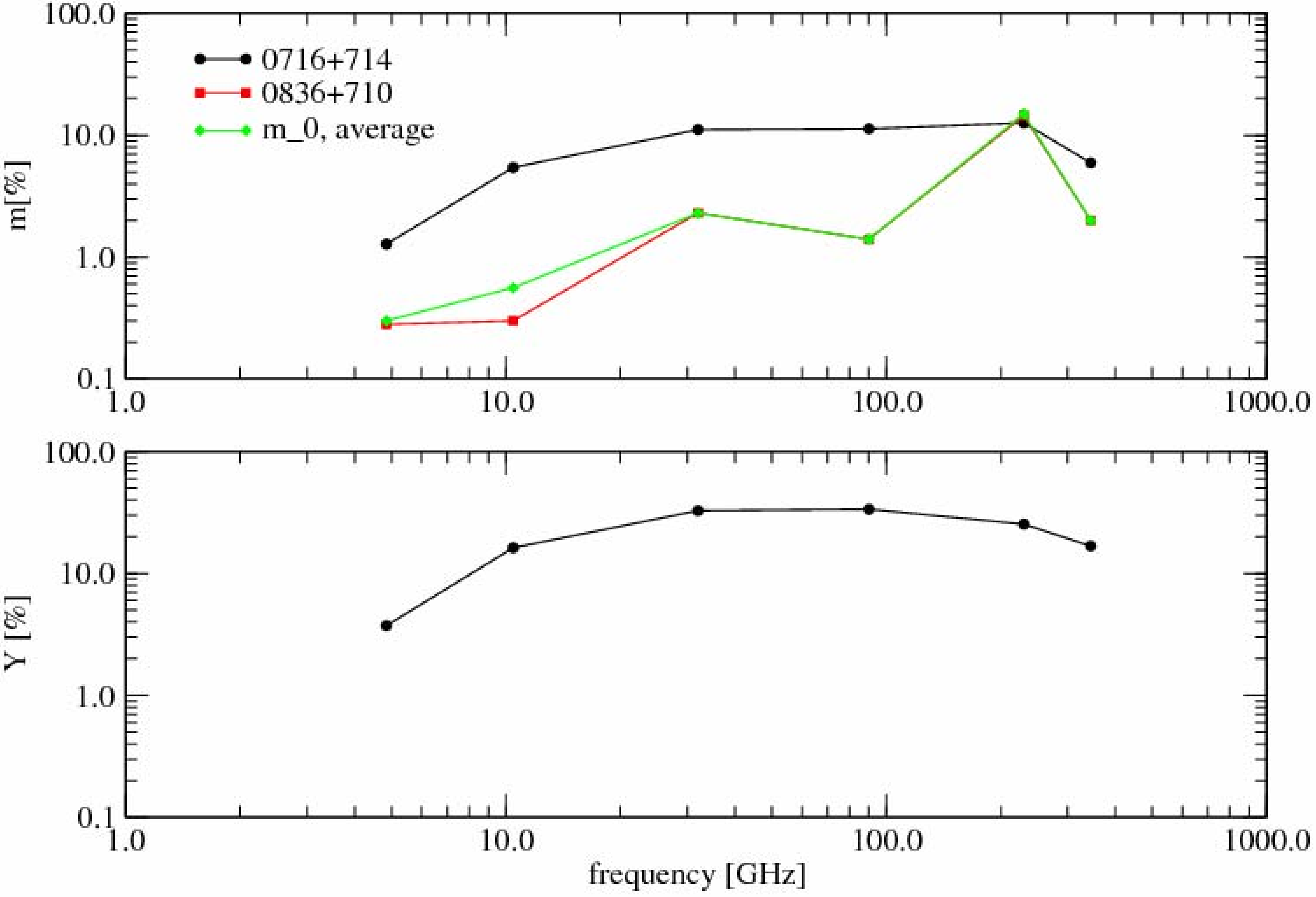
60mm - 28mm
28mm - 9mm
9mm - 3mm
3mm - 1mm
CCF
60 --> 28
28 --> 60
time lag [days]
time lag[days]



SF with interpolation in 2 directions


Spectral Evolution
(TJD 2955 - 2961)
10.0
1.0
1.0
10.0
100.0
1000.0
frequency [GHz]
flux density [Jy]
12955
12956
12957
12958
12959
12960
12961

Variability Amplitude vs. Frequency



Estimates of brightness temperatures from best defined light curves

ν	Smin	Smax	Delta t	type	TB1	TB2	delta 1	delta 2
[GHz]	[Jy]	[Jy]	[days]		[K]	[K]		
5,0	1,54	1,56	0,80	period.	7.1E16	9.2E14	41,5	9,7
5,0	1,56	1,61	3,00	period	1.3E17	4.0E14	23,3	7,4
10,5	2,17	2,53	4,70	slope	8.5E15	1.3E15	20,4	10,9
32,0	3,14	3,94	3,00	slope	5.0E15	1.1E15	17,1	10,4
90,0	3,68	5,14	3,60	slope	7.9E14	2.6E14	6,4	9,3

TB1 – using direct timescale

TB2 – using logarithmic timescale

Summary

- 0716+714 shows weak IDV at 6 & 2.8cm (I & P)
- a slow flux increase which is more pronounced at higher frequencies
- canonical timelag, with higher frequencies rising earlier
- evolving radio spectrum, peaking near 90 GHz
- brightness temperatures in excess of the IC limit
- Doppler factors >9-40, which are systematically lower at higher frequencies

Polarimetric mm to cm behavior of 0716+714 during the core campaign:

IRAM 30m and VLBA results

Iván Agudo
Max-Planck-Institut für Radioastronomie

T. P. Krichbaum, H. Ungerechts, A. Kraus, J. Klare,
A. Witzel, S. Wagner, E. Angelakis, A. Zensus

Overview of the talk

- IRAM 30m results
  - Introduction
  - 3mm total flux density results
  - 3mm linear polarization flux density results
  - 1.3mm total flux density results

- VLBA (7mm and 1.3cm) results
  - Introduction
  - Total flux density results
  - Linear polarization flux density results
  - Modeling the source structure

- Multi-frequency data discussion

- Summary

IRAM 30m: Introduction

- We observed from the 10th to the 16th of Nov. 2003

- Recording data simultaneously with 2 receivers at 3mm and two receivers at 1.3mm

- Each pair of receivers recorder relative orthogonal linear polarizations $\Rightarrow$ polarization information

- At 1.3 mm we loosed the data of one of the receivers (unstable)

- Accuracy of 1.3mm data reduced and no polarization at this λ

IRAM 30m mm Radio Telescope (Granada, Spain)

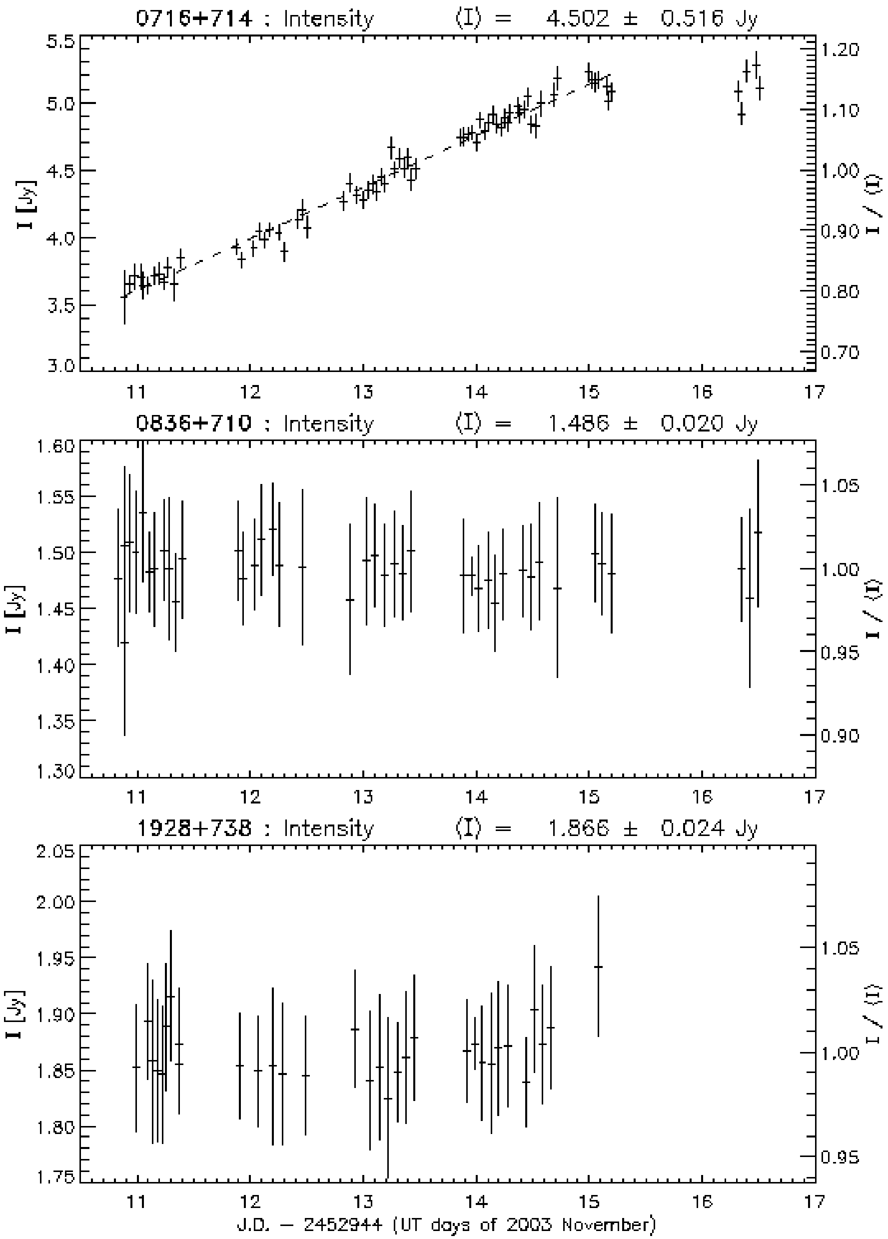
- Observation strategy based on the high densely time sampling of 0716+714 (every 30') and 6 calibrators (every 1h)

- Allowed for high accuracy calibration transfer from calibrators to 0716+714

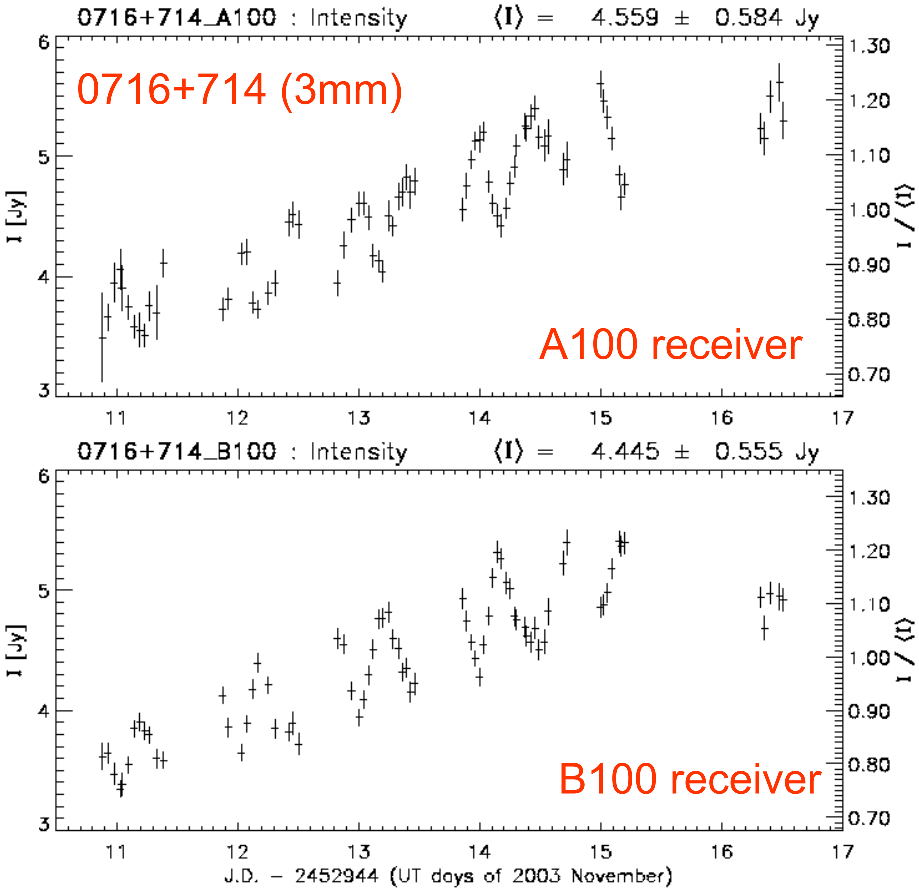
IRAM 30m: 3mm total flux density results

3mm results:

- Time series of the calibrators have an rms<2%
- Calibration accuracy better than 2%!!!
- No clear IDV pattern in 0716+714
- Increase in flux density of ΔS≈35% (~1.5 Jy) in 4-5 days (~0.382±0.006Jy/day)
- IV³ "Intra-**W**eek **V**ariability"



IRAM 30m: 3mm polarization results

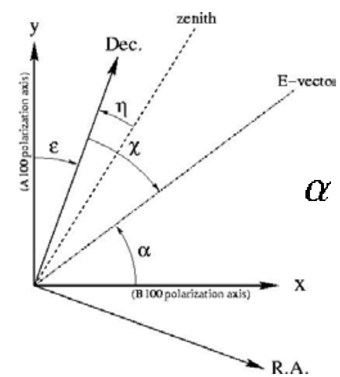


- 12h sinusoidal anti-phase patterns
- Typical of polarized sources when observed through a linear polarized

- To make a characterization of the polarization of 0716+714 we have modeled the response of the 3mm receivers (A100 and B100) as:

$$S_{A100}(\alpha) = \frac{S_0}{2} + \frac{1}{2} P cos 2(\alpha + \frac{\pi}{2})$$

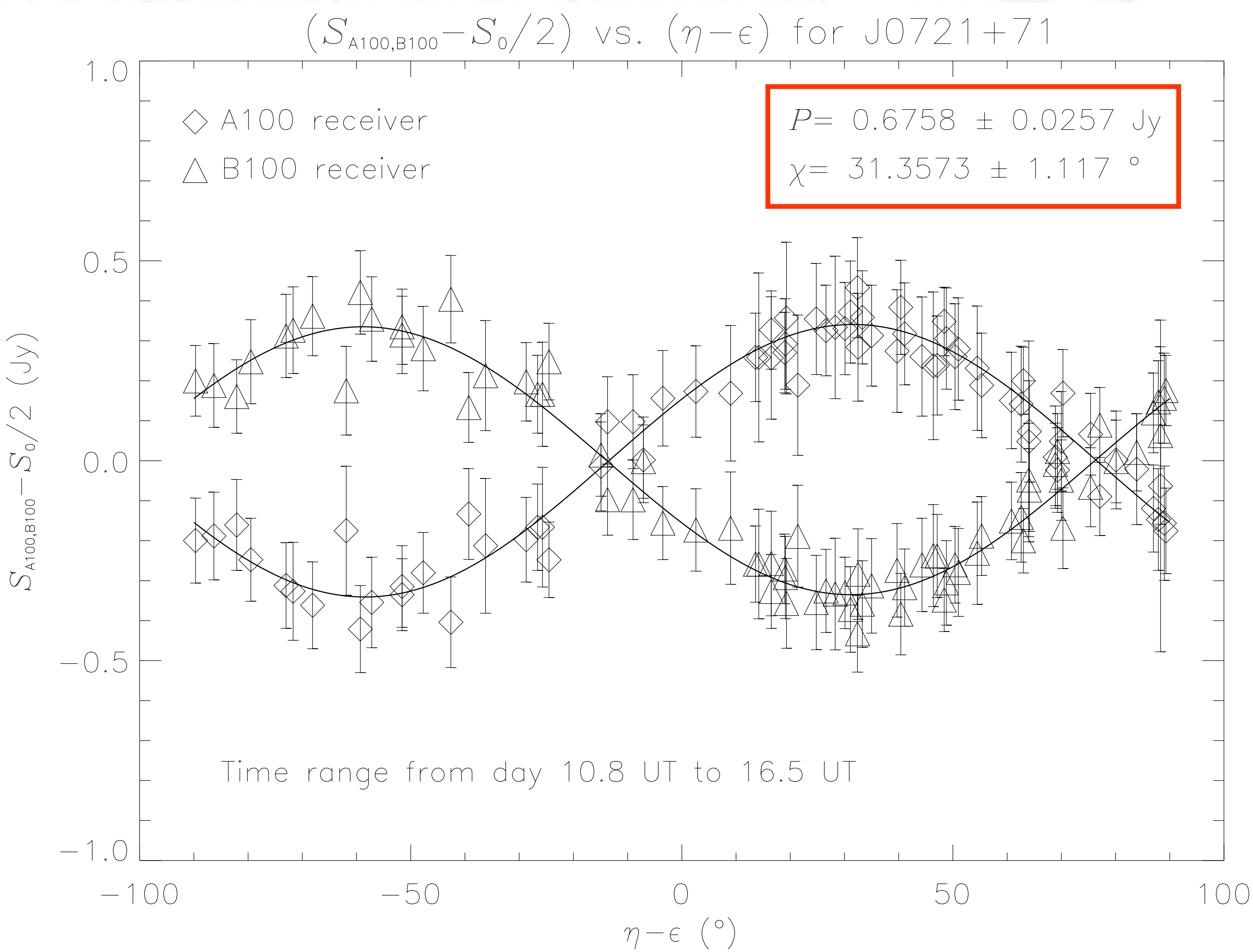
$$S_{B100}(\alpha) = \frac{S_0}{2} + \frac{1}{2} P cos 2(\alpha)$$



$$\alpha = \frac{\pi}{2} - \chi + \eta - \epsilon$$

- They contain the polarization information of the source
- Can be measured by fitting the data to the above expressions

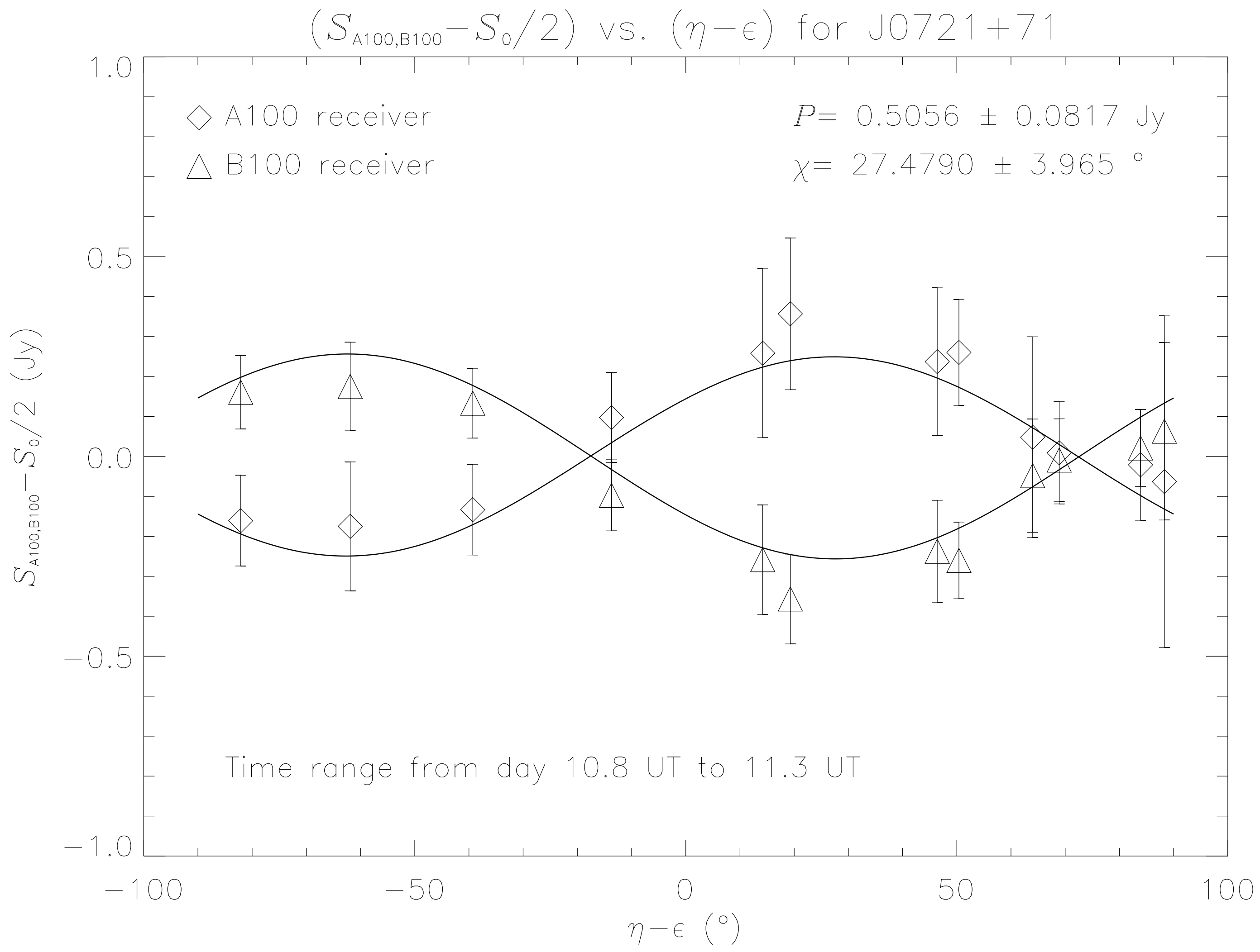
IRAM 30m: 3mm polarization results



- Unusual strong mean polarization degree <*p*>≈15.0%
- Mean polarization angle <χ>≈31º

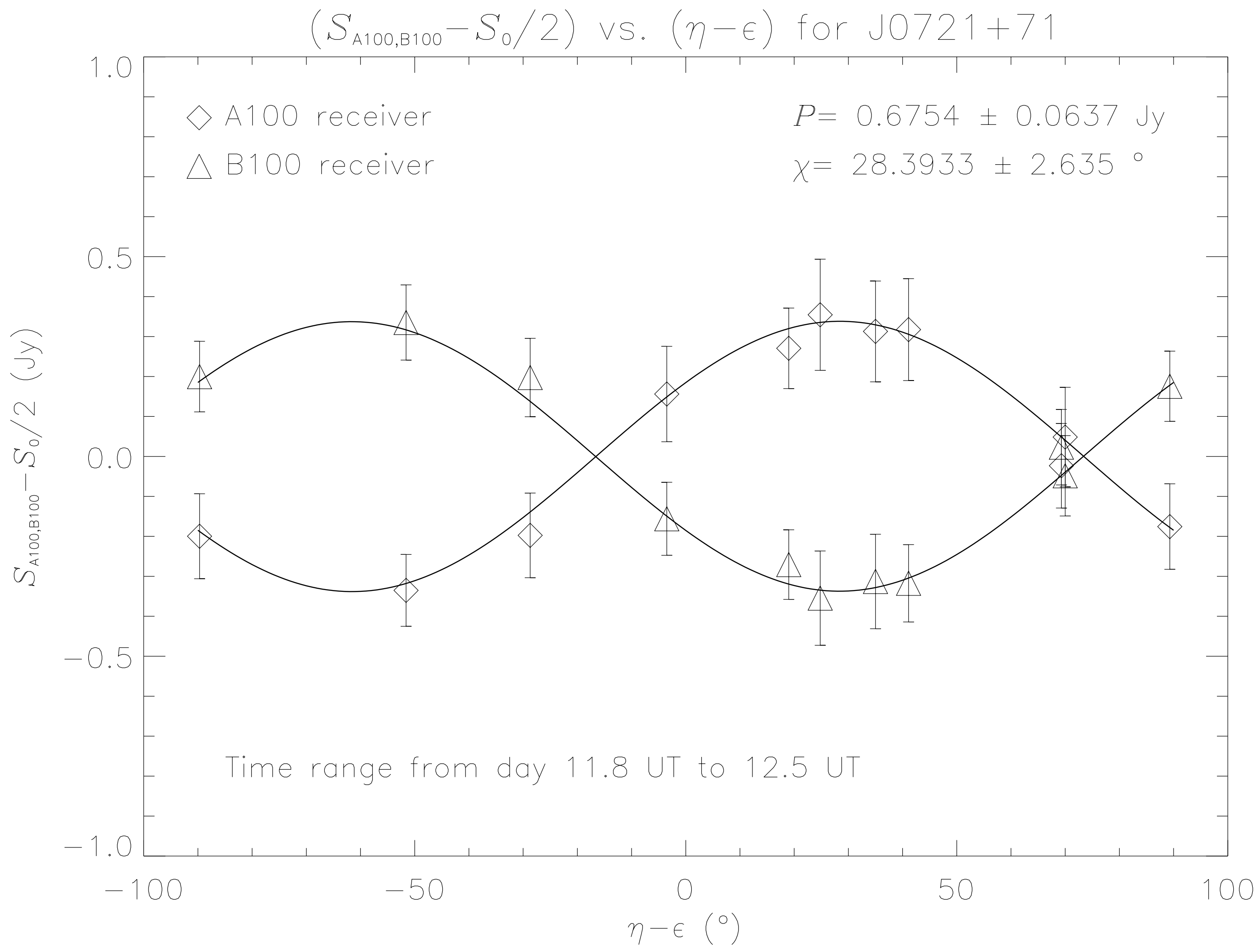
IRAM 30m: 3mm polarization results

Nov. 11



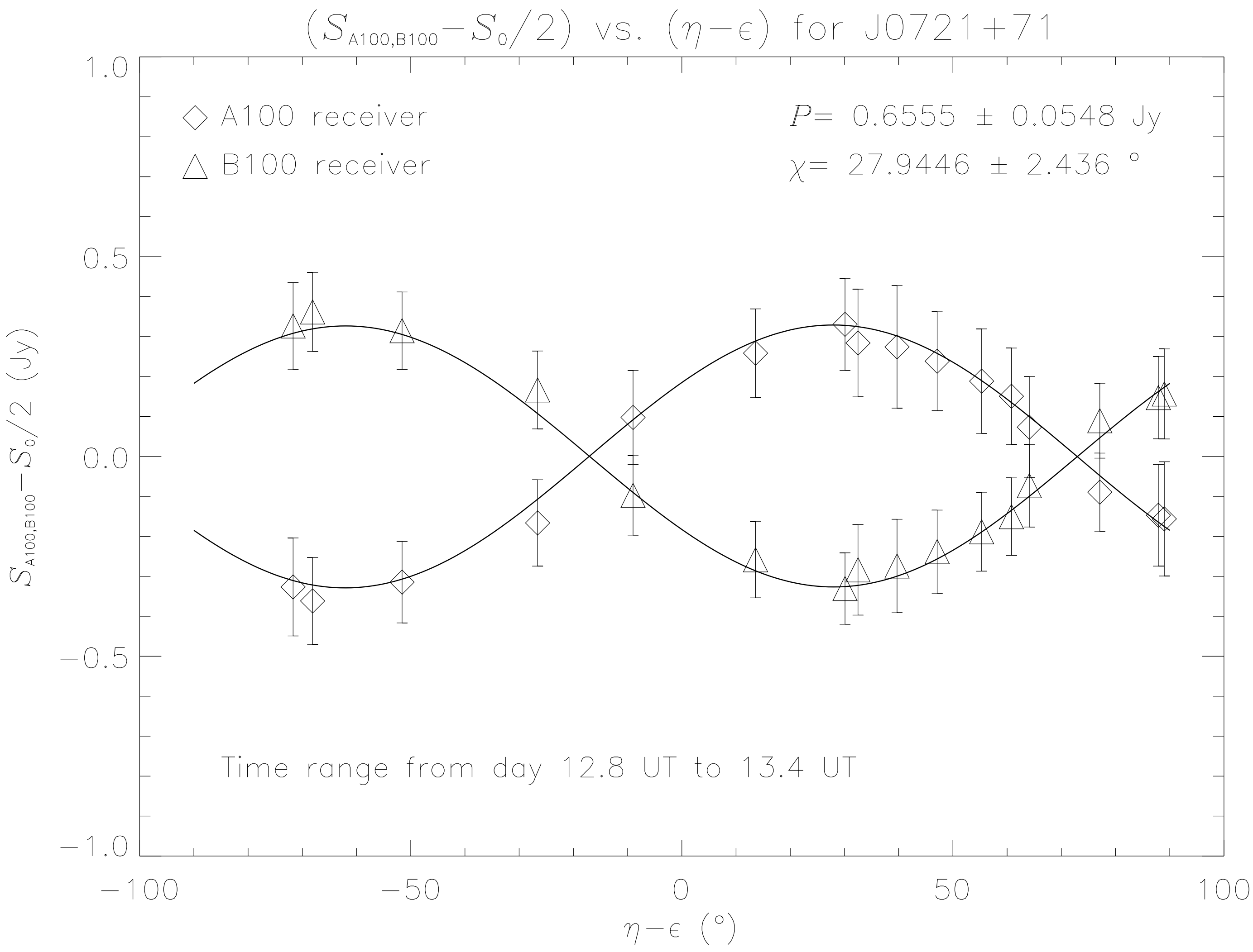
IRAM 30m: 3mm polarization results

Nov. 12



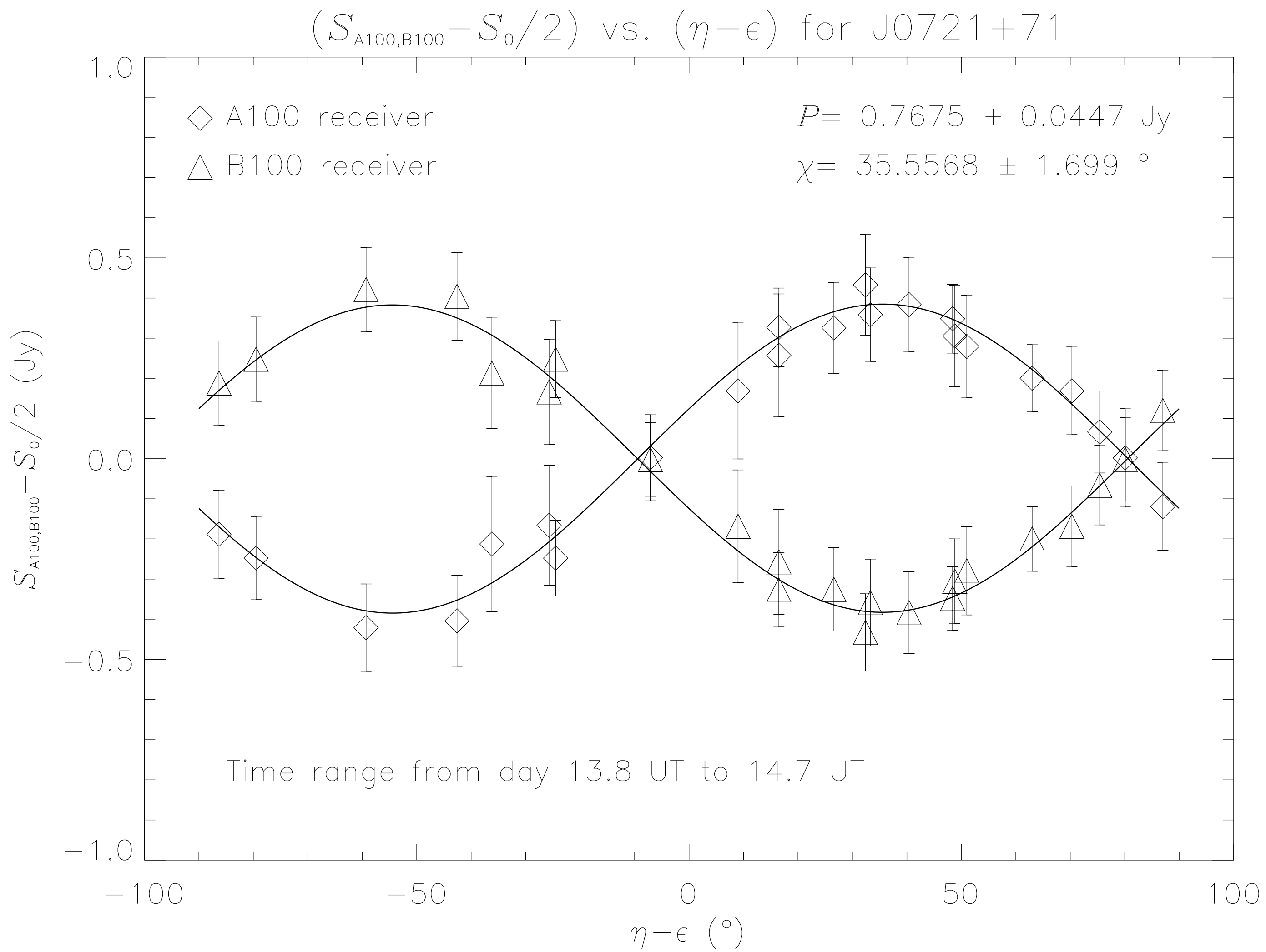
IRAM 30m: 3mm polarization results

Nov. 13



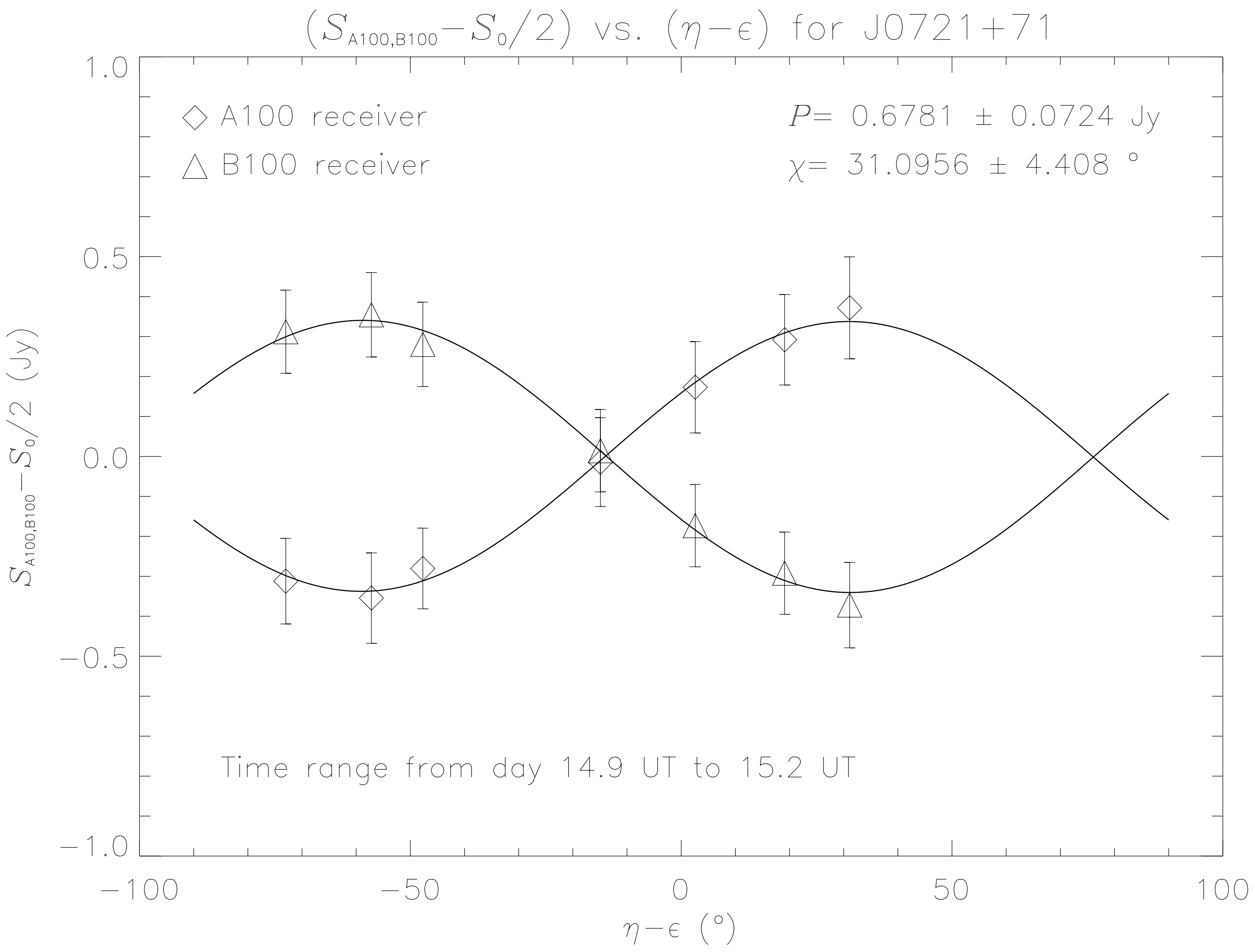
IRAM 30m: 3mm polarization results

Nov. 14



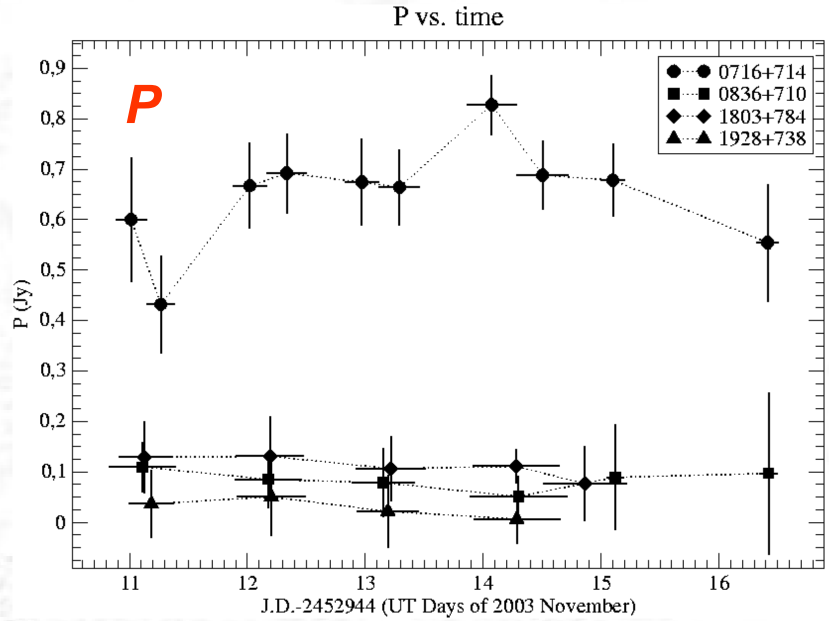
IRAM 30m: 3mm polarization results

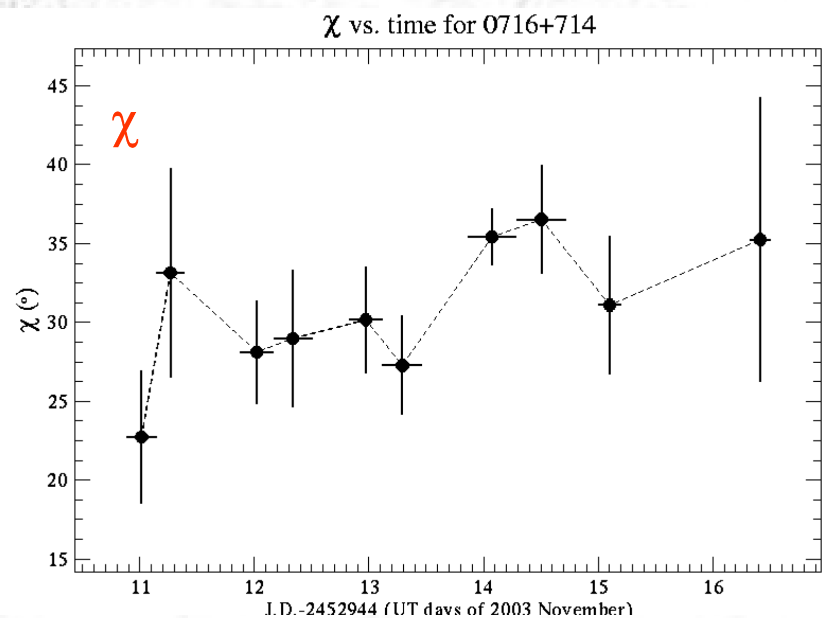
Nov. 15

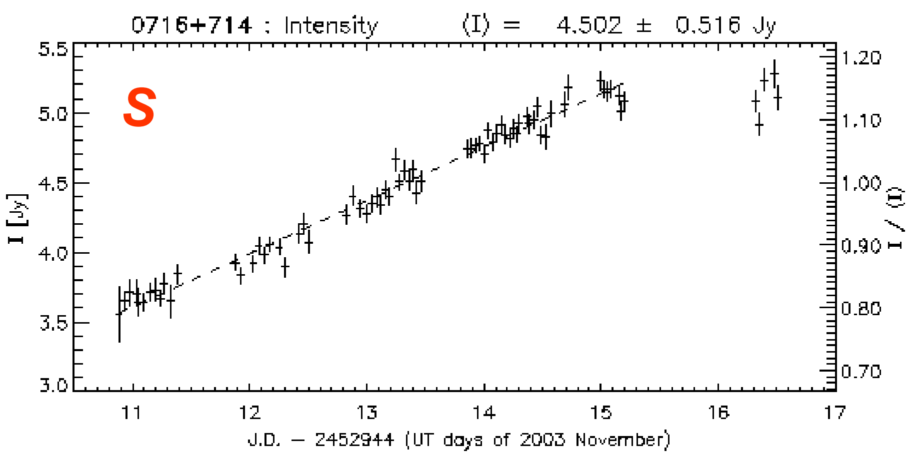


IRAM 30m: 3mm polarization results

- To improve our polarization time resolution we can perform fittings within time spans of ~12h :
  - Correlated *S*, *P* and χ increasing behavior
  - Evidence (not 3σ) of *P* and χ Intra-Day Variability

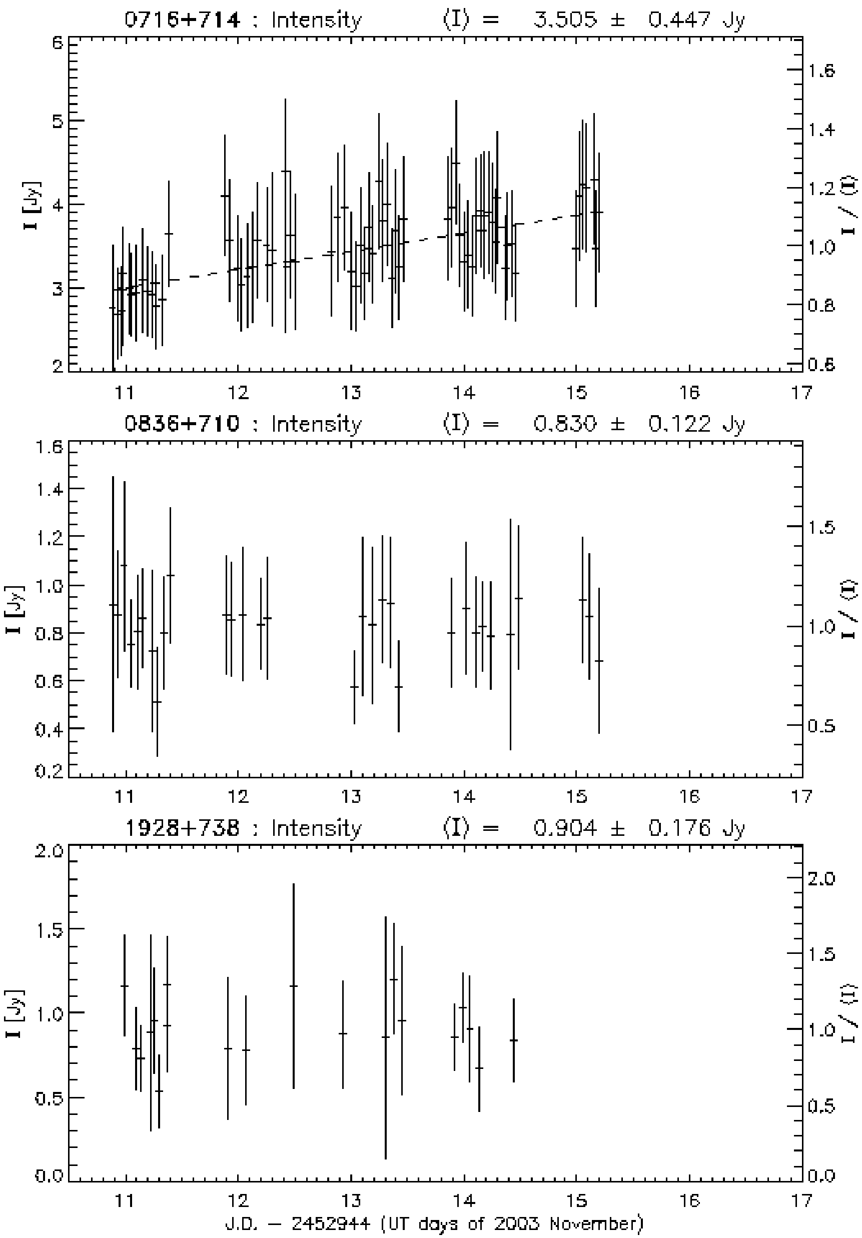






IRAM 30m: 1.3mm total flux density results

- At 1.3 mm we followed a similar calibration procedure than at 3mm
- Much poorer calibration accuracy (~16%)
- IDV is not possible to be detected because of >16% uncertainties
- Consistent flux density increase during the first 4-5 days
- This increase is slower than at 3mm (~0.22±0.06 Jy/day)



VLBA (7mm and 1.3cm): Introduction

- The VLBA observed 0716+714 and two calibrators (0836+710, 1803+784)
- 6 VLBI runs of 12 hours each from Nov. 11 to Nov. 16 2003
- 4 λ coverage: 18, 6, 1.3cm and 7mm
- In dual polarization mode

Very Long Baseline Array (VLBA) Interferometer

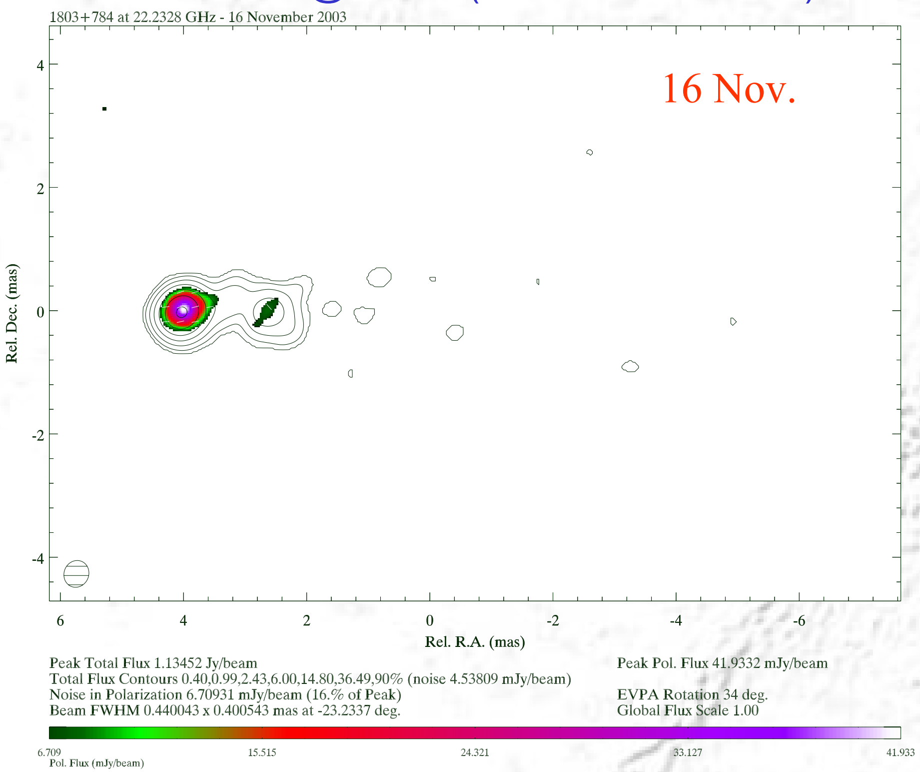
- Data reduction performed in the most possible homogeneous way:
  - same reducer
  - same procedures
  - same reference antenna when possible
  - 6 epochs at the same time

- Further non-standard calibration was applied (assuming calibrators stability) in order to account for the typical ~10% VLBI total intensity errors

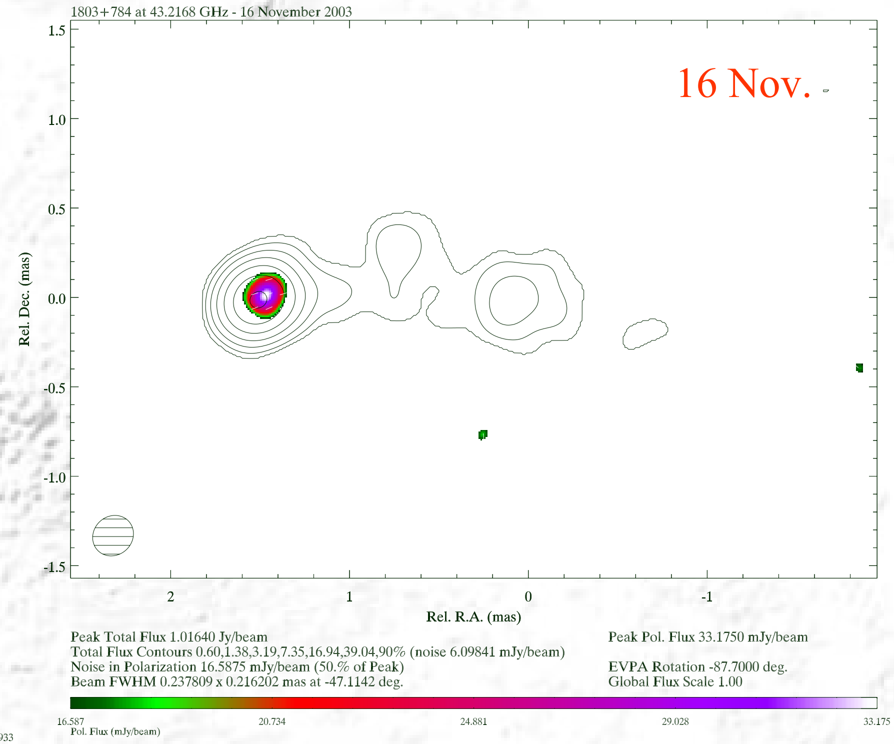
VLBA (7mm and 1.3cm): 1803+784 images

- Data at 1.3cm & 7mm is fully reduced and calibrated

1803+784 @ 1.3cm (≈0.4 mas resolution)



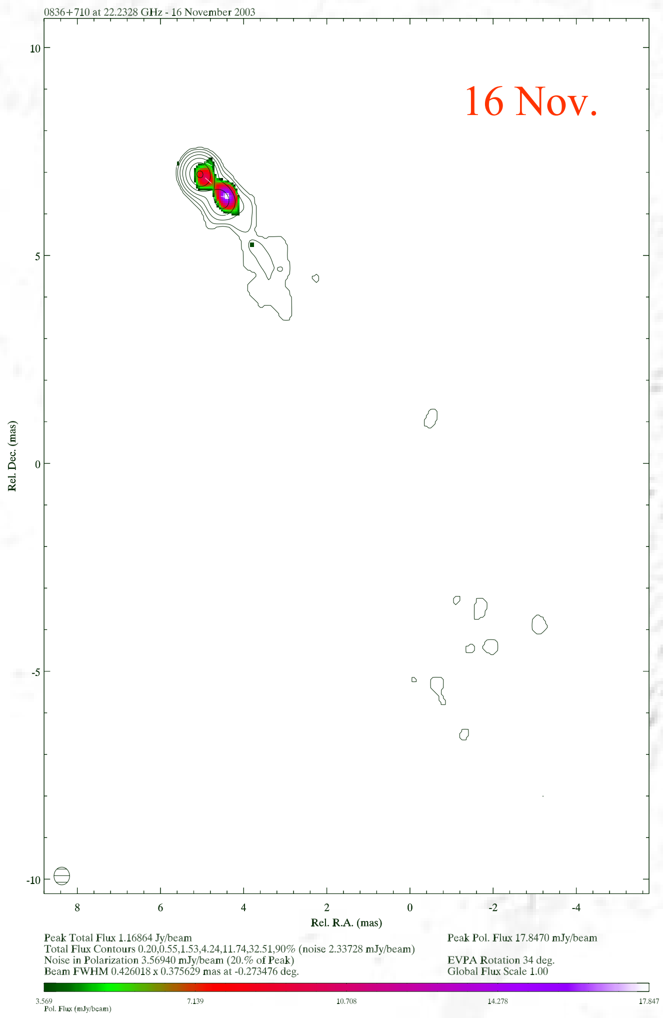
1803+784 @ 7mm (≈0.2 mas resolution)



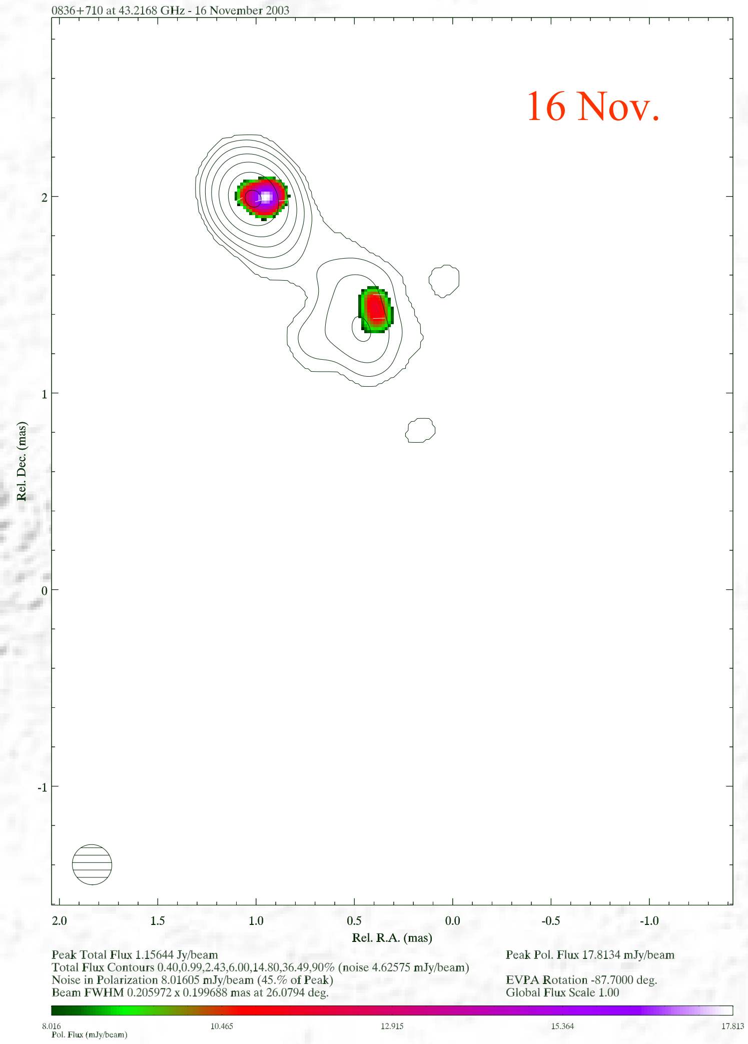
- Contours ⇒ total intensity
- Color scale ⇒ linearly polarized intensity
- Short sticks ⇒ electric vector polarization angle

VLBA (7mm and 1.3cm): 0836+710 images

0836+710 @ 1.3cm (≈0.4 mas resolution)

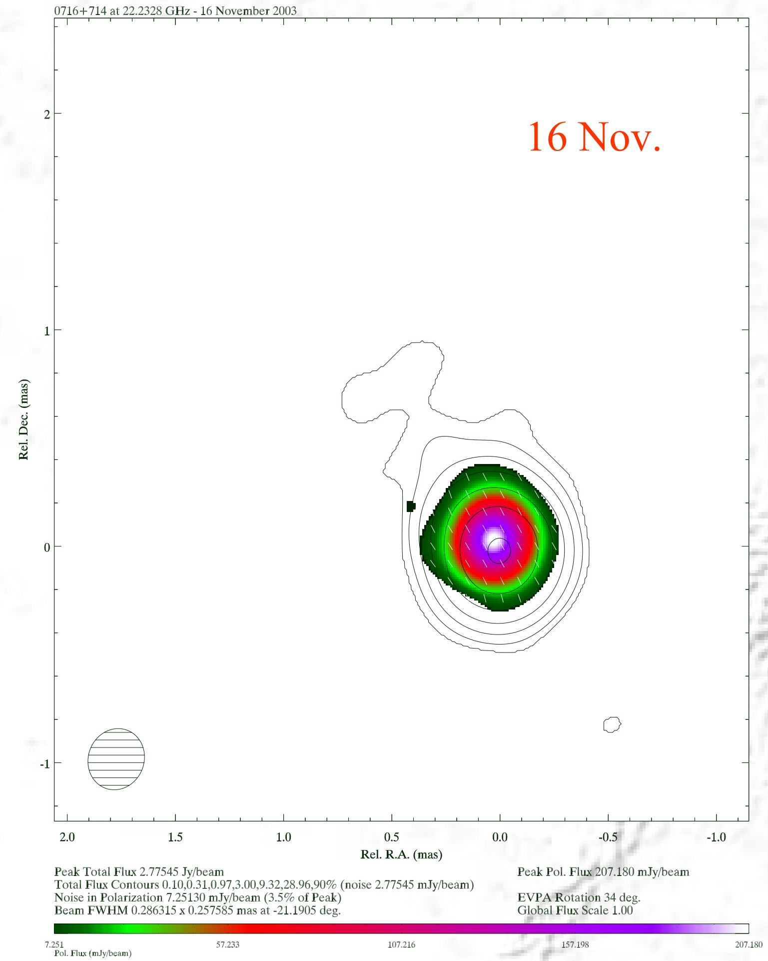


0836+710 @ 7mm (≈0.2 mas resolution)

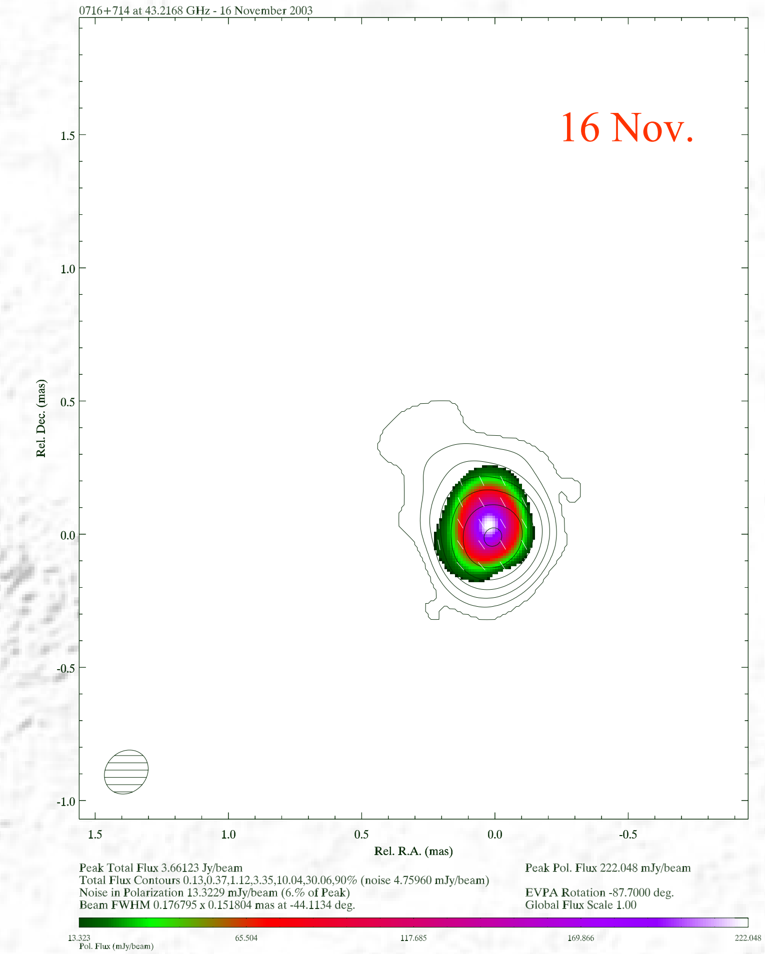


VLBA (7mm and 1.3cm): 0716+714 images

0716+714 @ 1.3cm (≈0.35 mas resolution)



0716+714 @ 7mm (≈0.17 mas resolution)



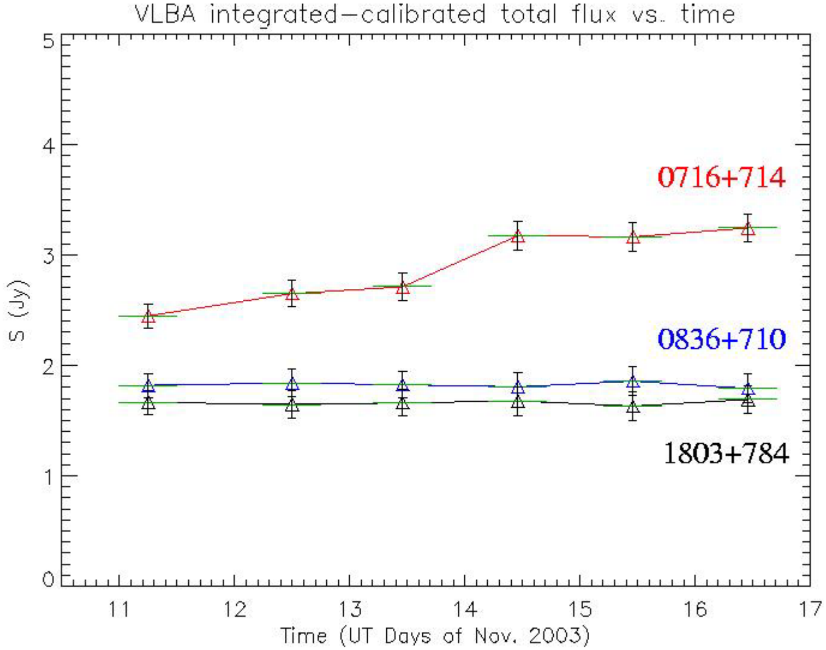
- Very compact structure at both 1.3cm and 7 mm
- Weak jet at PA≈30º

- The electric vector polarization angle was parallel to the jet direction

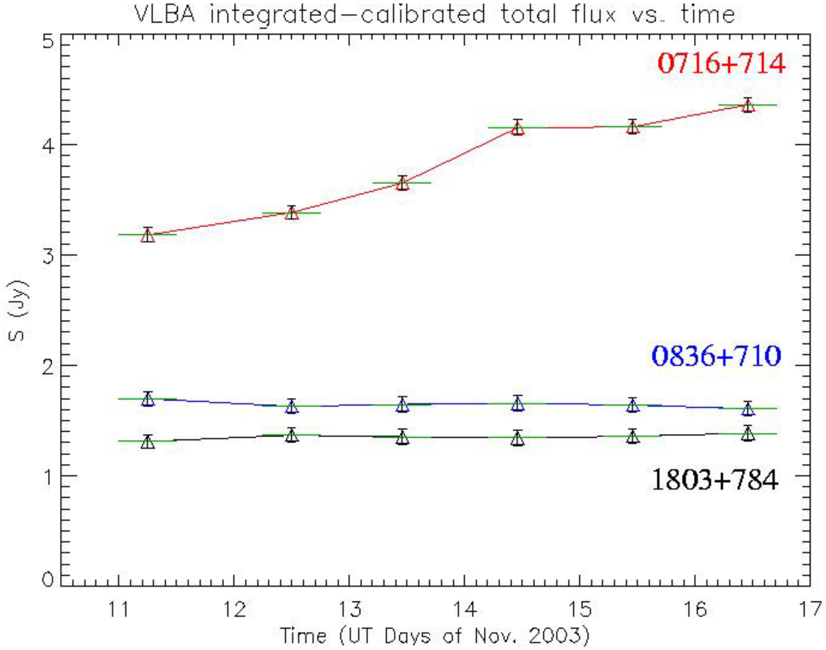
VLBA: Total flux density results

- Monotonic integrated total flux increase as observed at 3mm
- Spectrum inverted between 1.3cm and 7mm

Integrated total flux density evolution



1.3cm

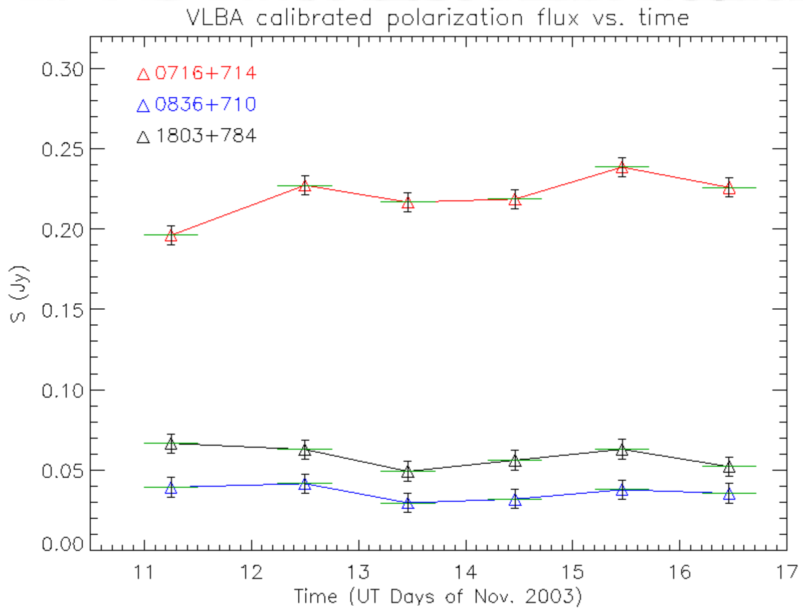


7mm

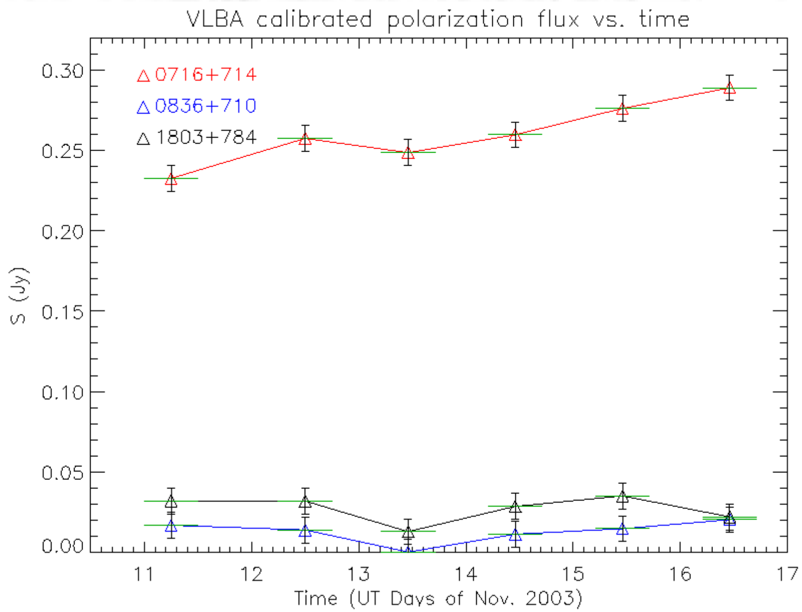
VLBA: Linearly polarized flux density results

- $<p(1.3cm)>=7.7\pm0.7\%$ $<p(7mm)>=6.9\pm0.5\%$
- Polarization flux density evolution consistent with a monotonic increase
- This trend seems to be less pronounced at 1.3 cm

Integrated polarization flux density evolution



1.3cm

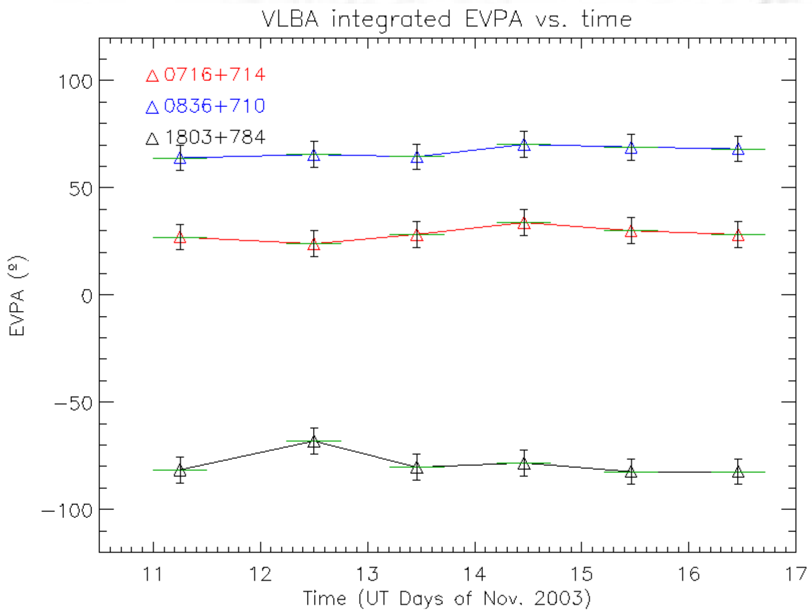


7mm

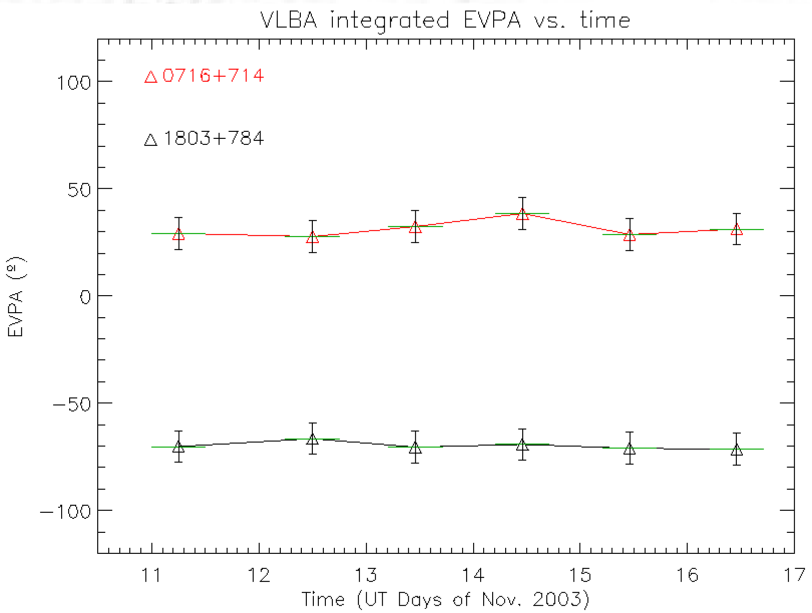
VLBA: Electric vector polarization angle results

- Electric vector polarization angle constant at both 1.3cm and 7mm

Integrated polarization angle evolution



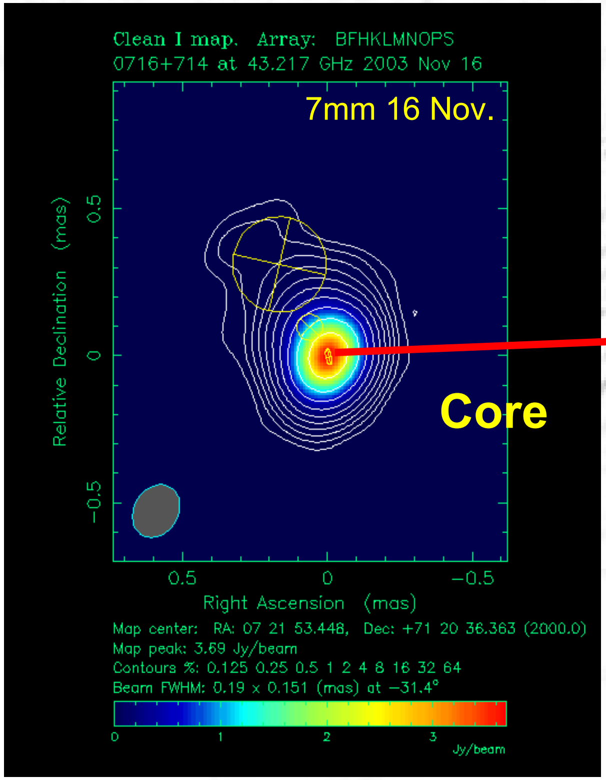
1.3cm

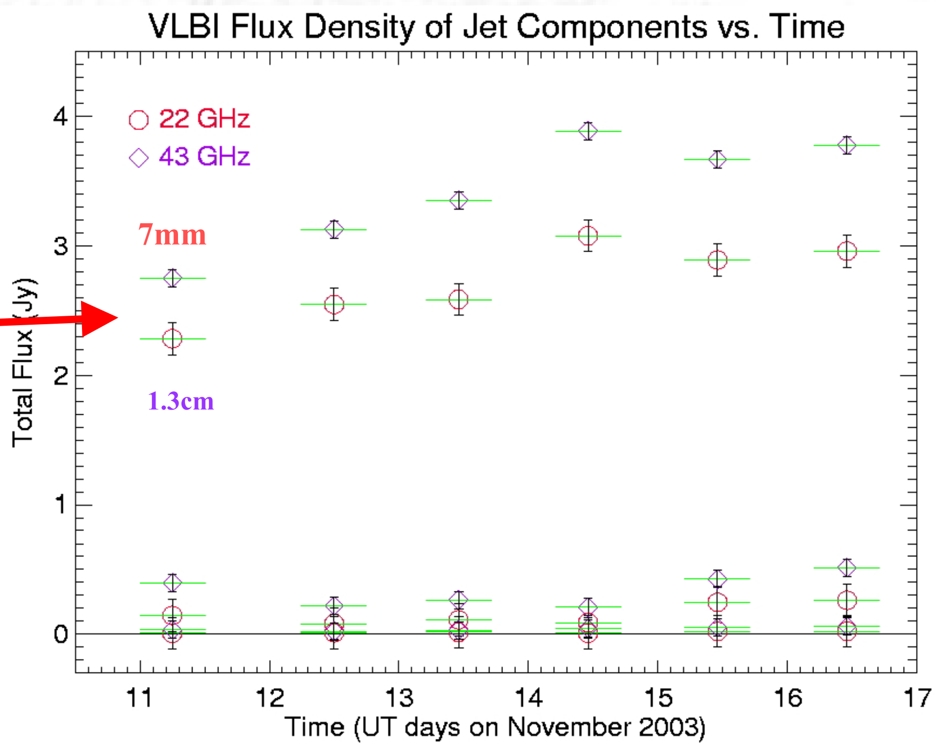


7mm

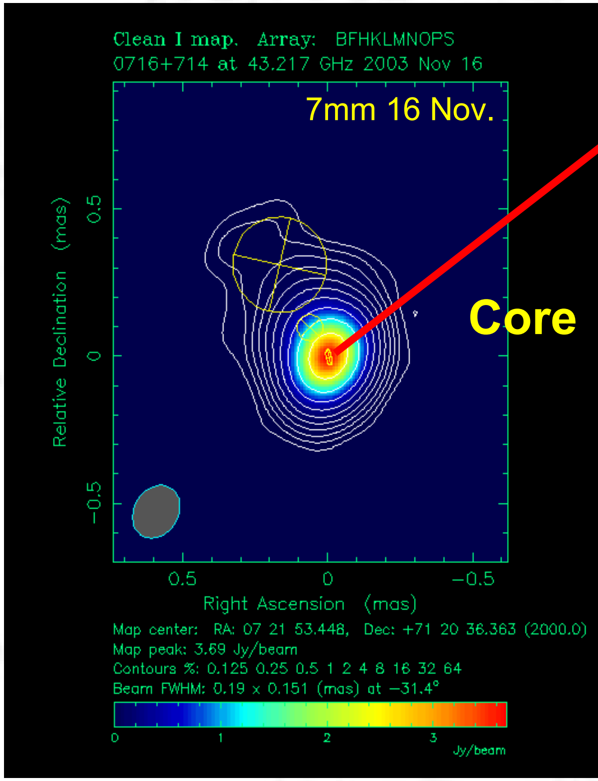
VLBA (7mm and 1.3cm): Modeling the source structure

- Fits of the jet structure to sets of Gaussian components:
  - Total flux density of the core 80-90% total flux density of the source
  - Core total flux density increase governs the source flux evolution
  - Core was optically thick between 1.3cm and 7mm





VLBA (7mm and 1.3cm): Modeling the source structure



- Axes of the "core Gaussian" at 43GHz:

θ_{maj}=0.055 mas **θ_{min}= 0.020 mas**

- Angular sizes smaller than the beam size

- Resolution limit:

$$\theta_{\lim,\psi} = 2^{2-\beta/2} b_\psi \left[\frac{\ln 2}{\pi} \ln\left(\frac{SNR}{SNR-1}\right)\right]^{1/2} = 0.015 \text{ mas}$$

Lobanov 2005, astro-ph/0503225

β=0 for uniform weighting VLBI maps

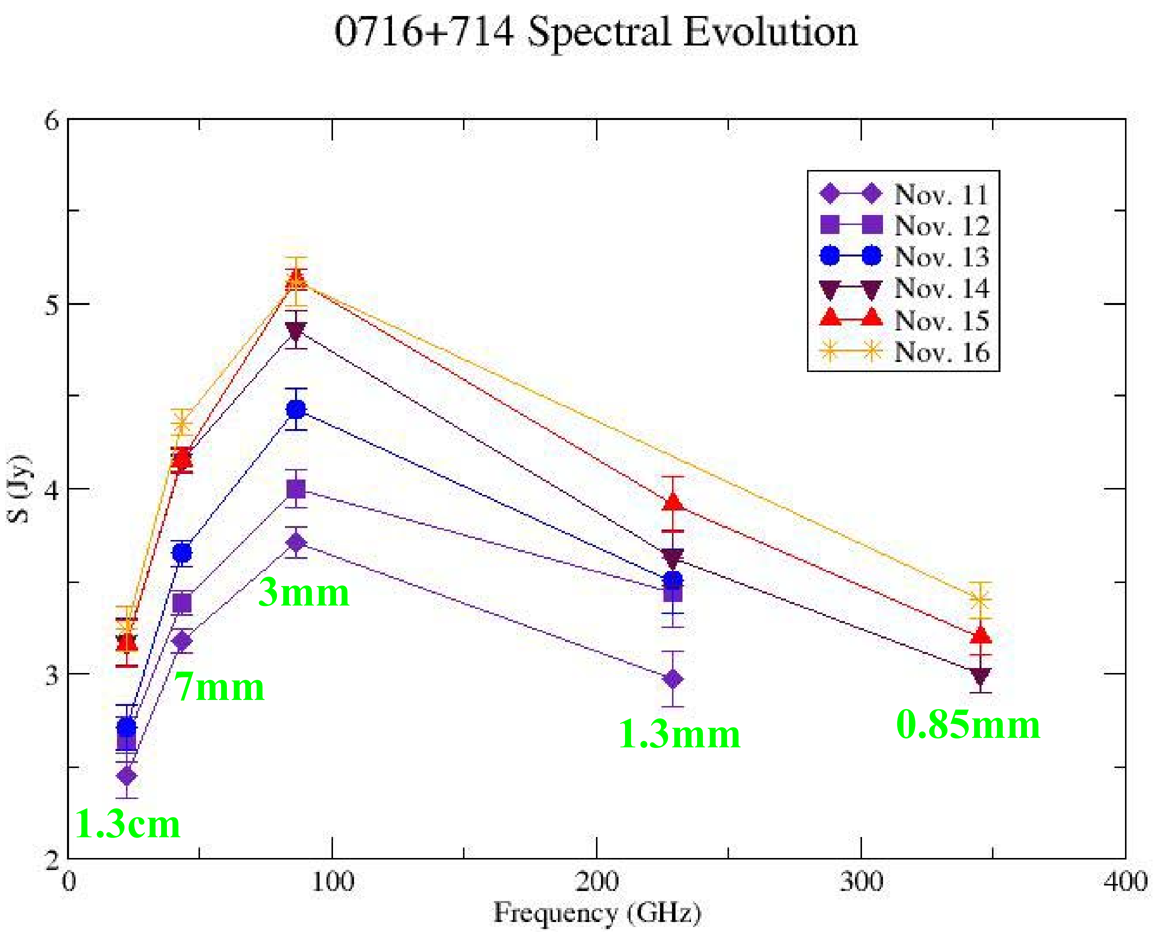
$b_\psi \approx$0.18 mas (PSF size)

$SNR \approx 532$

- $\theta_{lim} < \theta_{maj}$ and $\theta_{lim} < \theta_{min}$ $\Rightarrow$ We are above the resolution limit BUT!!!

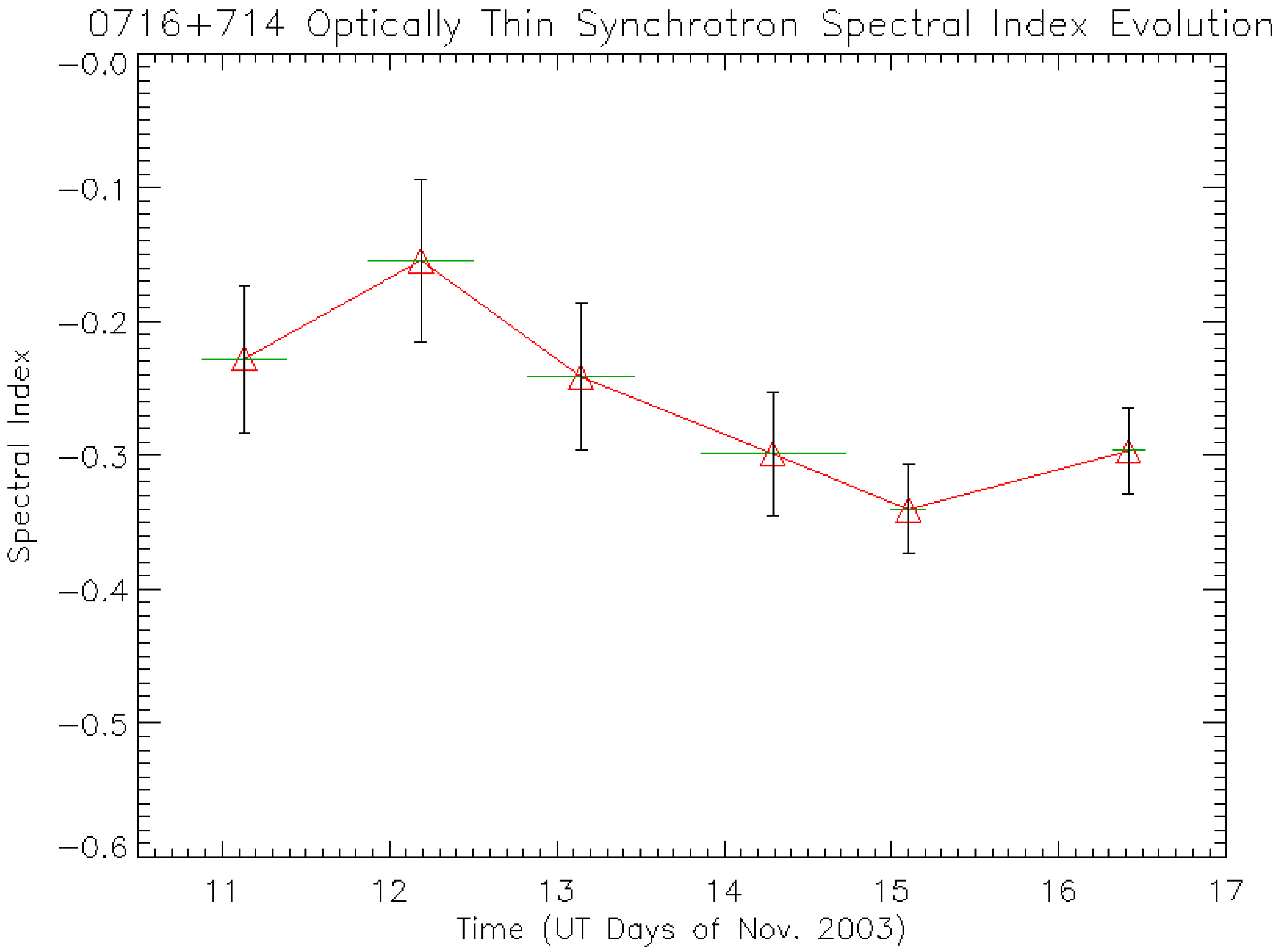
- θ_{maj} and θ_{min} are only upper limits:
  - They are measured at an optically thick frequency

Multi-frequency data discussion



- Synchrotron spectrum peaks at $\nu_m \approx 86$ GHz
- $S_{\nu m} \approx 3.7$-5.1 Jy as given by the 86 GHz data

Multi-frequency data discussion



- Optically thin synchrotron spectral index $\alpha \approx -0.25$
- Relaxing from $\alpha \approx -0.2$ to $\alpha \approx -0.3$

Summary

- Some important physical parameters to model the 0716+714 emission:
  - 80-90% source emission is dominated by the core of the jet
  - θ_{maj}<0.055 mas and θ_{min}<0.020 mas (UPPER LIMITS)
  - $\nu_m \approx 86$ GHz
  - $S_{\nu m}$ increased from 3.7Jy to 5.1Jy (as reported from the 86 GHz data)
  - Optically thin synchrotron spectral index $\alpha \approx -0.25$ (evidence of variability)
  - $\langle p_{\nu m} \rangle \approx 15.0$ %
  - $\langle \chi_{\nu m} \rangle \approx 31^{o}$ (close to the structural position angle of the jet)
  - $P_{\nu m}$ and $\chi_{\nu m}$ increased with $S_{\nu m}$
  - Some evidence of polarization IDV at ν_m

OJ 287 - not variability related data

Host galaxy: Best data give M_R = -23.9, r_e = 4.4 kpc

Ł $M_{BH} \sim 2...6 \cdot 10^9 M_\odot$

Ł Fits well, BUT: some studies show some extra (asymmetric) light

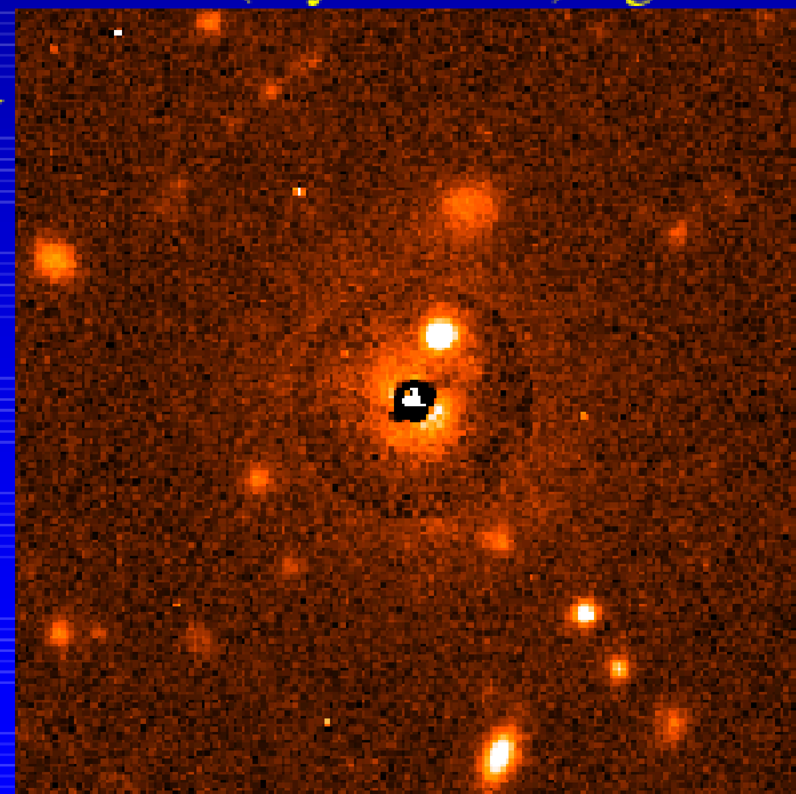
System might dynamically not be relaxed

Ł Global M/L ∝ L not valid?

Cluster environment:

Abell < 0,

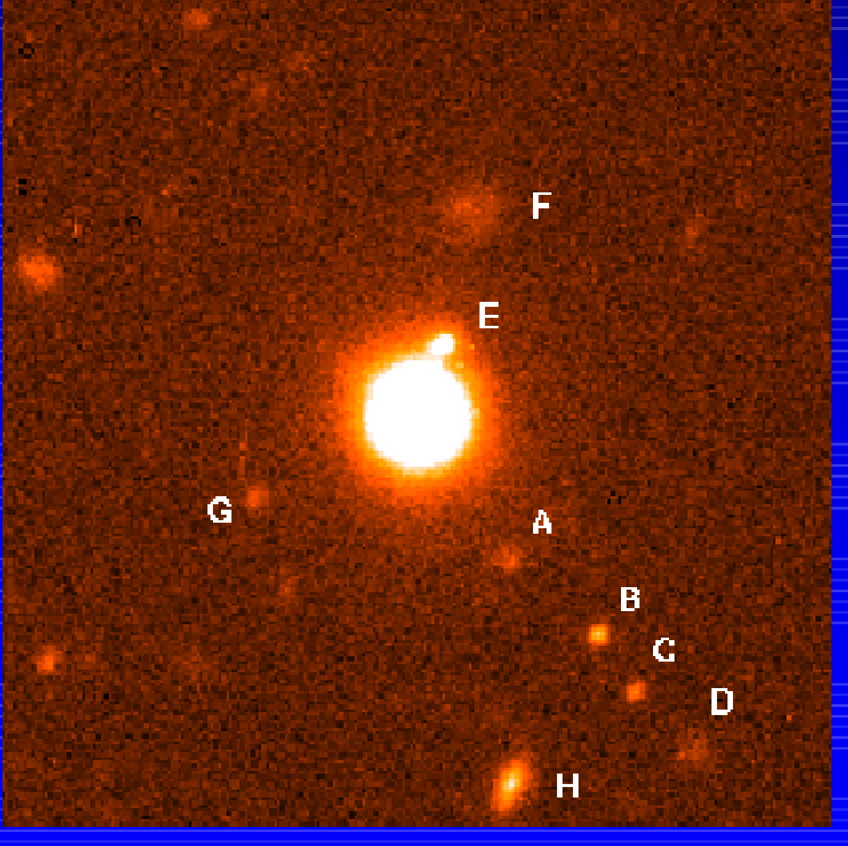
Ł not in a cluster!



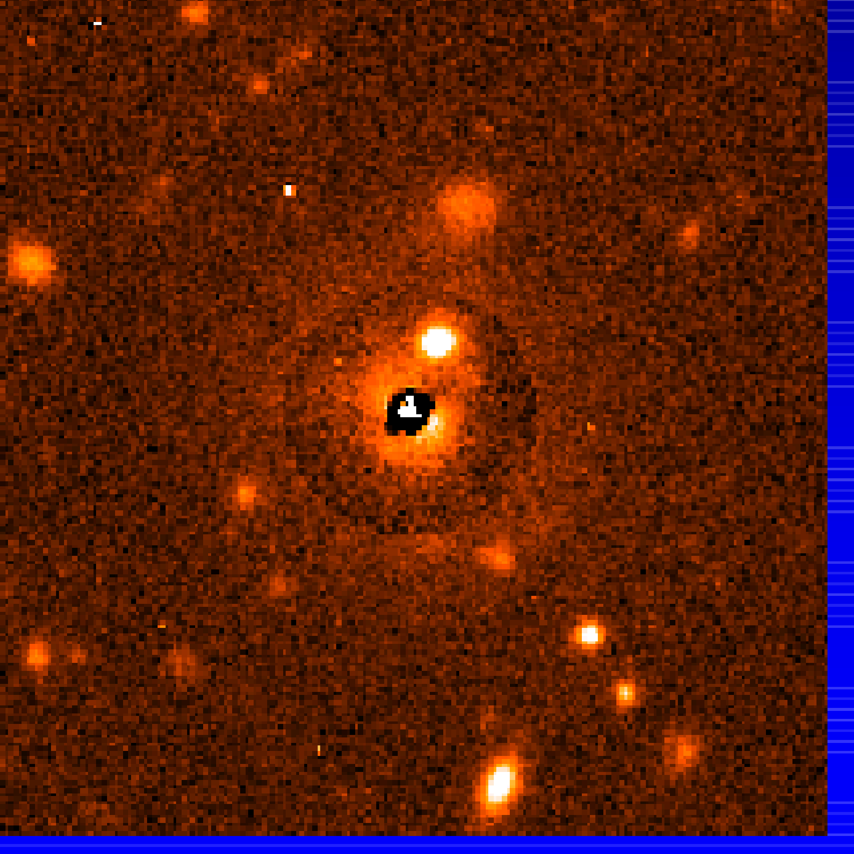
VLT, R-band, FOV 40“, PSF subtracted

Nearby environment:

Ł Quite a few nearby companion objects, several of them non-stellar



NOT, R-band, 40"



VLT, R-band, 40"

New VLT-spectra

H: 20" S (~120 kpc), same z

F: 10" N, much higher z

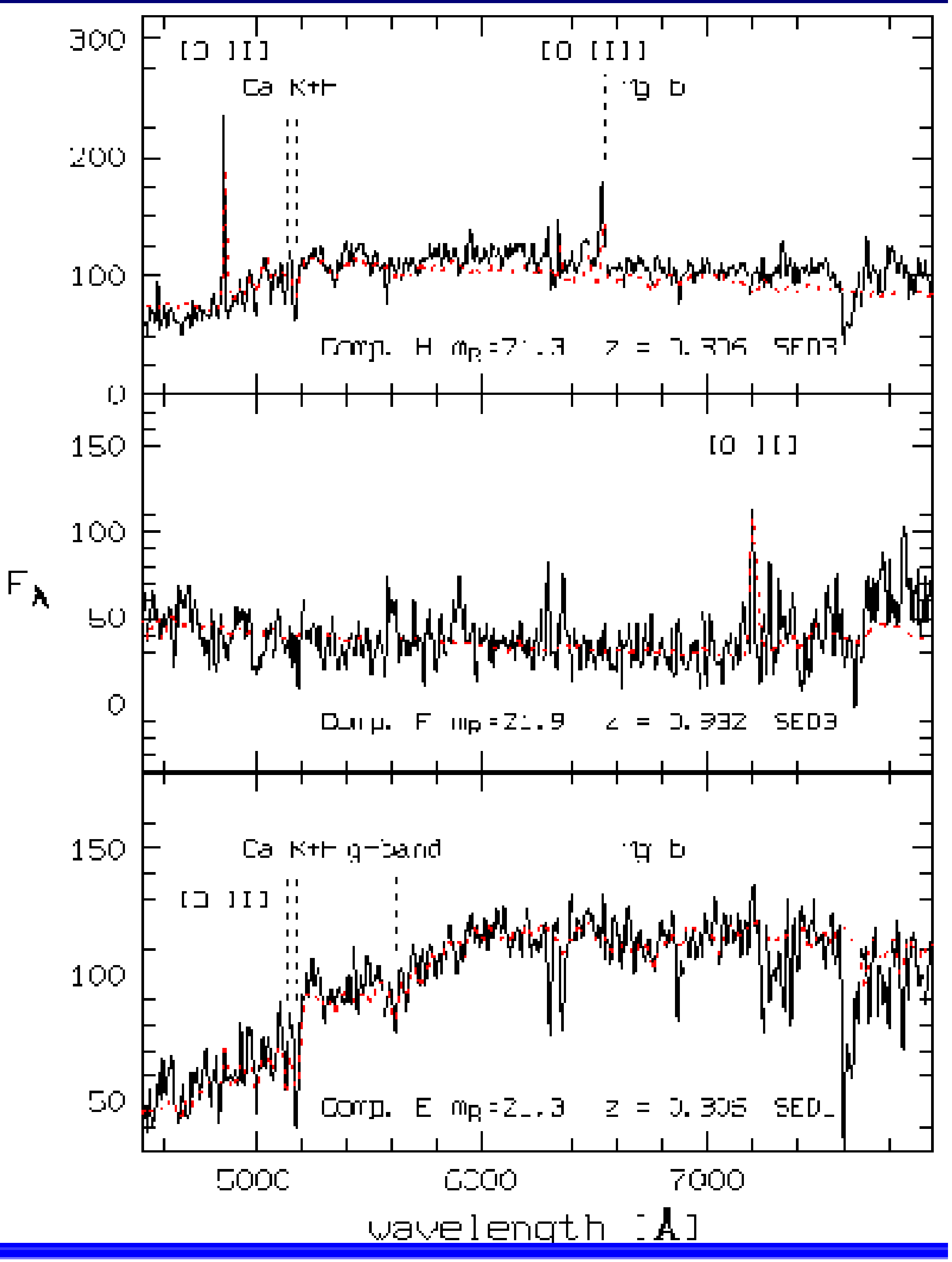
E: 3" N (19 kpc), same z,

Early-type, looks undisturbed, M_R ~ -20.9, M_{BH} ~ 10^8 $M_\odot$?, too massive for the 2nd BH

Ł 3 objects within 150 kpc

Ł Evidence for a small group

Ł Ł somewhat indirect evidence for BH model!



The next outburst of OJ 287

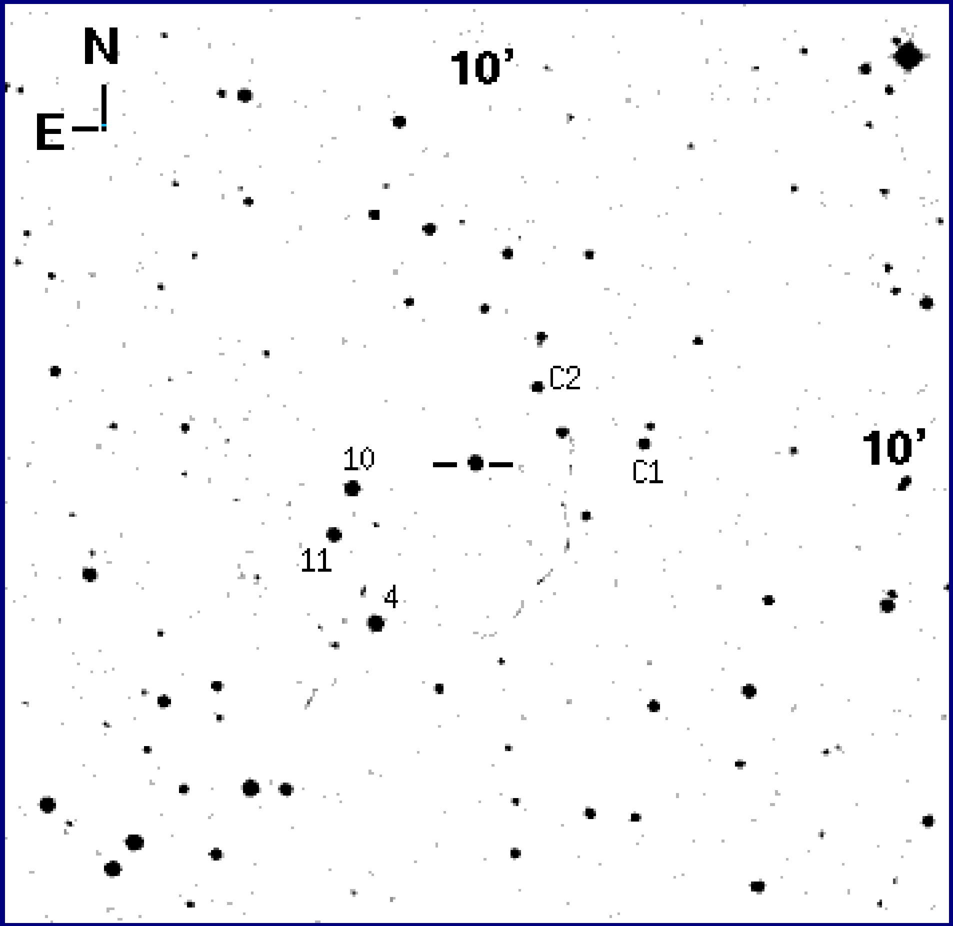
K. Nilsson, L. O. Takalo, A. Sillanpää,
S. Ciprini,
H. Lehto, M. Valtonen, E. Valtaoja

&

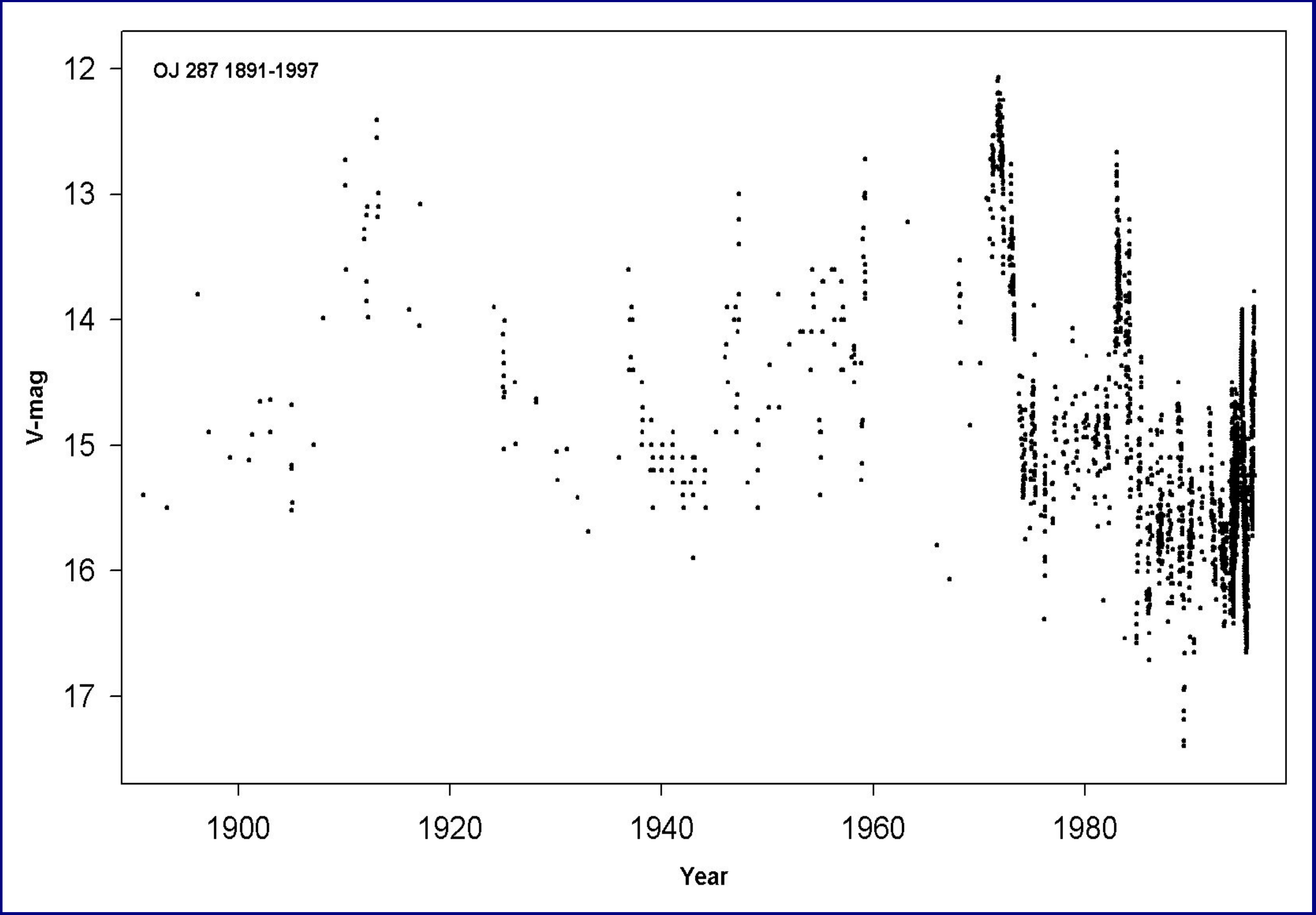
Tuorla Observatory AGN team

OJ 287

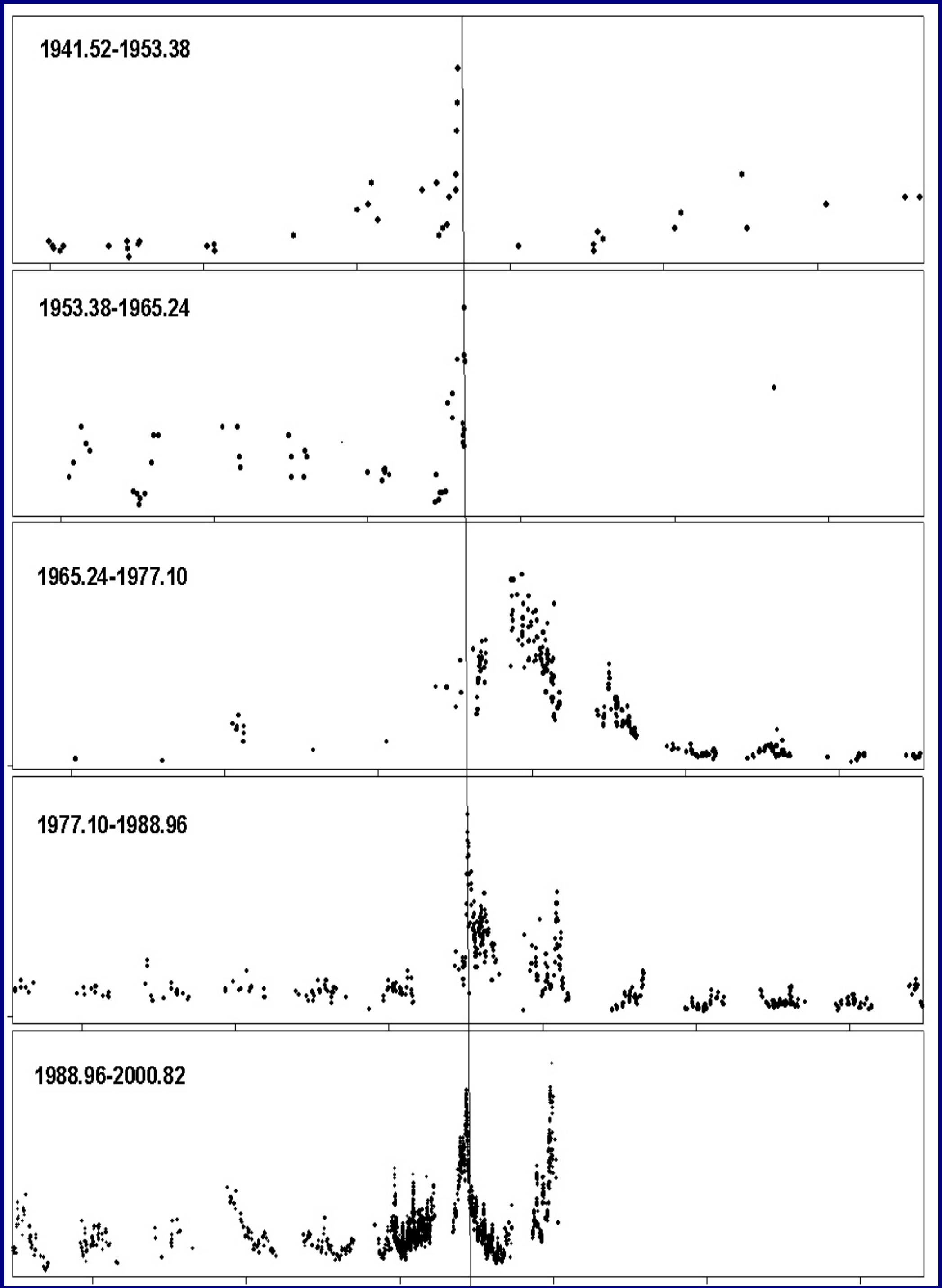
- BL Lac
- z = 0.306
- Observed properties:
  - Highly variable at radio and optical frequencies.
  - v/c = 4...11
  - ➔ $\Gamma = 15$, $\theta = 2^{O}$



Historical lightcurve of OJ 287

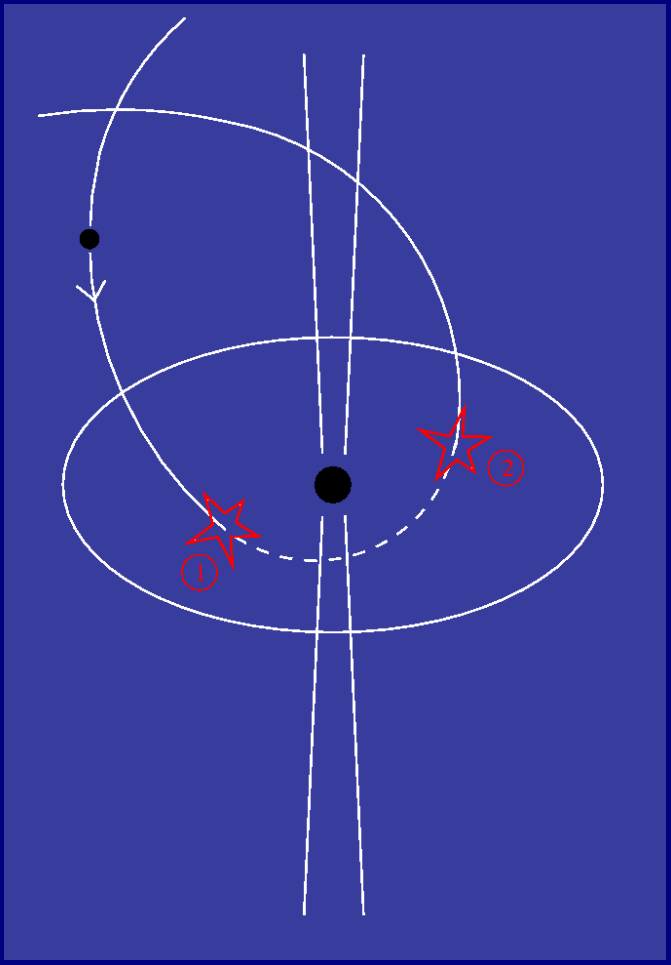


Folded lightcurve:
(P = 11.86 years)



Proposed models

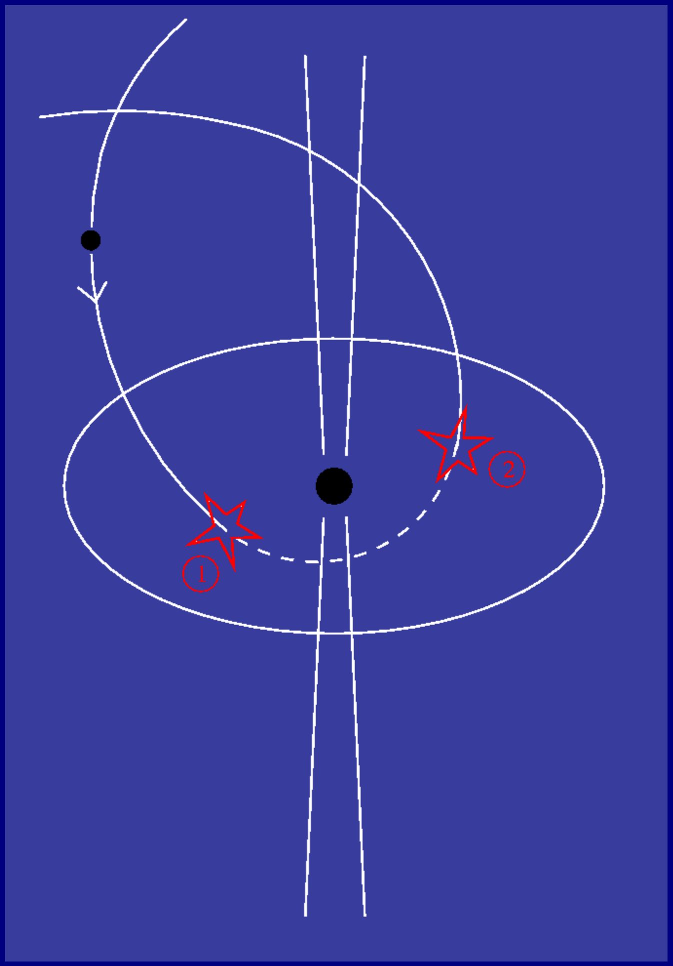
"LV model"



- Lehto & Valtonen (1996)

Proposed models

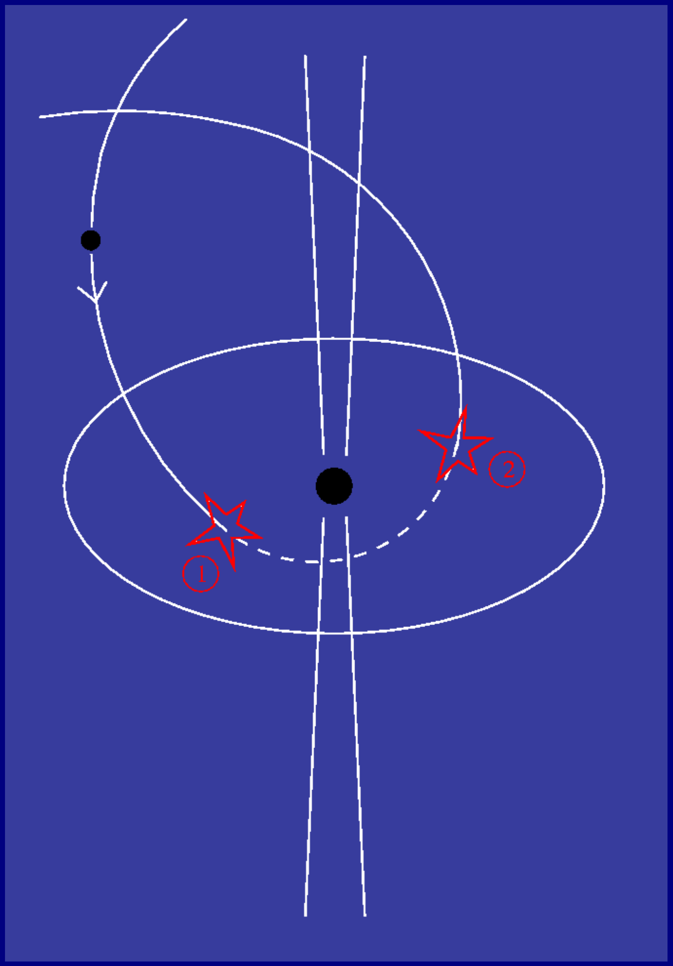
“LV model”



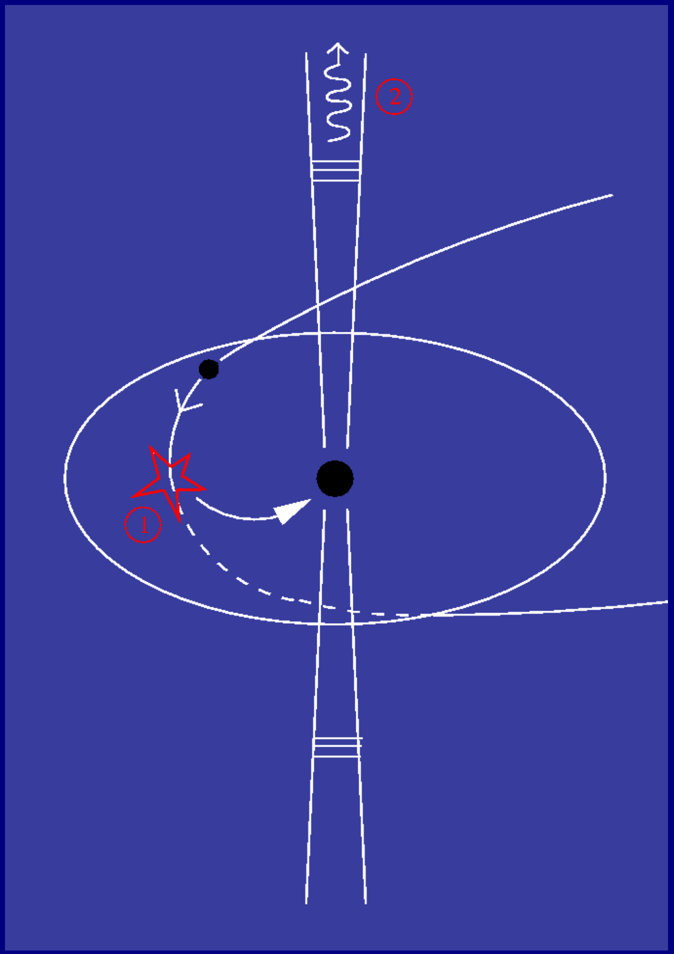
- Lehto & Valtonen (1996)
- high primary mass ($1.7\times10^{10}\ M_{\odot}$)
- P_{orb} = 12.07 y
- strong precession of the orbit

Proposed models

"LV model"



"SV model"

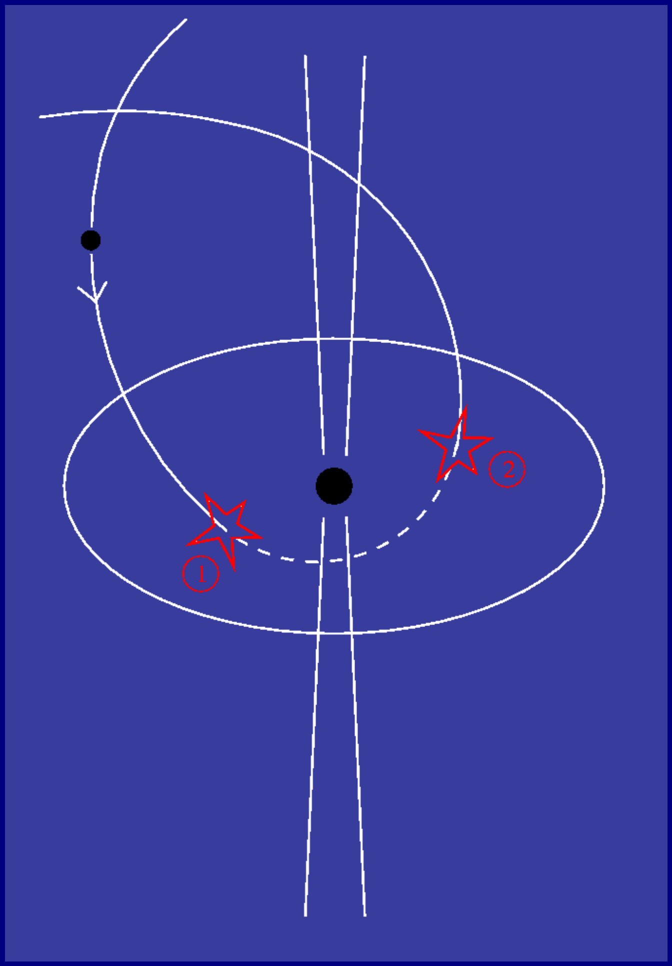


- Lehto & Valtonen (1996)
- high primary mass ($1.7\times10^{10}\ M_\odot$)
- P_{orb} = 12.07 y
- strong precession of the orbit

- Sillanpää, Valtaoja (1998,2000)

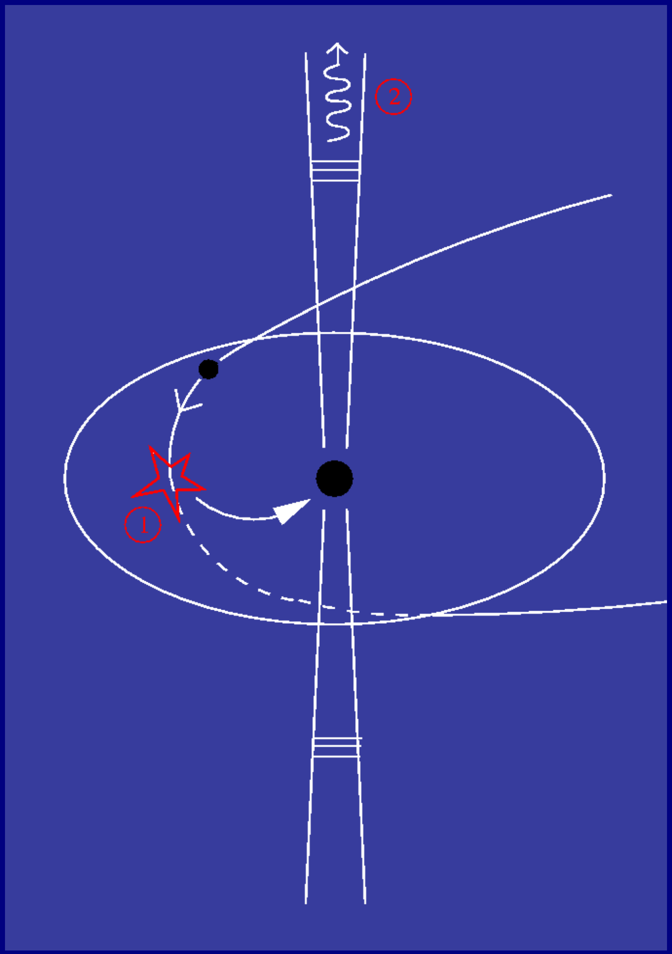
Proposed models

“LV model”



- Lehto & Valtonen (1996)
- high primary mass ($1.7\times10^{10}\ M_\odot$)
- P_{orb} = 12.07 y
- strong precession of the orbit

“SV model”



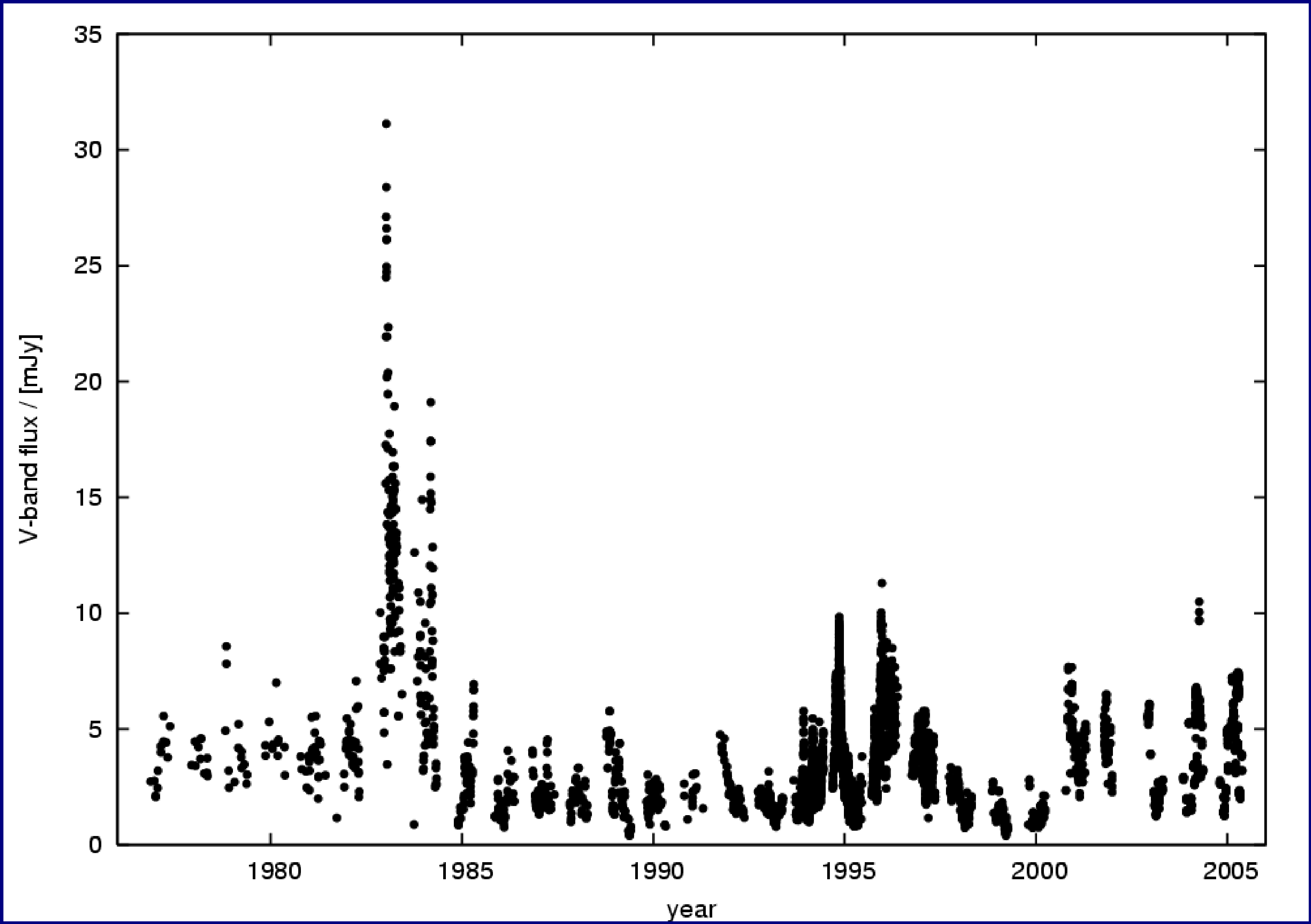
- Sillanpää, Valtaoja (1998,2000)
- no constraint on BH masses
- P_{orb} = 11.86 y
- no precession

OJ 287 2005-2008 project

- Multifrequency flux monitoring
- Polarization monitoring
- VLBI structure
- Optical spectroscopy

Flux monitoring (1)

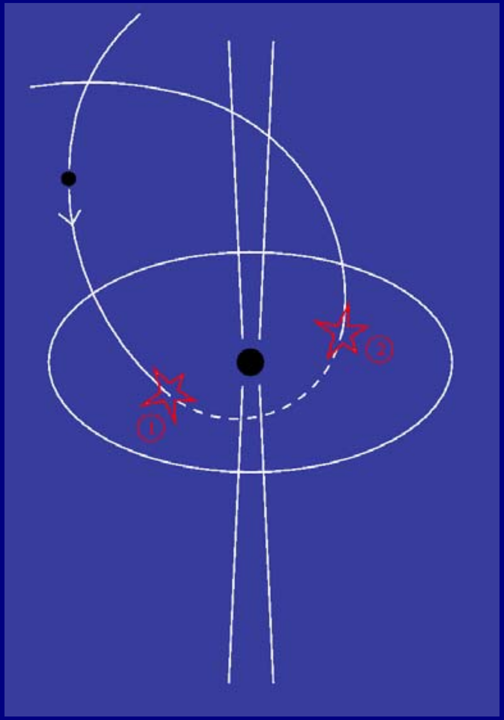
- Optical outbursts
  - Confirm the double-peaked structure
  - Timing of the first outburst
    - LV model : march 2006
    - SV model : september 2006



35
30
25
20
15
10
5
0
V-band flux / [mJy]
1980
1985
1990
1995
2000
2005
year

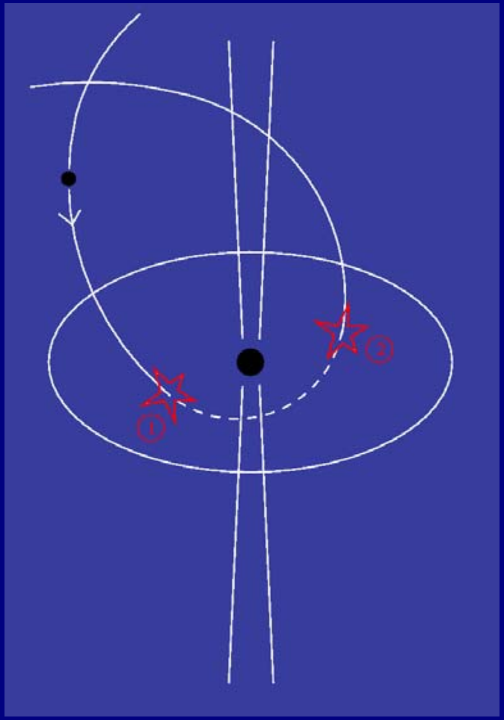
Flux monitoring (2)

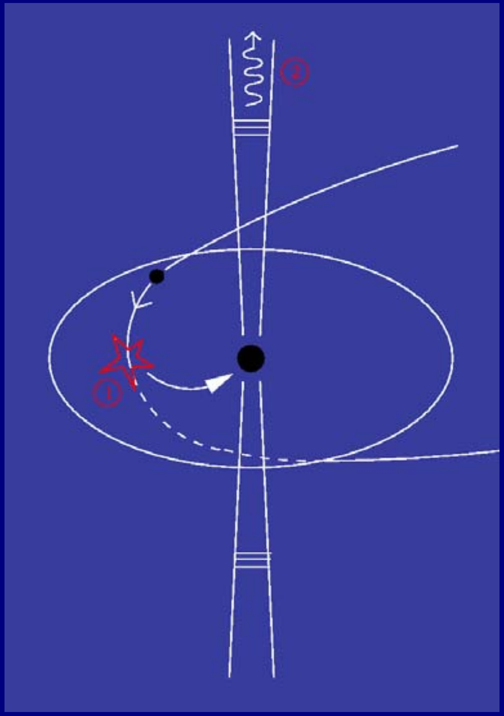
- Radio ourbursts
  - LV model : optical outbursts have no radio counterpart



Flux monitoring (2)

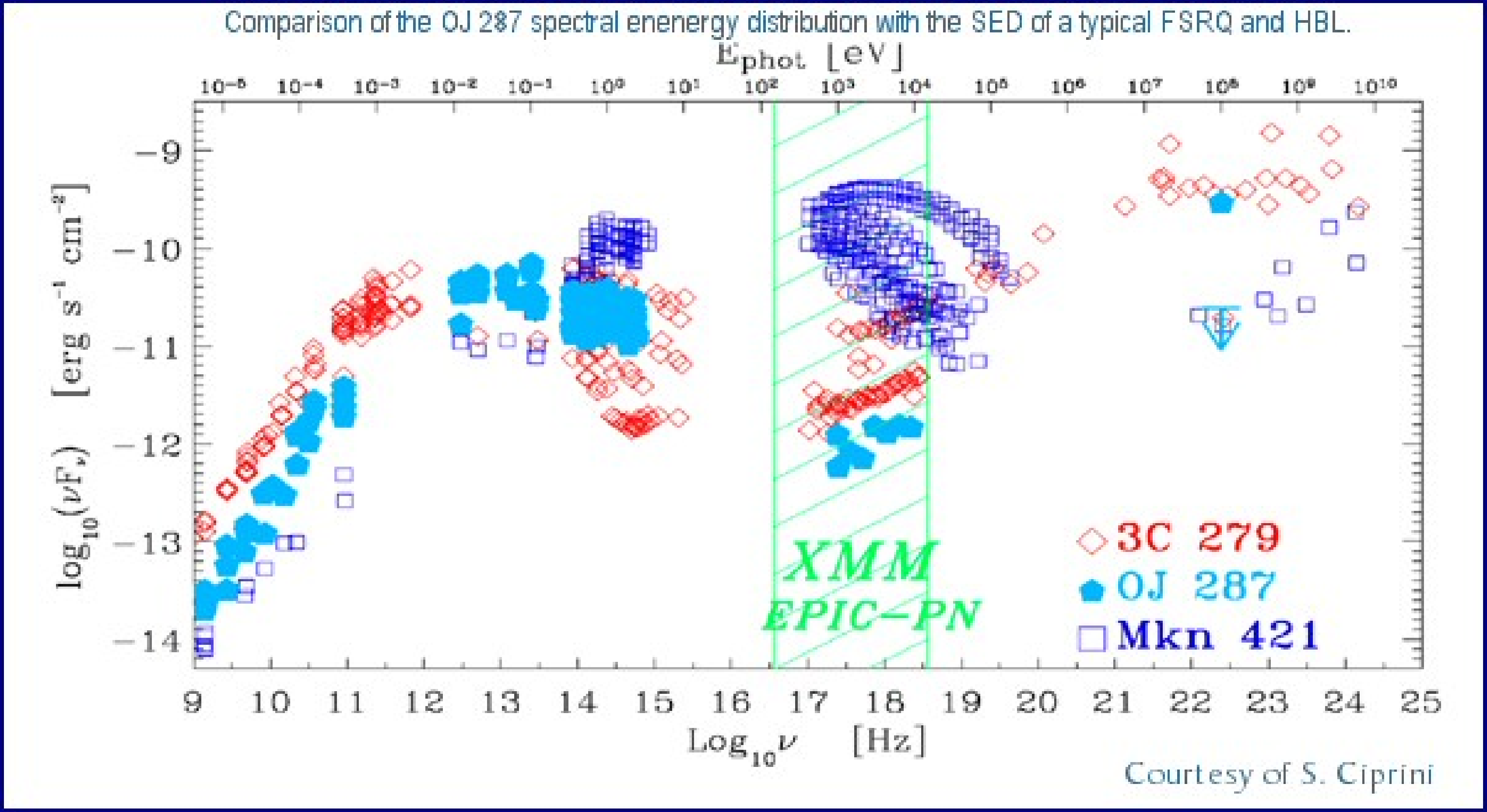
- Radio outbursts
  - LV model : optical outbursts have no radio counterpart
  - SV model : the second outburst has a radio conterpart





Flux monitoring (3)

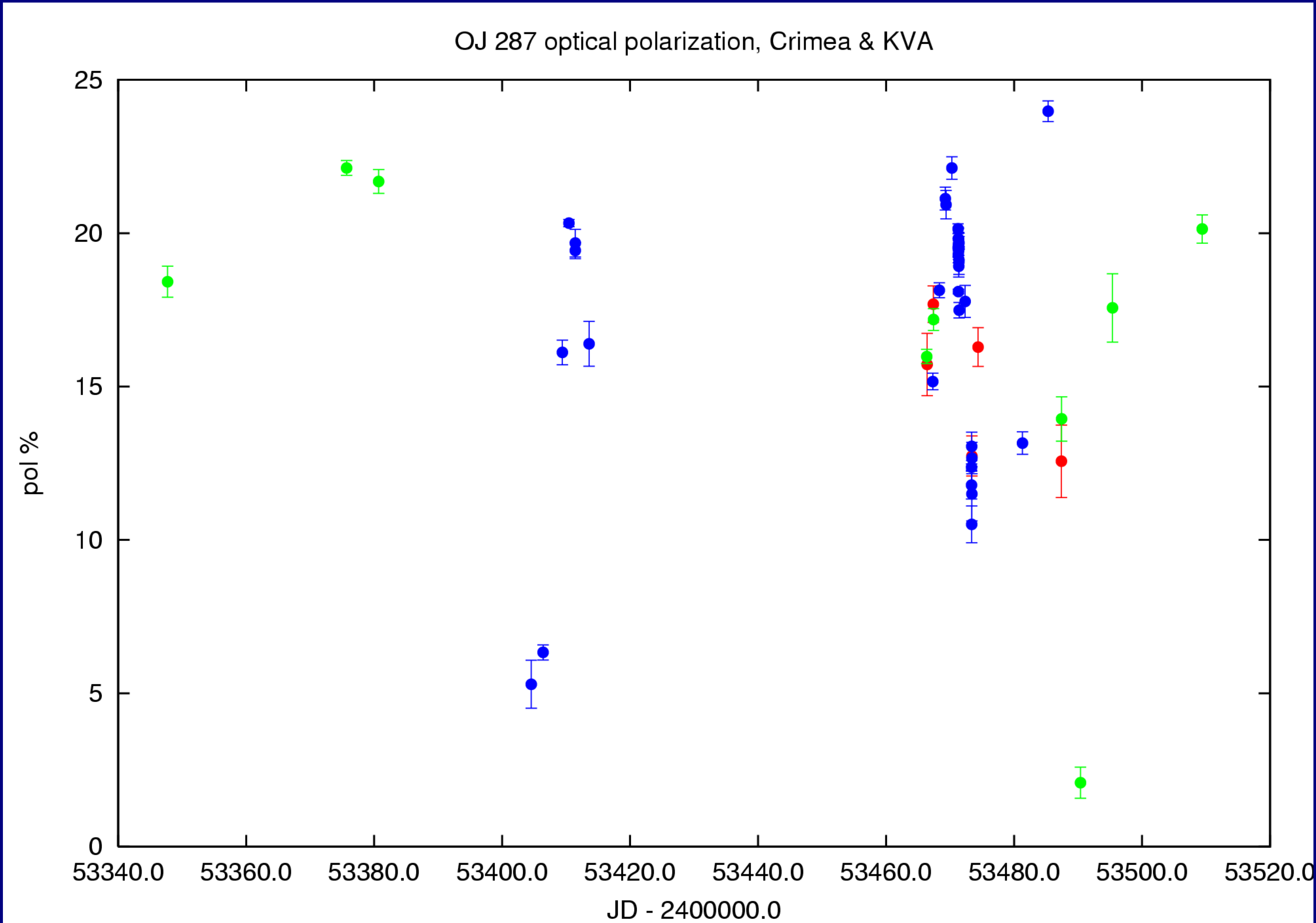
- Multifrequency monitoring
  - XMM 40 ks integration in Apr 2005



Optical polarization

- LV model : both outburts are unpolarized
  - P decreases, PA : no change
- SV model : the second outburst is polarized
  - P changes, PA changes

KVA 60 cm telescope



OJ 287 optical polarization, Crimea & KVA
pol %
25
20
15
10
5
0
53340.0
53360.0
53380.0
53400.0
53420.0
53440.0
53460.0
53480.0
53500.0
53520.0
JD - 2400000.0

VLBI structure

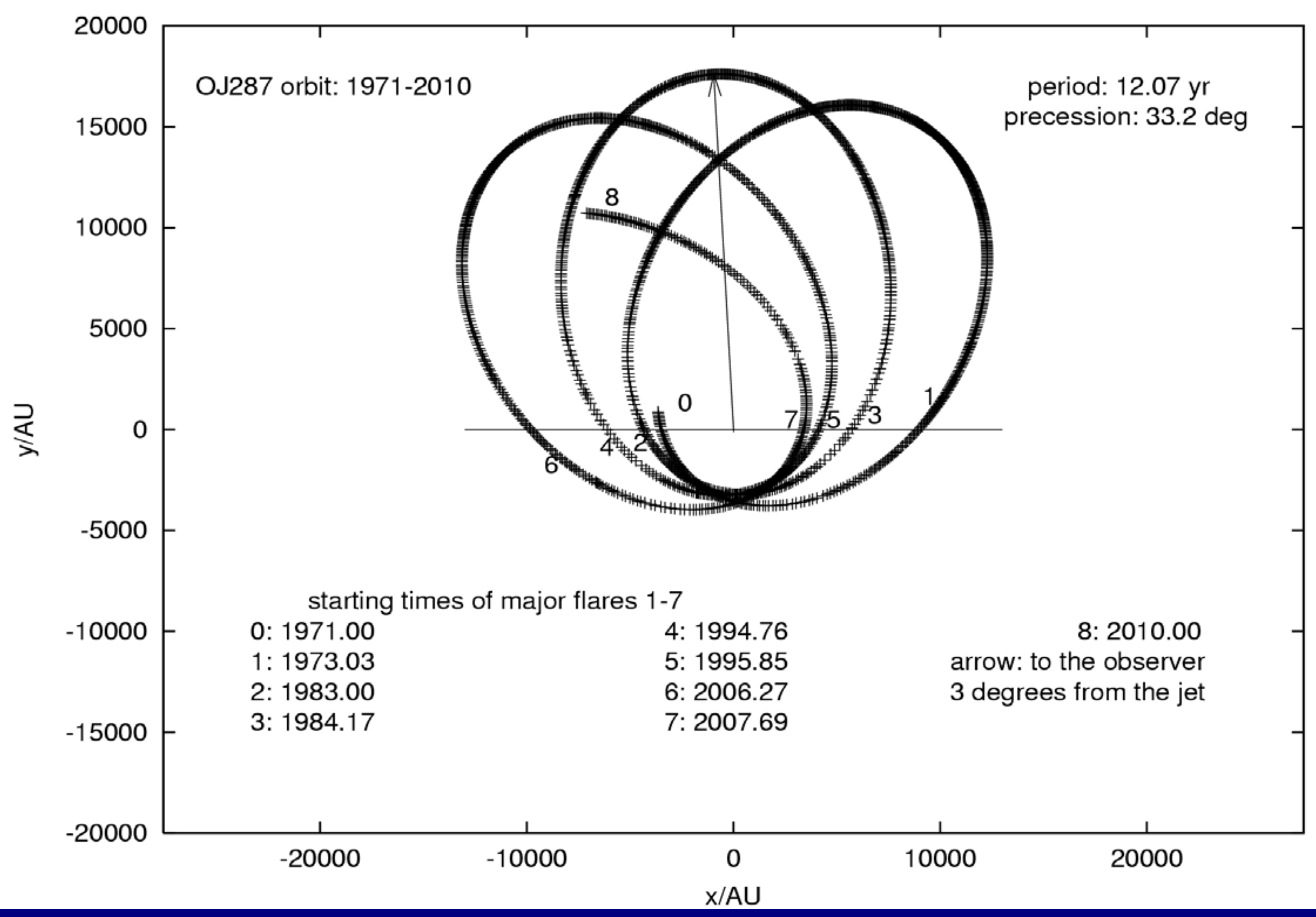
- Changes in the jet after the 2nd outburst?
  - Changes in the VLBI core?
  - Changes in jet velocity?
  - Polarization of the core connected to the optical polarization?

VLBI structure

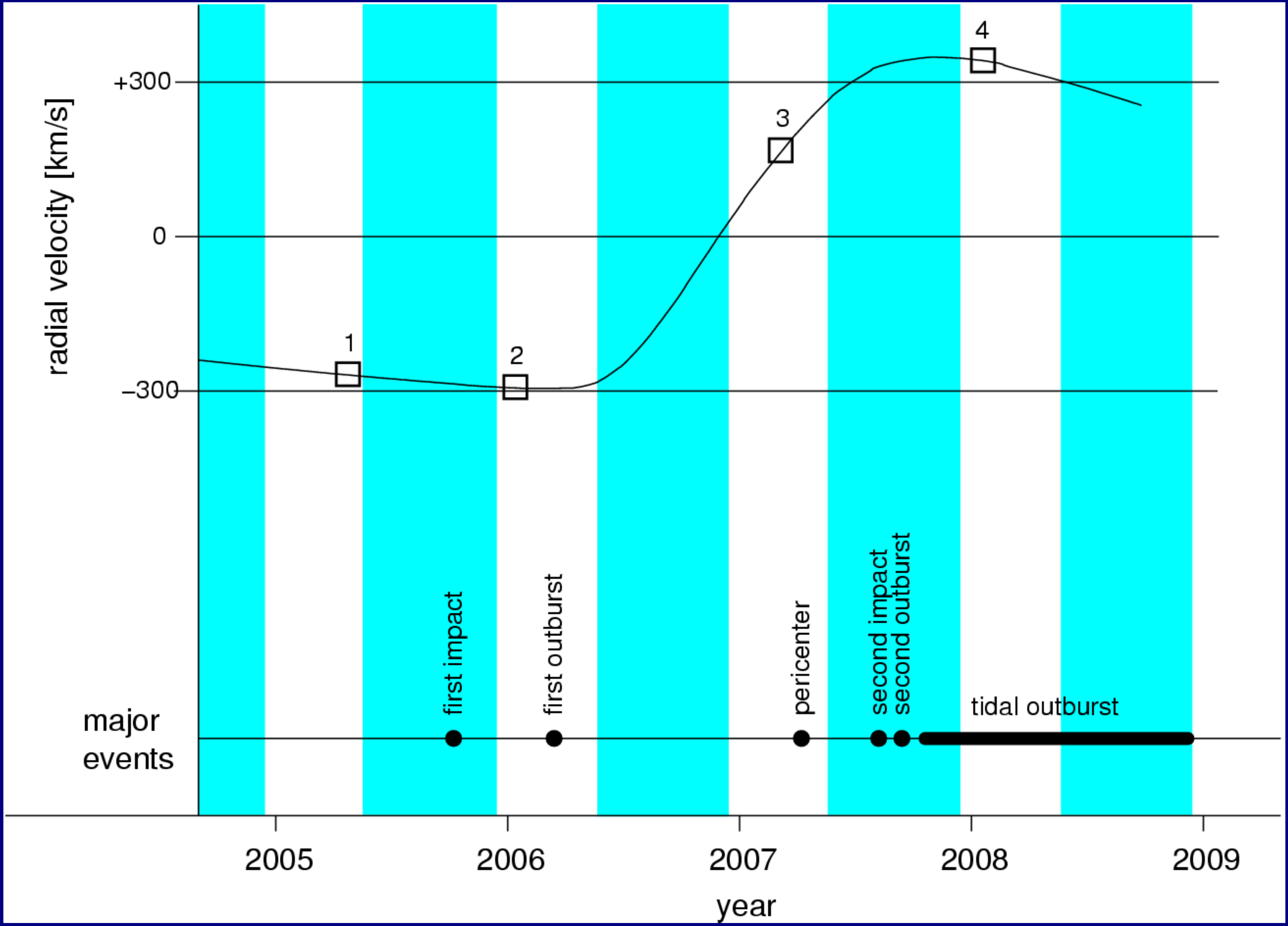
- Changes in the jet after the 2nd outburst?
  - Changes in the VLBI core?
  - Changes in jet velocity?
  - Polarization of the core connected to the optical polarization?
- 6 VLBA epochs obtained for 2005-06

Black hole motion

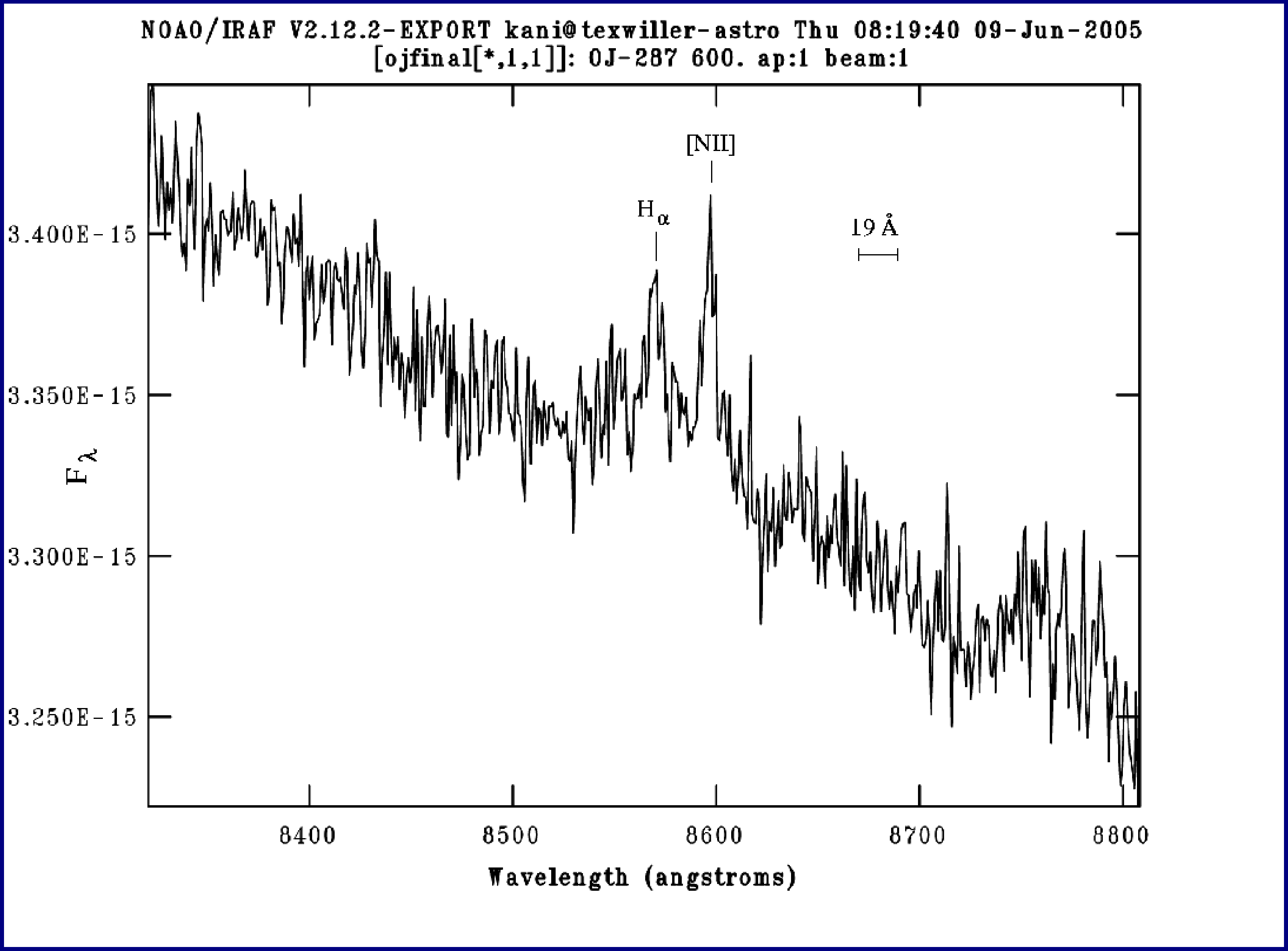
Secondary orbit (LV model) :



Primary radial motion (LV model, Valtonen 2000)



VLT spectrum



Project website

www.astro.utu.fi/OJ287MMVI/index.html

Stefano Ciprini
Tuorla Astronomical Observatory
University of Turku - Piikkiö, Finland
(EC Young Researcher Training Network ENIGMA)

A First Glance at the OJ 287 Campaign

(Tasks: 3-4)

5th ENIGMA Meeting

June 13-17, 2005 – H. Bornmüehle, Neubrandenburg, GERMANY

OJ 287 Campaign

OJ 287 2005-2008 Project

OJ 287 available historical optical light curve shows several large major outbursts, that occur every 11-12 years. The last outburst was followed by the OJ94 project (period 1993-1997). The next possible outburst is expected to occur in 2006-2007 (Mar.2006 and Oct.2007 or Sept.2006 and Nov.2007… or other times, or nothing…). Low-sampling (1, 2 data points per week) regular monitoring of OJ 287 continuing until May 2008. Intensive observations during the outburst. Scientific case also in the case of no outburst.

XMM-Newton esa Two XMM-Newton Observations in 2005

OJ 287 Campaign

Extended ENIGMA campaign
(ENIGMA teams and who is interested in)

April 2005 (probably all the 2004-2005 season) and the next season (October 2005 - April 2006)

WEBT campaign

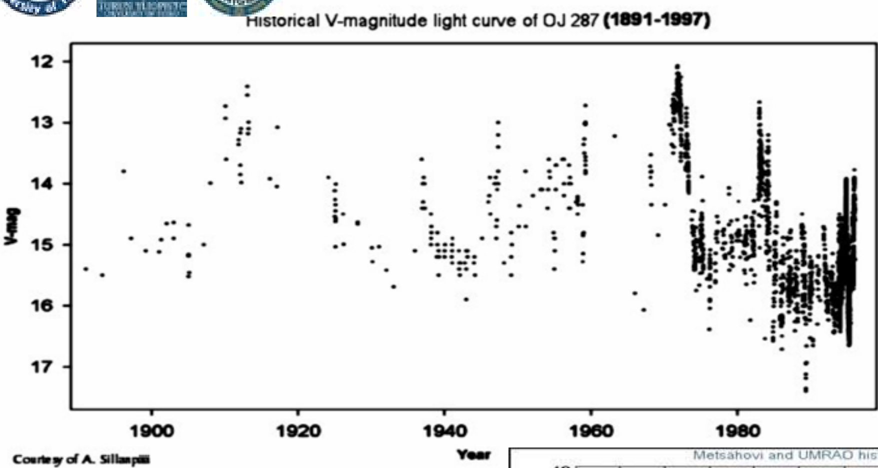
April 11-14, 2005, and November 2-5, 2005 (preliminary date)

The strategy is to cover a large range of variability timescales and a large range of electromagnetic frequencies.

OJ 287 Observations Schedule

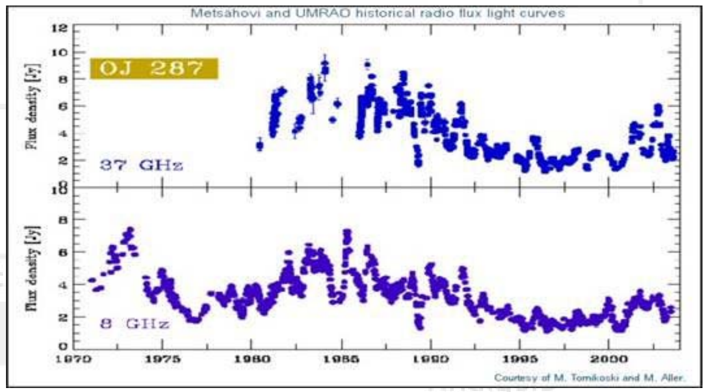
- Long-term monitoring (OJ 287 2005-2008 Project and ENIGMA Campaign) started in late 2004 (PM/CM: L. Takalo, A. Sillanpää).
- Intensive intra-night observations at NOT (Feb.1, 2005): almost totally lost due to bad weather in Europe (PI: K. Nilsson).
- VLBA radio-structure/polarization observations in 5 bands: 6 times, 8h for the period 2005-2006 (PI: T. Savolainen). More observations planned in the period 2007-2008.
- VLBA and global 3mm-VLBI radio-mm-structure/polarization observations as a calibrator (4 and 17 April 2005) (PI: I. Agudo).
- ESO VLT spectroscopic observations in ESO Period 75, (PI: K. Nilsson).
- XMM-Newton X-ray observations: 2 pointings of about 40 ksec each in cycle AO-4 (12 April 2005 and beginning of November 2005), (PI: S. Ciprini).
- Short WEBT campaign around the two XMM pointing (CM: S. Ciprini)
- ToO Effelsberg 100m flux/polarization observations on 12 April (ToO PI: L. Fuhrmann)
- 4 sessions of Global 3mm-VLBI observations in period Oct.2005-Apr.2007 (PI: E. Rastorgueva, K. Wiik).

OJ 287 Historical Lightcurves

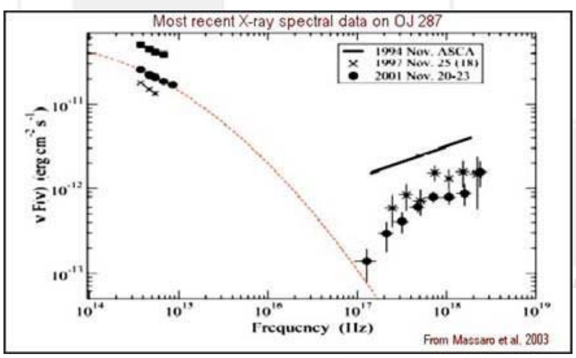


Optical

Radio

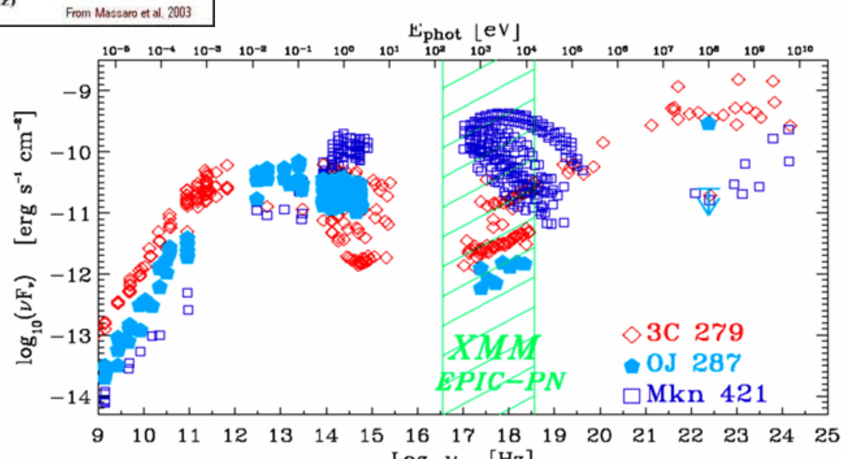


The SED of OJ 287



The most recent X-ray spectral energy distributions of OJ 287.

The broad-band spectral energy distribution of OJ 287 in comparison with the SED of a typical FSRQ (3C 279) and TeV-HBL (Mkn 421).



Goals

- ❑ Study the spectral and temporal behaviour of OJ 287, on both short and long time scales, before and during the next possible outburst.
- ❑ X-ray data will provide information on the high-energy spectral component (likely inverse Compton emission), while radio-to-optical observations will map the behaviour of the synchrotron emission component.
- ❑ Possibly clarify basic physics, and relevance of geometrical and energetic models in the interpretation of long/short-term variability, during both the quiescent and outburst phases.
- ❑ Search for multiwavelenght flux-flux correlations, x-ray-flux-radio-structure correlations, possible precursory events (predicted by some models).

Information and visibility of OJ 287 by XMM in 2005:

Source name	Other names	Redshift	EGRET detection	X-rays past observations	X-rays integral flux [erg cm^{-2} s^{-1}]	XMM AO-4 source visibility periods	Optical visibility window†
OJ 287	PKS 0851+202 PG 0851+202	$z = 0.306$	YES	Einstein,EXOSAT,ROSAT ASCA,*BeppoSAX*	$1.35\text{-}5.0 \times 10^{-12}$ (2-10 keV) (ASCA, SAX)	2005.Apr.12 - 2005.May.05 2005.Oct.16 - 2005.Nov.18	Oct-May

† Calculated for the mean latitude of the WEBT and ENIGMA collaboration telescopes.

Target_Name	RA	Dec	Position_Angle	
OJ 287	08:54:48.87	+20:06:30.6	285:05:17.8	
XMM Obs_Duration	XMM Obs: **Start Time**	XMM Obs: **End Time**	Satellite Revolution	IB
40000 sec	2005-04-12 at 12:55 UT	2005-04-13 at 00:03 UT	0978	E3

XMM-Newton Satellite

- **XMM (X-ray Multi-Mirror space telescope)**

- Cornerstone Mission of ESA's Horizon 2000 Program
- Successfully launched on board the Ariane-5 Flight 504 on Dec. 10th 1999 from Kourou

weight: 3.8 tons, length: 10 m

· squarish service module also carrying three 'mirrors modules' at its forward broader end

· the focal plane assembly housing the X-ray cameras and detectors at its other extremity

· 3 Wolter telescopes with 58 mirrors each

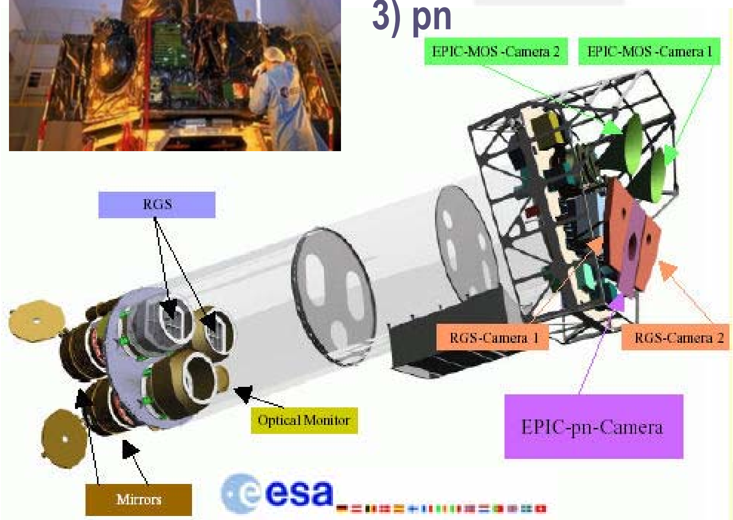
· 2 solar panels with 16 metre span

XMM-Newton Satellite

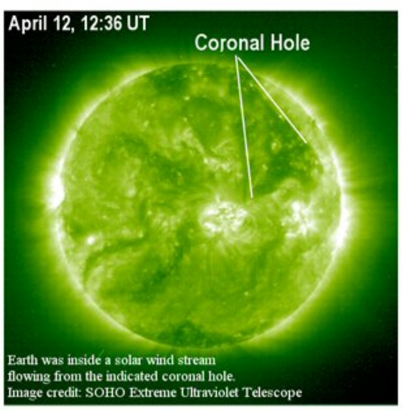
XMM-Newton has three mirror modules:

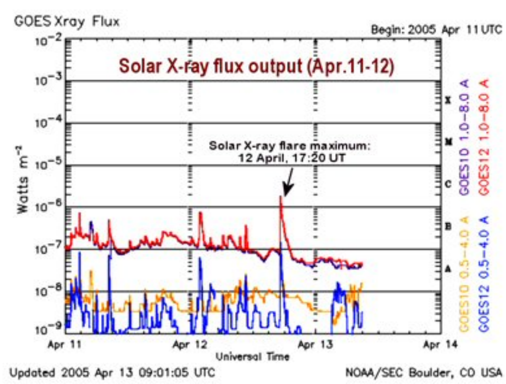
- Instruments behind:
  1) RGS-1 and MOS-1
  2) RGS-2 and MOS-2
  3) pn

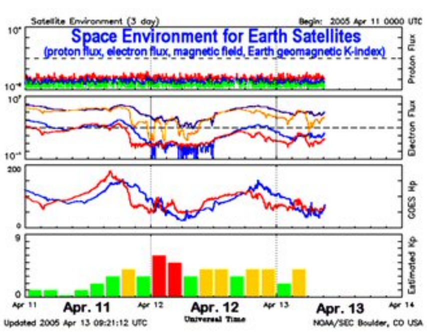
- **EPIC:** MOS1, MOS2 and pn
- **RGS:** RGS-1, RGS2
- **OM:** Optical Monitor

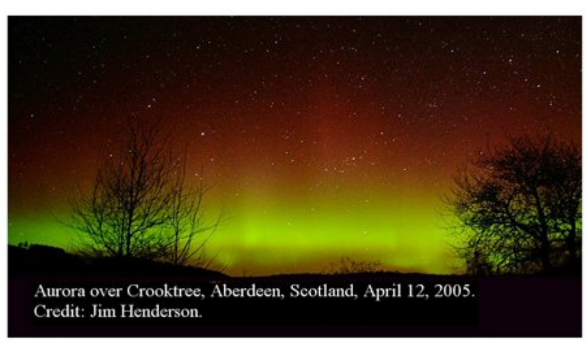


April 12: Space Weather







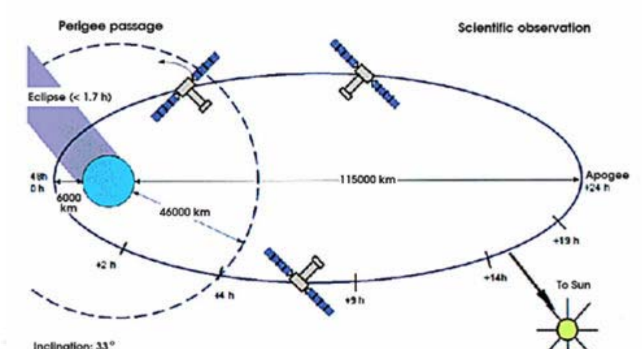


XMM Observation of OJ 287

The first XMM observation was affected by high background radiation (mostly proton radiation belt). Observation partially stopped. Of the original 40 ksec granted (with overheads) only about 11 ksec performed and only about 4 ksec useful for science analysis.

Anyway:

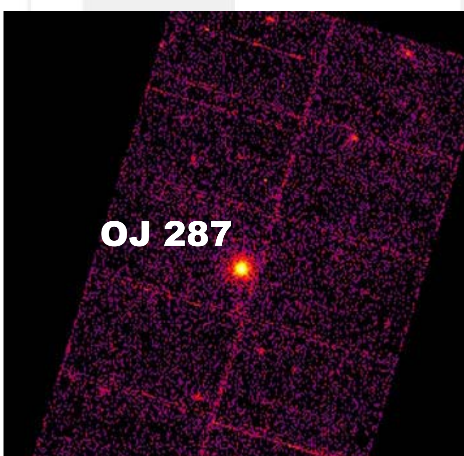
- *EPIC pn*: the excellent camera collected enough photons to construct a spectra.
- *RGS*: no detection.
- *OM*: UV, U,B,V, observation performed.
- The extra-time (~ 20ksec) will be added to the next 40ksec pointing in November.

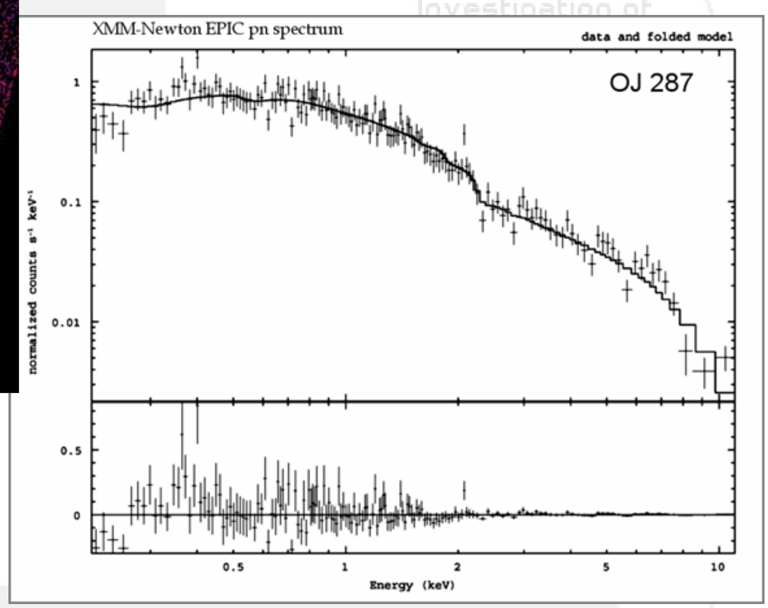


XMM-Newton

esa

XMM Preliminary EPIC pn Image and Spectrum





Power law + absorption

ENIGMA-WEBT Campaign

Participating Observatories

Institutes/Observatories with data and contact-persons (list updated by June 3, 2005):

Optical:

Osaka Kyoiku University Observatory - Kashiwara, Osaka, Japan (K. Sadakane)
Lulin Observatory - Lulin, Taiwan (W. P. Chen)
Xinglong Station of NAOC - Yanshan Mountains, China, (J.-H. Wu)
ARIES Sampurnanand Telescope - Naini Tal, Uttaranchal, India (R. Sagar, G. Krishna)
Abastumani Astrophysical Observatory - Mt. Kanobil, Georgia, (O. Kurtanidze)
Crimean Astrophysical Observatory - Nauchny, Crimea, Ukraine (Y. Efimov, V. Larionov)
Çanakkale Onsekiz Mart University Observatory - Çanakkale, Turkey (A. Erdem)
Jakokoski Observatory - Jakokoski, Finland (P. Pääkkönen)
Nyrölä Observatory - Nyrölä, Finland (A. Oksanen, K. Nilsson)
Tuorla Observatory - Piikkio, Finland (L. Takalo, A. Sillanpää)
Catania Observatory - Catania, Italy (A. Frasca)
Campo Imperatore Observatory - L'Aquila, Italy (V. Larionov)
Armenzano Observatory - Armenzano, Assisi, Italy (D. Carosati)
Perugia Observatory - Perugia, Italy (G. Tosti, S. Ciprini)
Torino Observatory - Torino, Italy (C. Raiteri, M. Villata)

ENIGMA-WEBT Campaign

Optical (cont.):

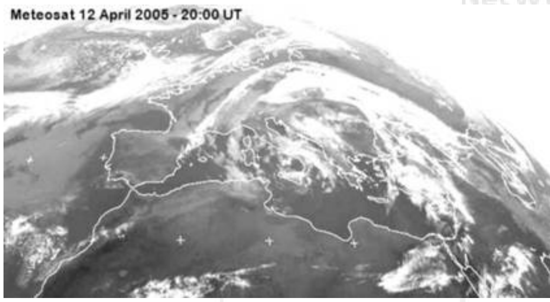
Heidelberg Observatory - Heidelberg, Germany (J. Heidt)
Michael Adrian Observatory- Trebur, Germany (J . Ohlert)
Agrupacio Astronomica de Sabadell - Sabadell, Spain (J. A. Ros)
KVA Telescope - La Palma, Canary Islands, Spain (L. Takalo, A. Sillanpää)
Nordic Optical Telescope - La Palma, Canary Islands, Spain (T. Pursimo)
Mt. Lemmon KASI Observatory - Mount Lemmon, Arizona, USA (L. Chung-Uk)
Kitt Peak SARA Observatory - Kitt Peak, Arizona, USA (J. Webb)
Tenagra Observatories - Sonoran desert, Arizona, USA (A. Sadun)
Coyote Hill Observatory - Wilton, California, USA (C. Pullen)

Radio-mm:

RATAN-600 (Special Astrophys. Obs.) (576 m) - Zelenchukskaya, Russia (Y. Kovalev)
Metsähovi Radio Telescope (14 m) - Metsähovi, Finland (M. Tornikoski, A. Lahteenmaki)
Noto Radio Observatory - Noto, Siracusa, Italy (C. Raiteri, P. Leto)
Effelsberg Radio Telescope (100 m) - Effelsberg, Germany (T. Krichbaum, L. Fuhrmann)
IRAM Millimeter Telescope (30 m) - Pico Veleta, Spain (T. Krichbaum, H. Ungerechts)
Univ. of Michigan Radio Astron. Obs. (UMRAO) (26 m) - Dexter, Michigan, USA (M. Aller)

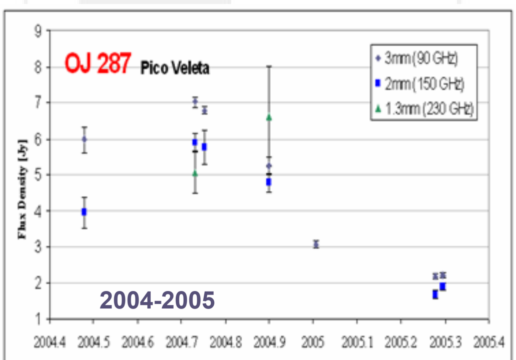
ENIGMA-WEBT Campaign

- Optical ground-based observations obstructed by bad weather in Europe in April 12.
- Effelsberg radio-observations well carried out.
- In the other 4-days of the WEBT campaign there are rather good optical observations.
- Few optical-polarization and near-IR data also available.
- VLBA & 3mm-VLBI observations on April 4 and 17.
- Radio data and optical monitoring available during April month by several observatories.

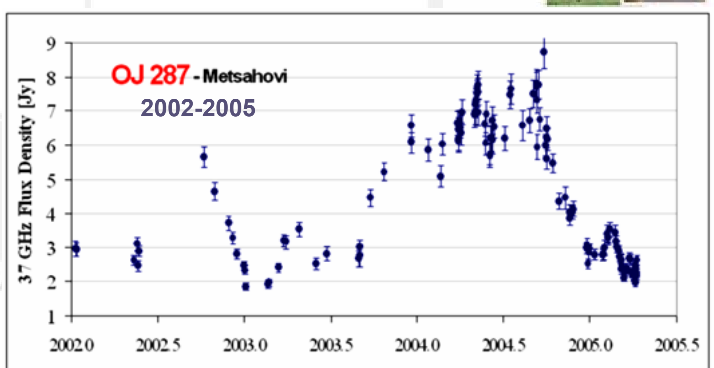


5 Optical observatories in center Italy (2 amateur, 3 professional) alerted/involved personally for April 12… but bad luck with weather!

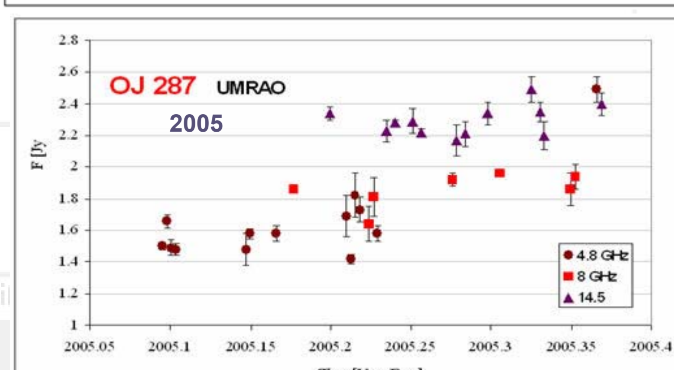
Preliminary Radio Lightcurves



Courtesy of T. Krichbaum

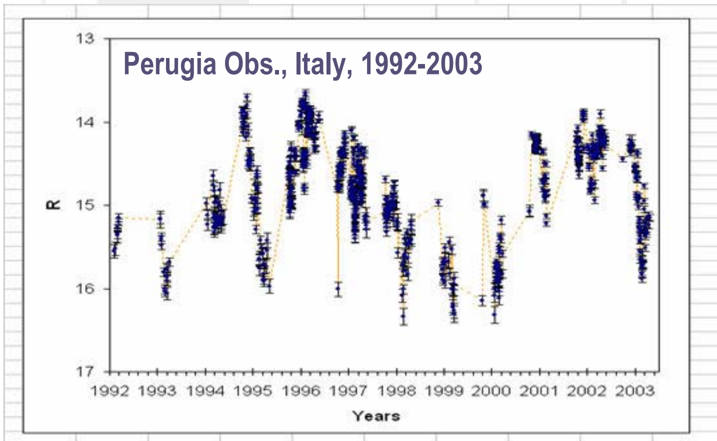


Courtesy of M. Tornikoski

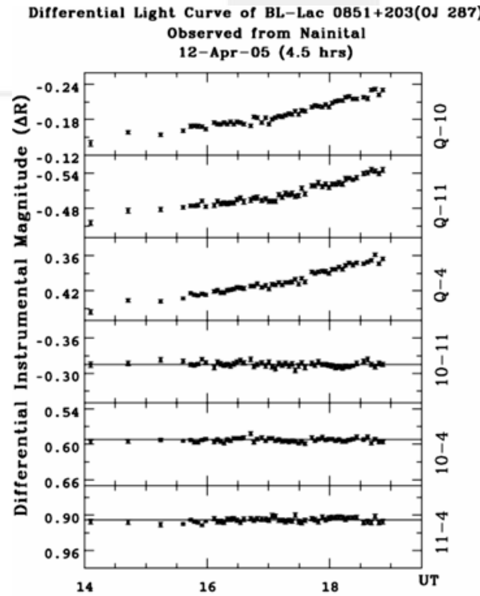


Courtesy of M. Aller

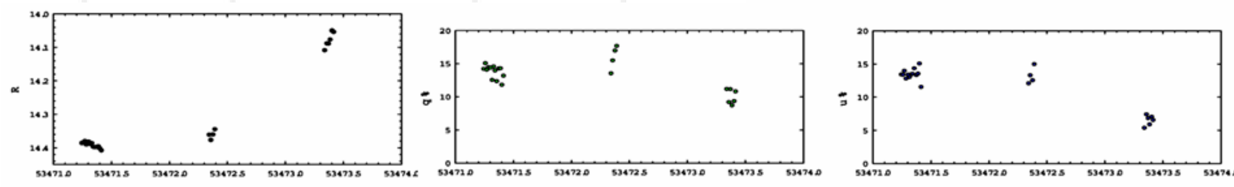
Some Optical Lightcurves



Naini-Tal Obs., India

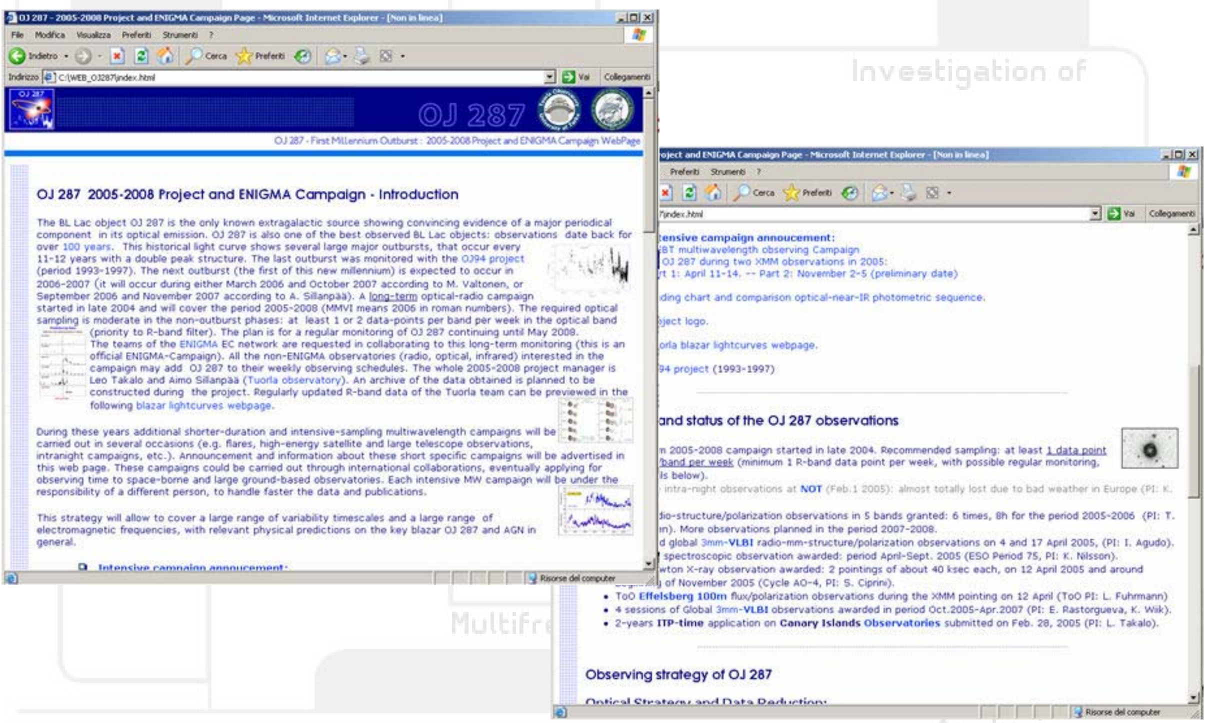


Crimea Obs., Ukraine



Campaign Summary Webpage

Web page of the Campaign: `www.astro.utu.fi/OJ287MMVI`



5 GHz Polarization Observation of 3 RI Quasars

Andreas Papageorgiou

CIT

Introduction

- **Radio intermediates**

Radio “loudness”

$$R = \frac{F_{cent}}{F_{opt}}$$

RQ:0.1-3   RL~100 - 1000

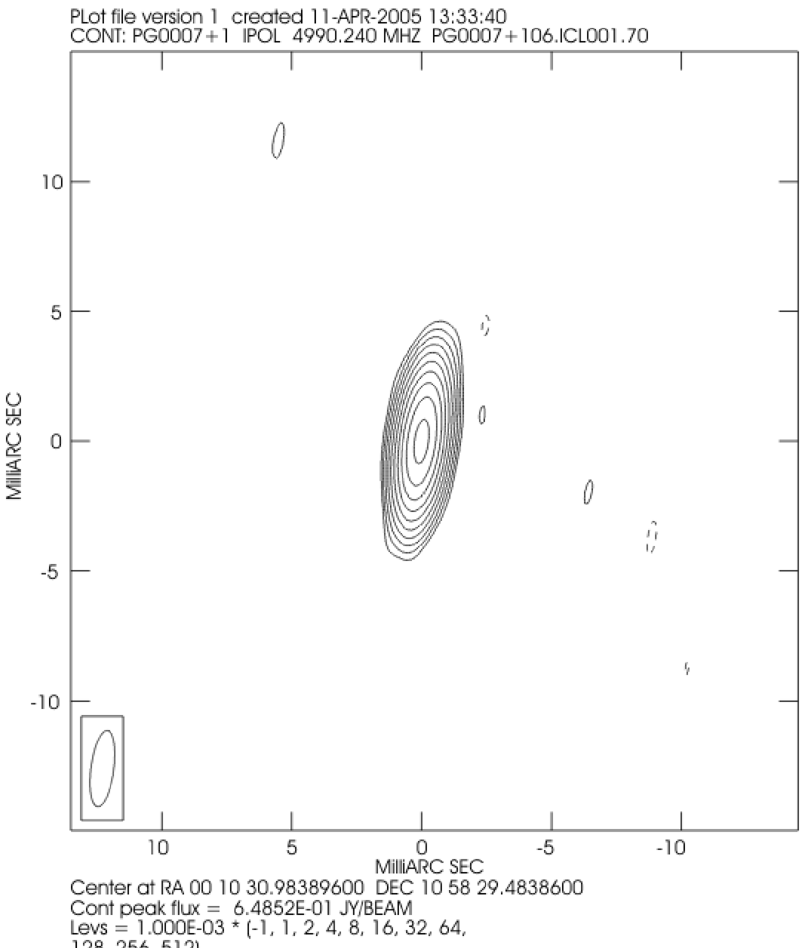
- **Aim of experiment**

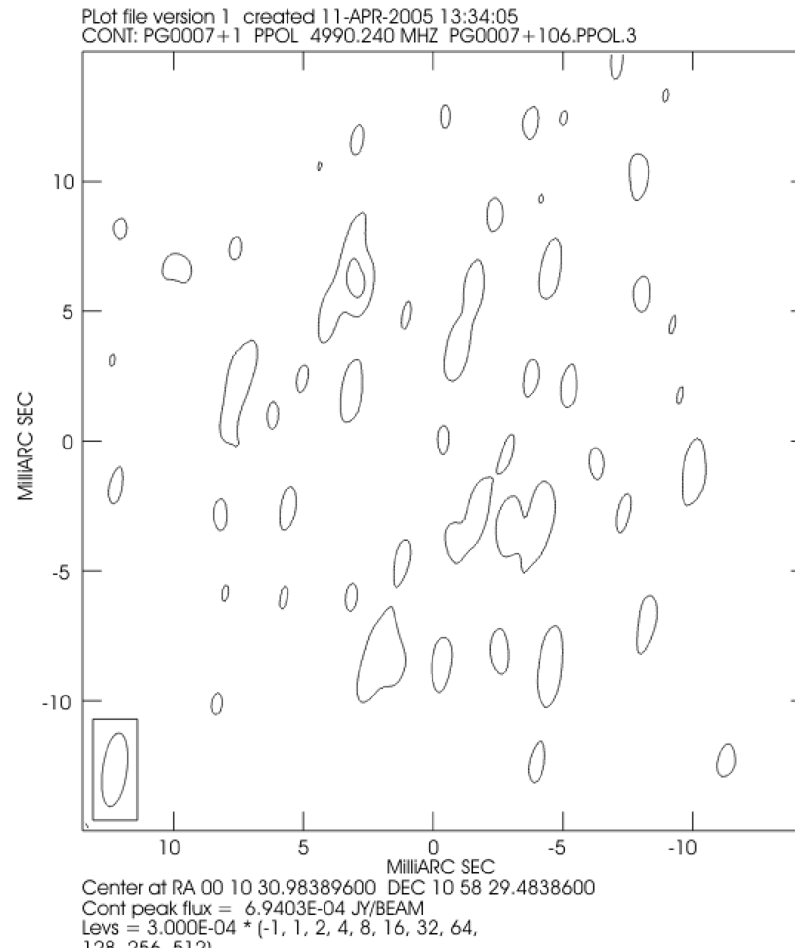
Report of superluminal component. Study polarization

The sources

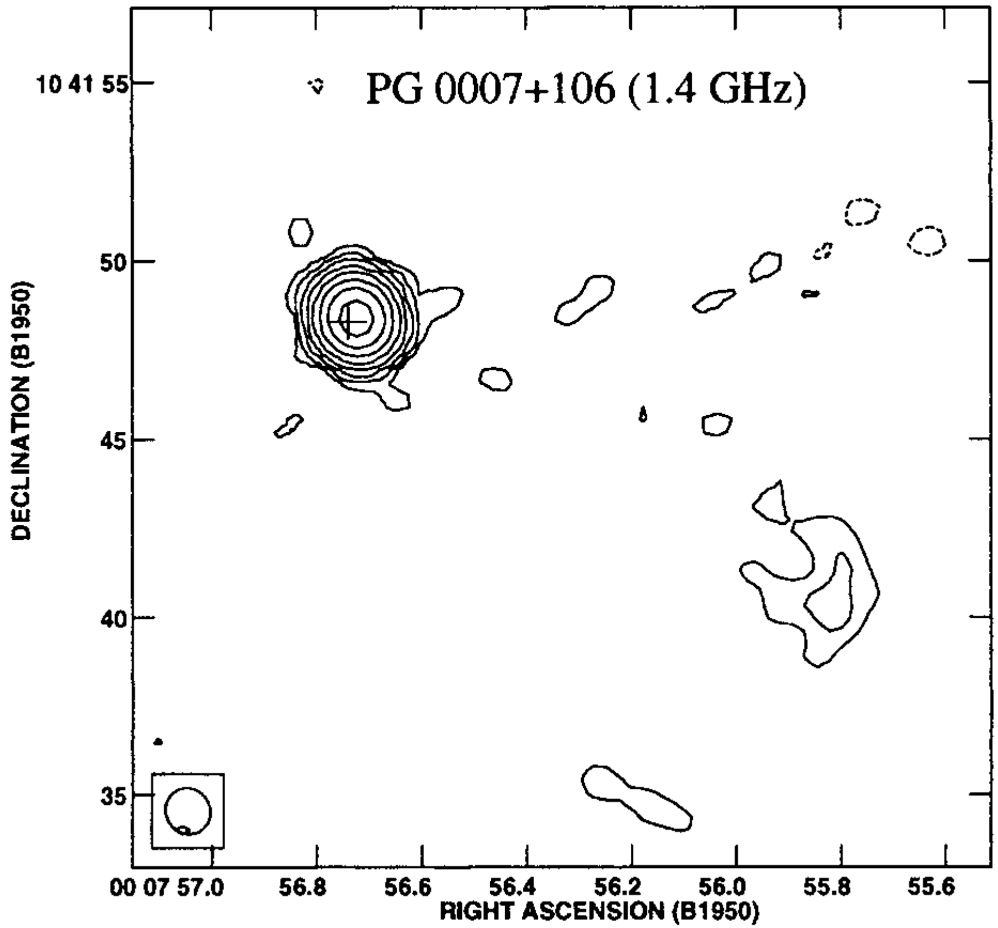
PG0007+106	z=0.089
PG1718+48	z=0.07
PG2209+18	z=1.084

PG0007+106

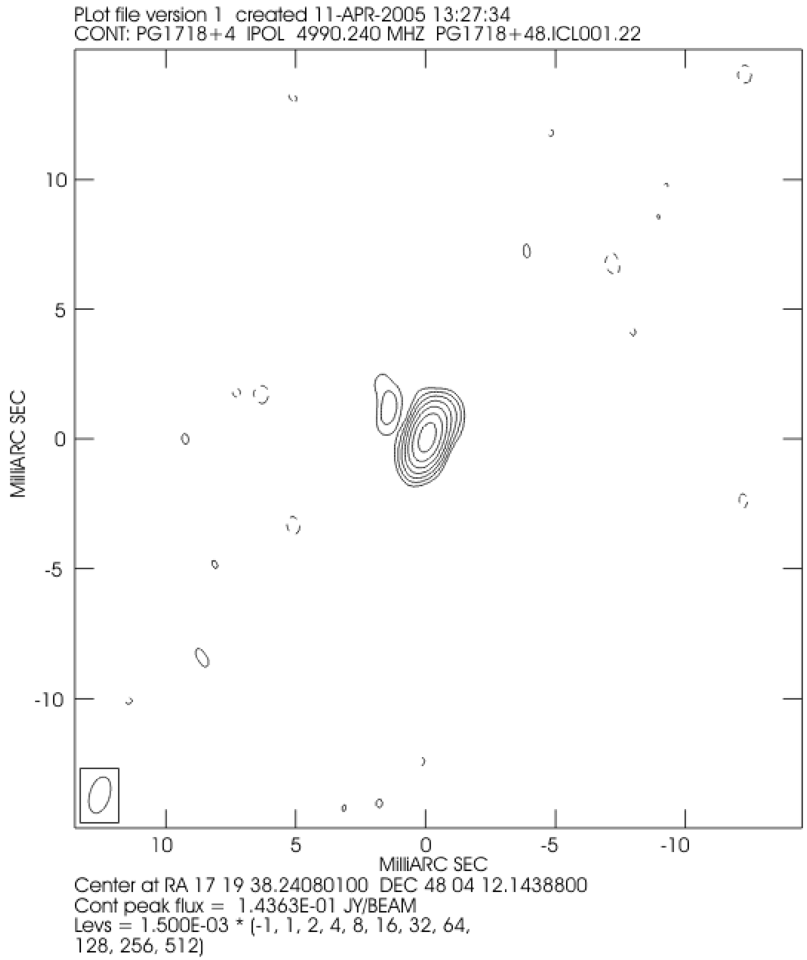

PLot file version 1 created 11-APR-2005 13:33:40
CONT: PG0007+1 IPOL 4990.240 MHZ PG0007+106.ICL001.70
MilliARC SEC
MilliARC SEC
10
5
0
-5
-10
Center at RA 00 10 30.98389600 DEC 10 58 29.4838600
Cont peak flux = 6.4852E-01 JY/BEAM
Levs = 1.000E-03 * (-1, 1, 2, 4, 8, 16, 32, 64,
128, 256, 512)

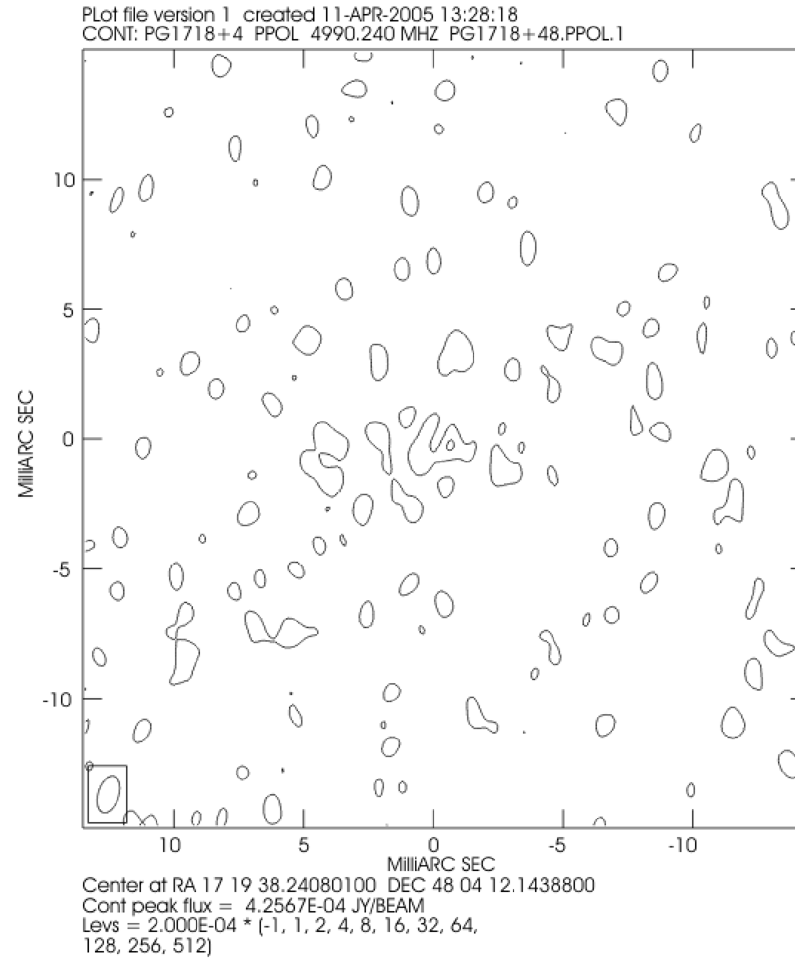

PLot file version 1 created 11-APR-2005 13:34:05
CONT: PG0007+1 PPOL 4990.240 MHZ PG0007+106.PPOL.3
MilliARC SEC
MilliARC SEC
10
5
0
-5
-10
Center at RA 00 10 30.98389600 DEC 10 58 29.4838600
Cont peak flux = 6.9403E-04 JY/BEAM
Levs = 3.000E-04 * (-1, 1, 2, 4, 8, 16, 32, 64,
128, 256, 512)

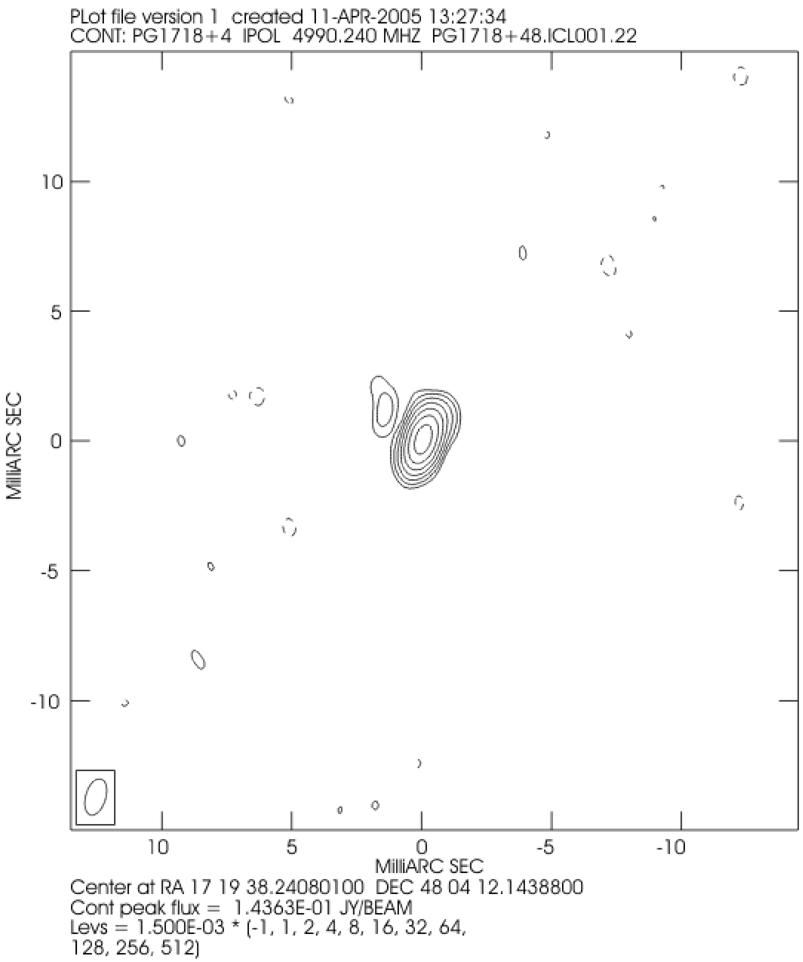
Kukula et al. 1998

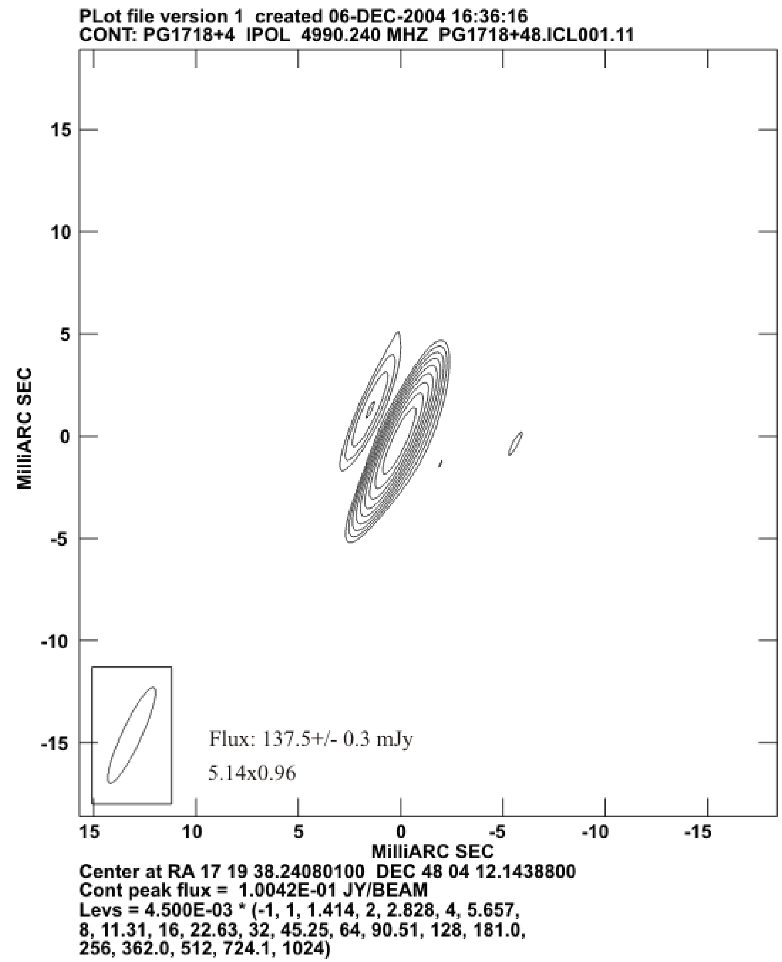


PG1718+48


PLot file version 1 created 11-APR-2005 13:27:34
CONT: PG1718+4 IPOL 4990.240 MHZ PG1718+48.ICL001.22
MilliARC SEC
MilliARC SEC
10
5
0
-5
-10
Center at RA 17 19 38.24080100 DEC 48 04 12.1438800
Cont peak flux = 1.4363E-01 JY/BEAM
Levs = 1.500E-03 * (-1, 1, 2, 4, 8, 16, 32, 64,
128, 256, 512)

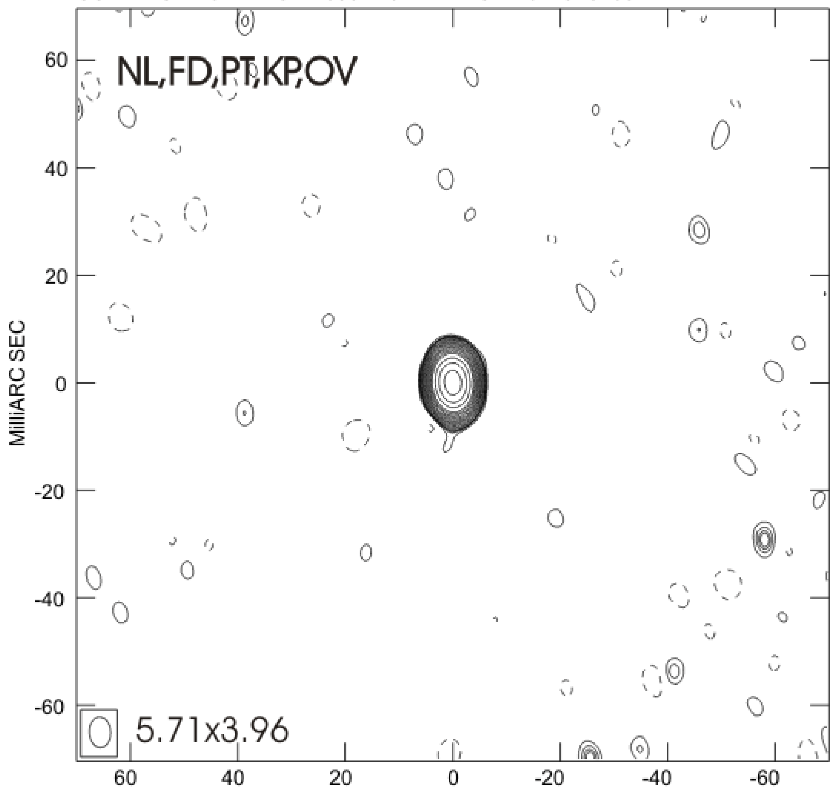

PLot file version 1 created 11-APR-2005 13:28:18
CONT: PG1718+4 PPOL 4990.240 MHZ PG1718+48.PPOL.1
MilliARC SEC
MilliARC SEC
10
5
0
-5
-10
Center at RA 17 19 38.24080100 DEC 48 04 12.1438800
Cont peak flux = 4.2567E-04 JY/BEAM
Levs = 2.000E-04 * (-1, 1, 2, 4, 8, 16, 32, 64,
128, 256, 512)


PLot file version 1 created 11-APR-2005 13:27:34
CONT: PG1718+4 IPOL 4990.240 MHZ PG1718+48.ICL001.22
MilliARC SEC
MilliARC SEC
Center at RA 17 19 38.24080100 DEC 48 04 12.1438800
Cont peak flux = 1.4363E-01 JY/BEAM
Levs = 1.500E-03 * (-1, 1, 2, 4, 8, 16, 32, 64,
128, 256, 512)

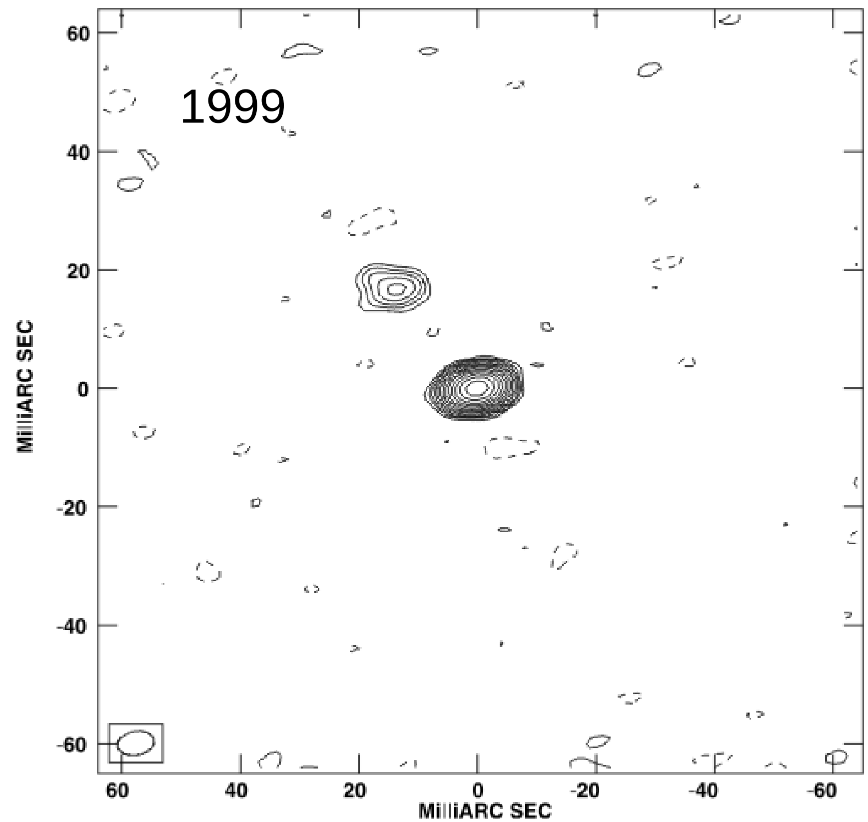

PLot file version 1 created 06-DEC-2004 16:36:16
CONT: PG1718+4 IPOL 4990.240 MHZ PG1718+48.ICL001.11
MilliARC SEC
Flux: 137.5+/- 0.3 mJy
5.14x0.96
MilliARC SEC
Center at RA 17 19 38.24080100 DEC 48 04 12.1438800
Cont peak flux = 1.0042E-01 JY/BEAM
Levs = 4.500E-03 * (-1, 1, 1.414, 2, 2.828, 4, 5.657,
8, 11.31, 16, 22.63, 32, 45.25, 64, 90.51, 128, 181.0,
256, 362.0, 512, 724.1, 1024)

Caccianiga et al. 2001

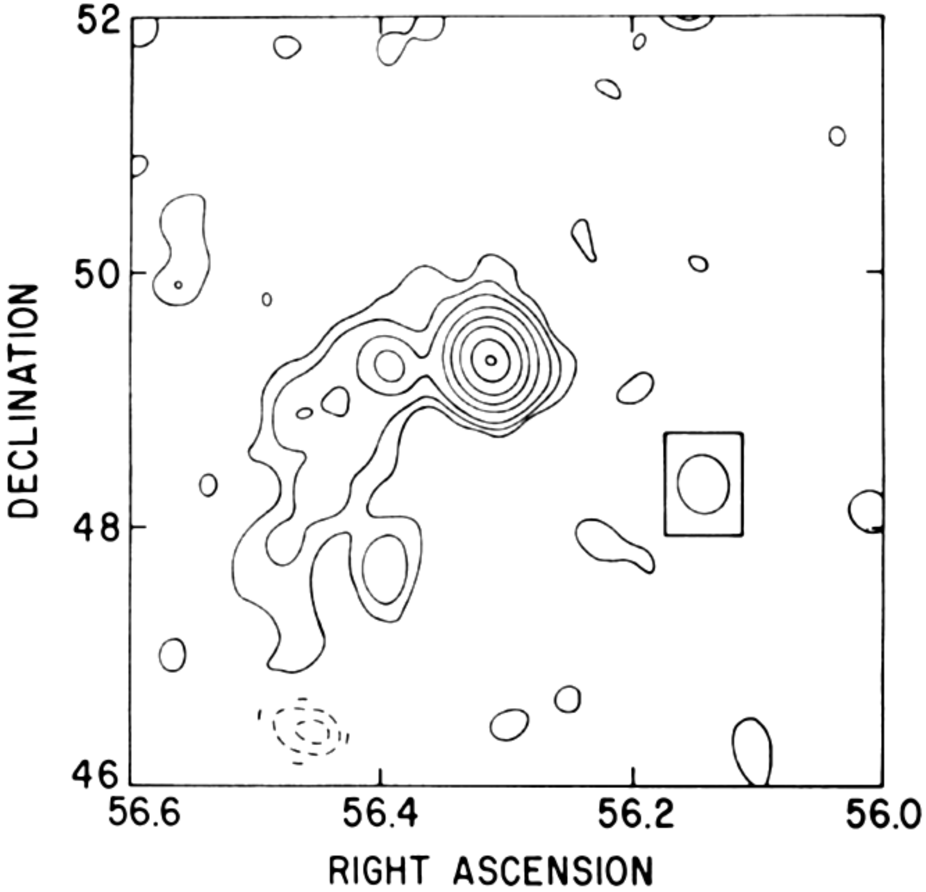
PLot file version 1 created 07-JUN-2005 16:07:41
CONT: PG1718+4 IPOL 4990.240 MHZ PG1718+48.ICL001.21



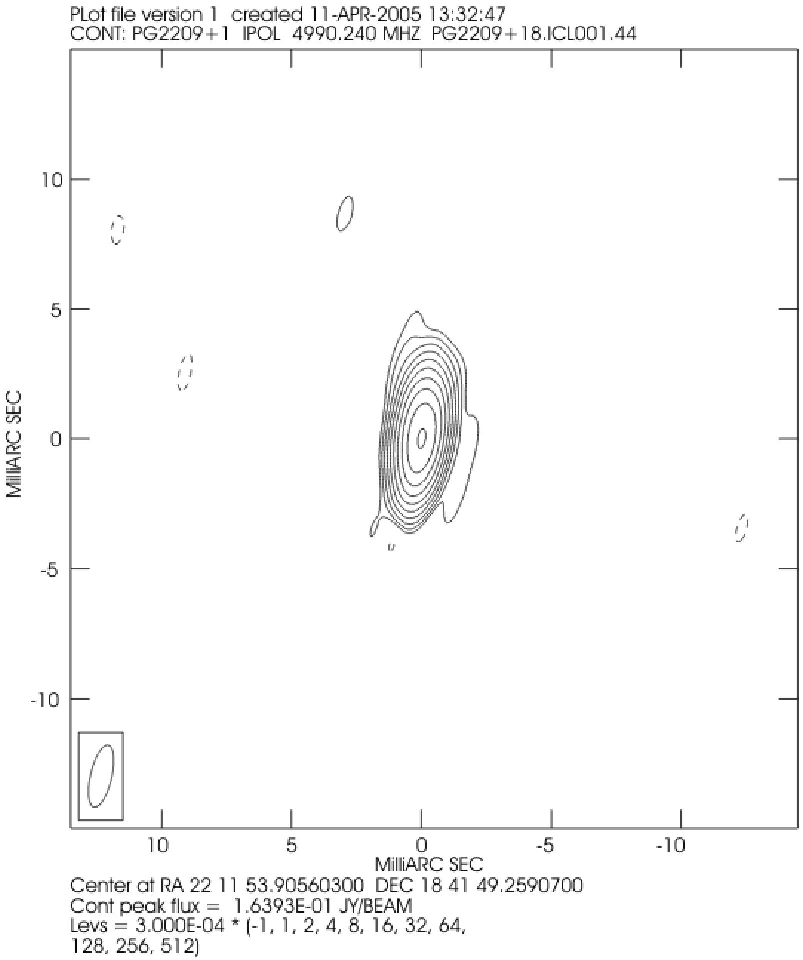
Center at RA 17 19 38.2408010 DEC 48 04 12.143880
Cont peak flux = 1.2879E-01 JY/BEAM
Levs = 4.000E-05 * (-2.50, 2.500, 4, 5, 5.600, 8, 11.30, 16, 23, 32, 45, 64, 90, 128, 181, 256, 512, 1024, 2048)

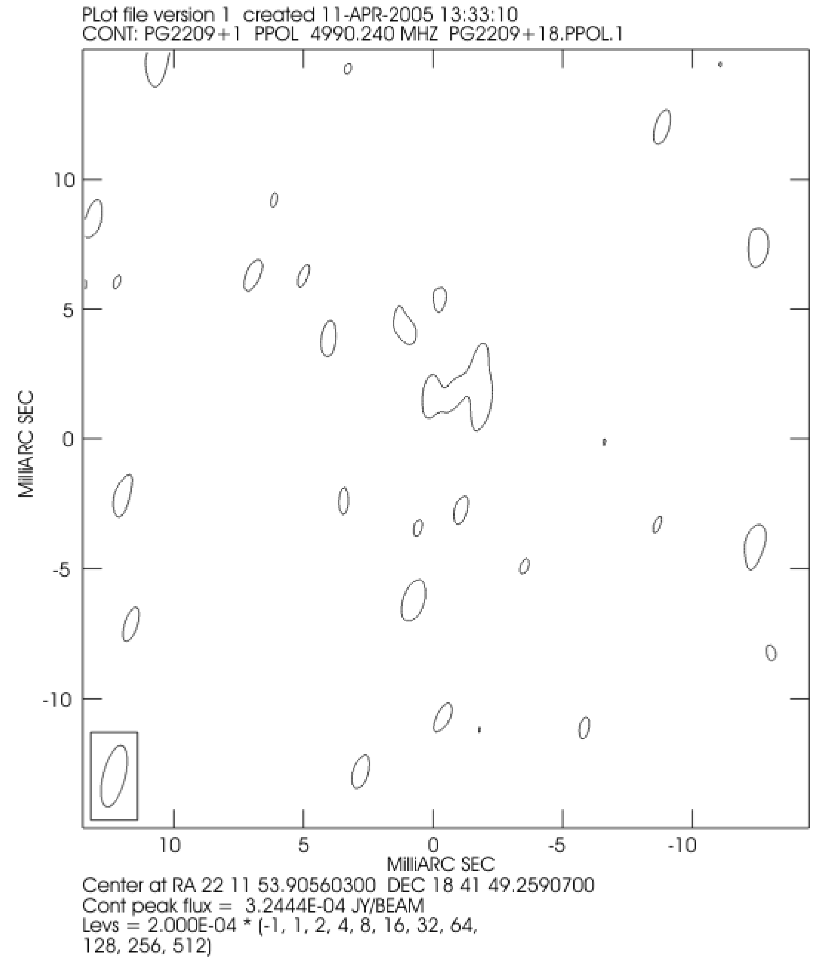


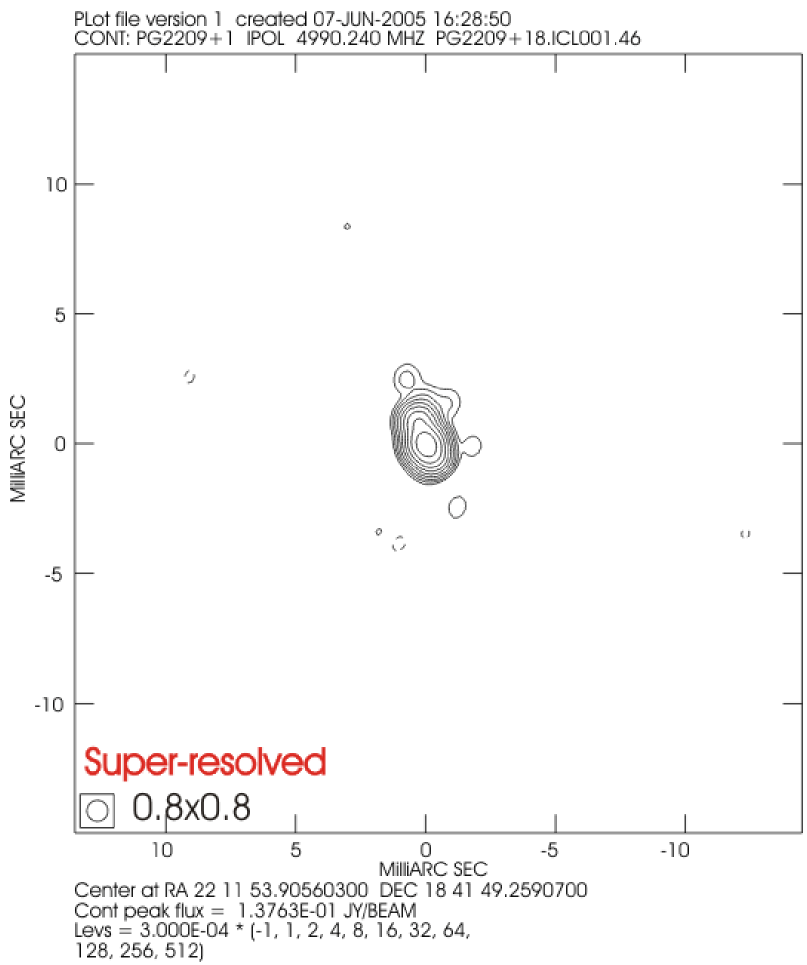
Puschell et al. 1986



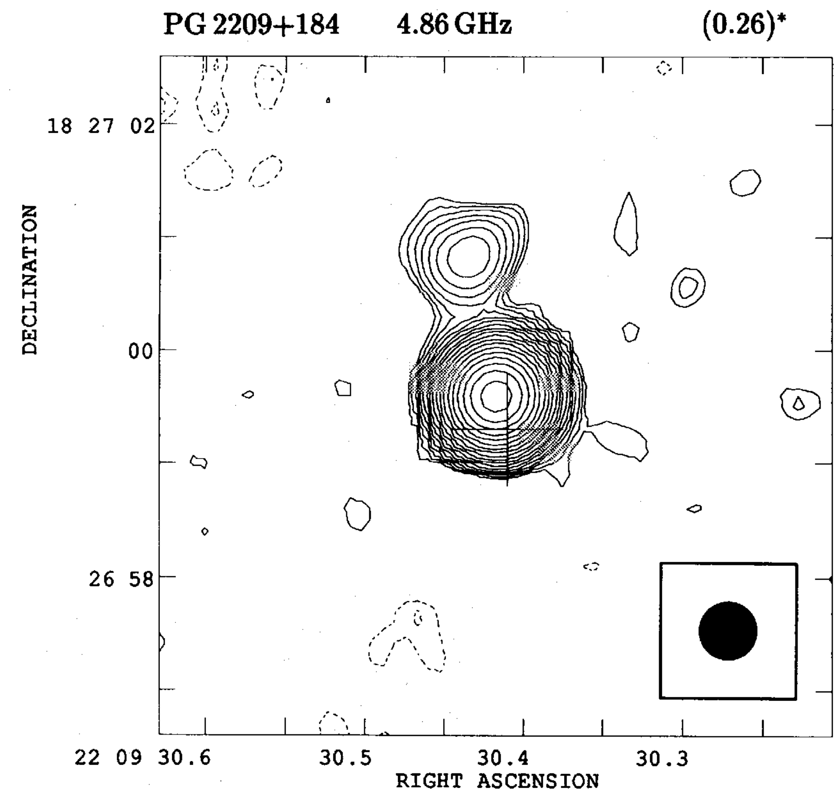
PG2209+18


PLot file version 1 created 11-APR-2005 13:32:47
CONT: PG2209+1 IPOL 4990.240 MHZ PG2209+18.ICL001.44
MilliARC SEC
10
5
0
-5
-10
Center at RA 22 11 53.90560300 DEC 18 41 49.2590700
Cont peak flux = 1.6393E-01 JY/BEAM
Levs = 3.000E-04 * (-1, 1, 2, 4, 8, 16, 32, 64,
128, 256, 512)

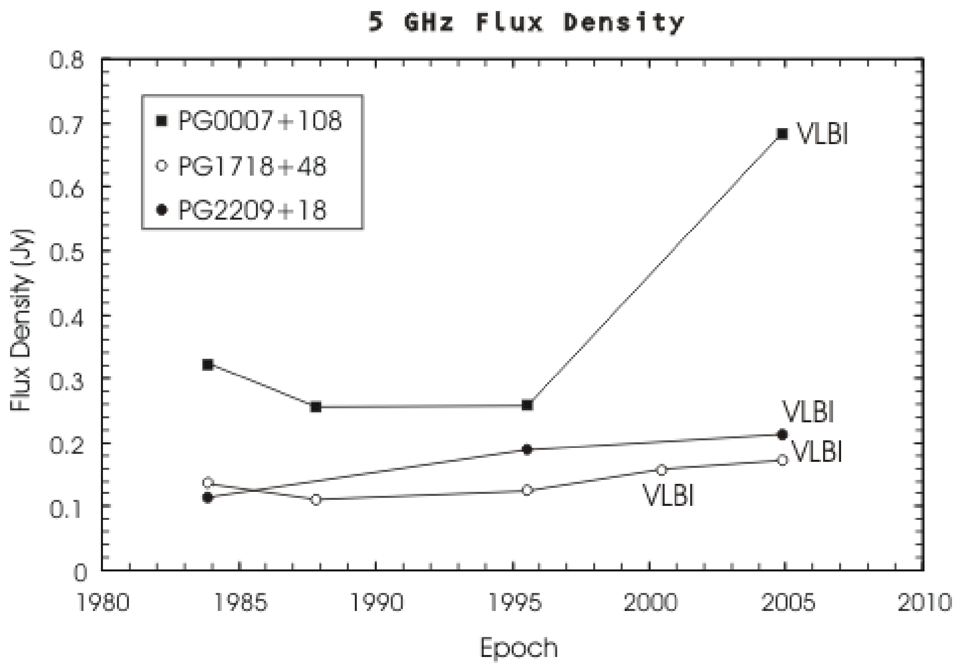

PLot file version 1 created 11-APR-2005 13:33:10
CONT: PG2209+1 PPOL 4990.240 MHZ PG2209+18.PPOL.1
MilliARC SEC
10
5
0
-5
-10
Center at RA 22 11 53.90560300 DEC 18 41 49.2590700
Cont peak flux = 3.2444E-04 JY/BEAM
Levs = 2.000E-04 * (-1, 1, 2, 4, 8, 16, 32, 64,
128, 256, 512)



Miller et al. 1993



Flux


5 GHz Flux Density
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Flux Density (Jy)
PG0007+108
PG1718+48
PG2209+18
VLBI
VLBI
VLBI
VLBI
1980
1985
1990
1995
2000
2005
2010
Epoch

Summary

- No detectible polarization at 5GHz
- Tentative evidence of a component NE of the core in PG 1718+48. If real, it shows no evidence of motion. Pc-scale jet PA different from VLA scale. Apparent curvature due to independent components released at different angles?
- PG 2209+18 shows extended emission N-NE from the core. In accordance with VLA structure.
- PG0007+108 unresolved at 5 GHz

Future work

- Higher frequency observations (15, 22, 43 GHz) (?)
- Check previous observation (43GHz).

ENIGMA 5th meeting

13 – 17 June, 2005

Neubrandenburg

High-frequency, multi-wavelength VLBI observations of BL Lac objects *(Task 4)*

Vladislavs Bezrukovs

Cork Institute of Technology,

Irish team

- Kuhr and Schmidt sample of BL Lac objects > 1 Jy at 5 GHz (K&S, 1990)

- All 34 objects in Kuhr & Schmidt BL Lac sample were observed earlier with VLBA at 15 GHz, 8.4 GHz and 5 GHz (February 1997 or June 1999)

- My project:

Analyze VLBA data for this sample at 43 GHz, 22 GHz and 15 GHz (May 2002, August 2002, March 2003, August 2004)

- Preliminary calibration and D-term calibration finished for:
  May 2002
  August 2002 - at all 3 frequencies
  August 2004

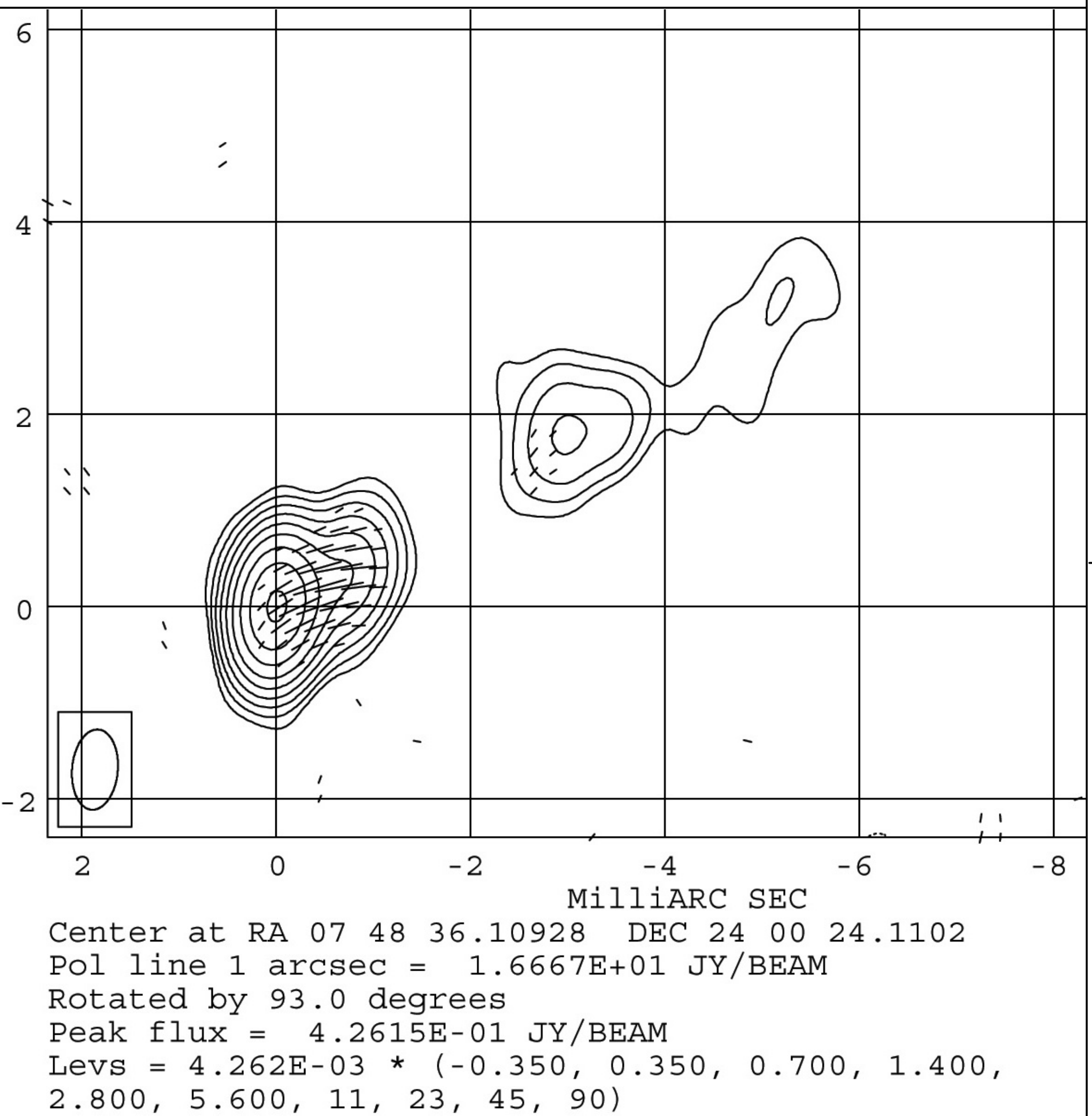
- Polarization angle calibration partly done;

- Maps made for about 20 sources at 22 GHz;

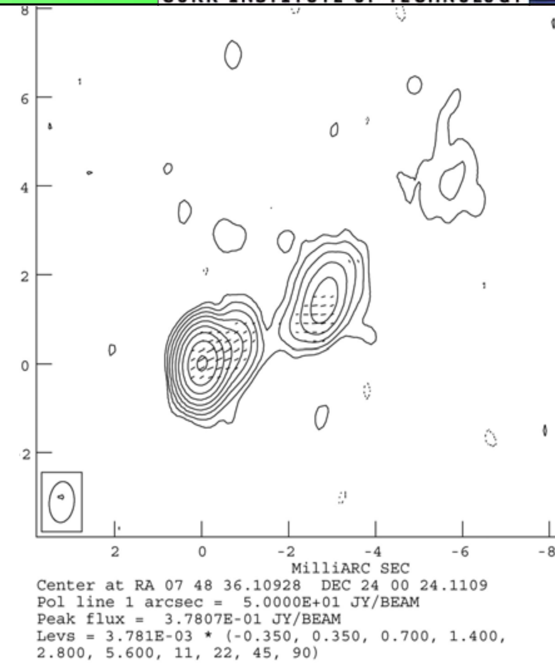
- A few have maps at 2 or all 3 frequencies.

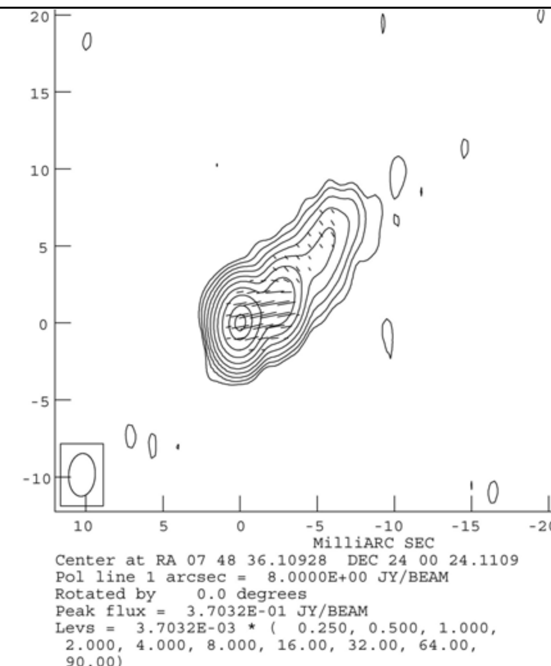
0745+241

15285.459 MHZ (May 2002)



15285.459 MHZ (February 1997)

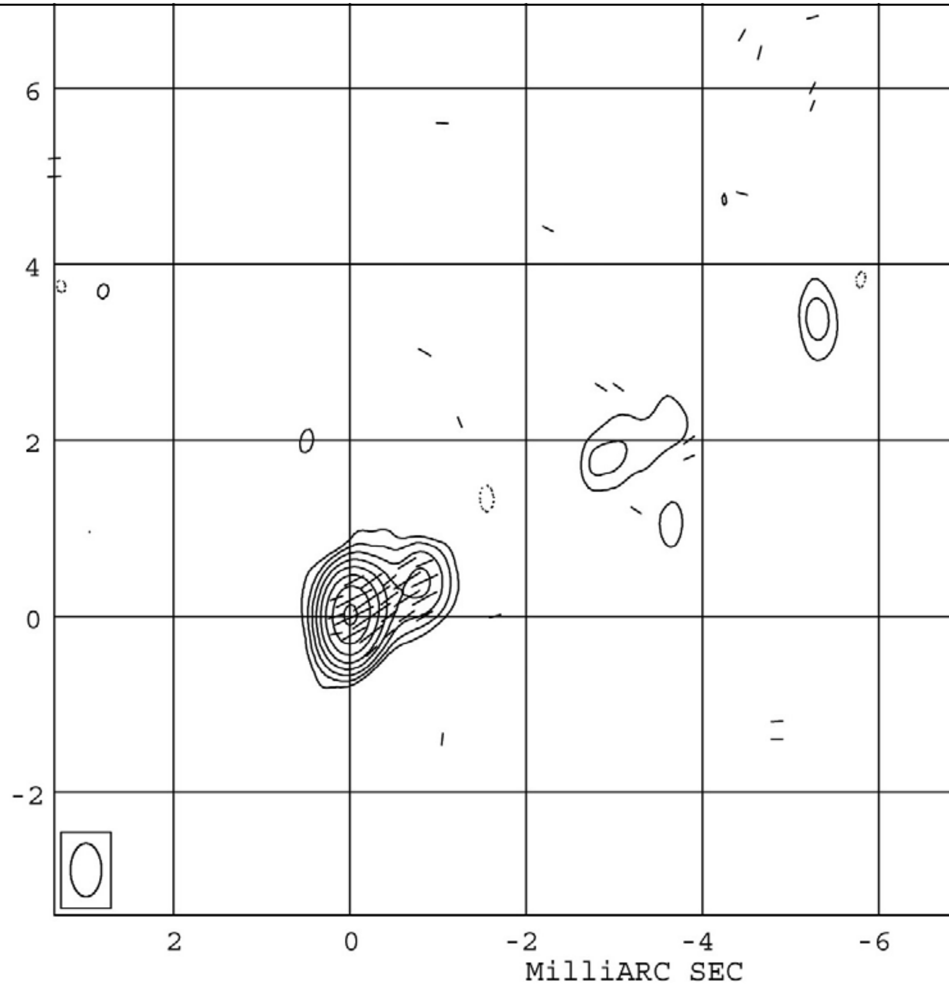




4971.490 MHZ (February 1997)

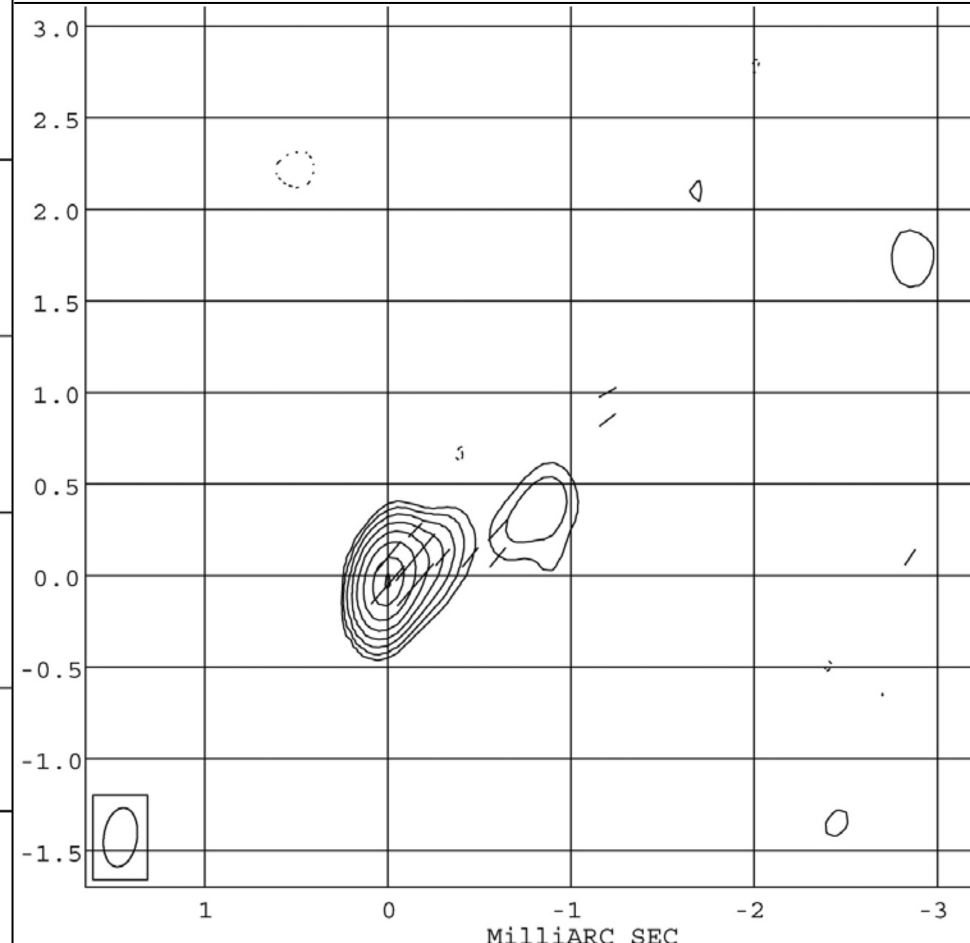
0745+241

22235.459 MHZ (May 2002)



Center at RA 07 48 36.10928 DEC 24 00 24.1102
Pol line 1 arcsec = 1.6667E+01 JY/BEAM
Rotated by 60.0 degrees
Peak flux = 4.1539E-01 JY/BEAM
Levs = 4.154E-03 * (-0.700, 0.700, 1.400, 2.800, 5.600, 11, 22, 45, 90)

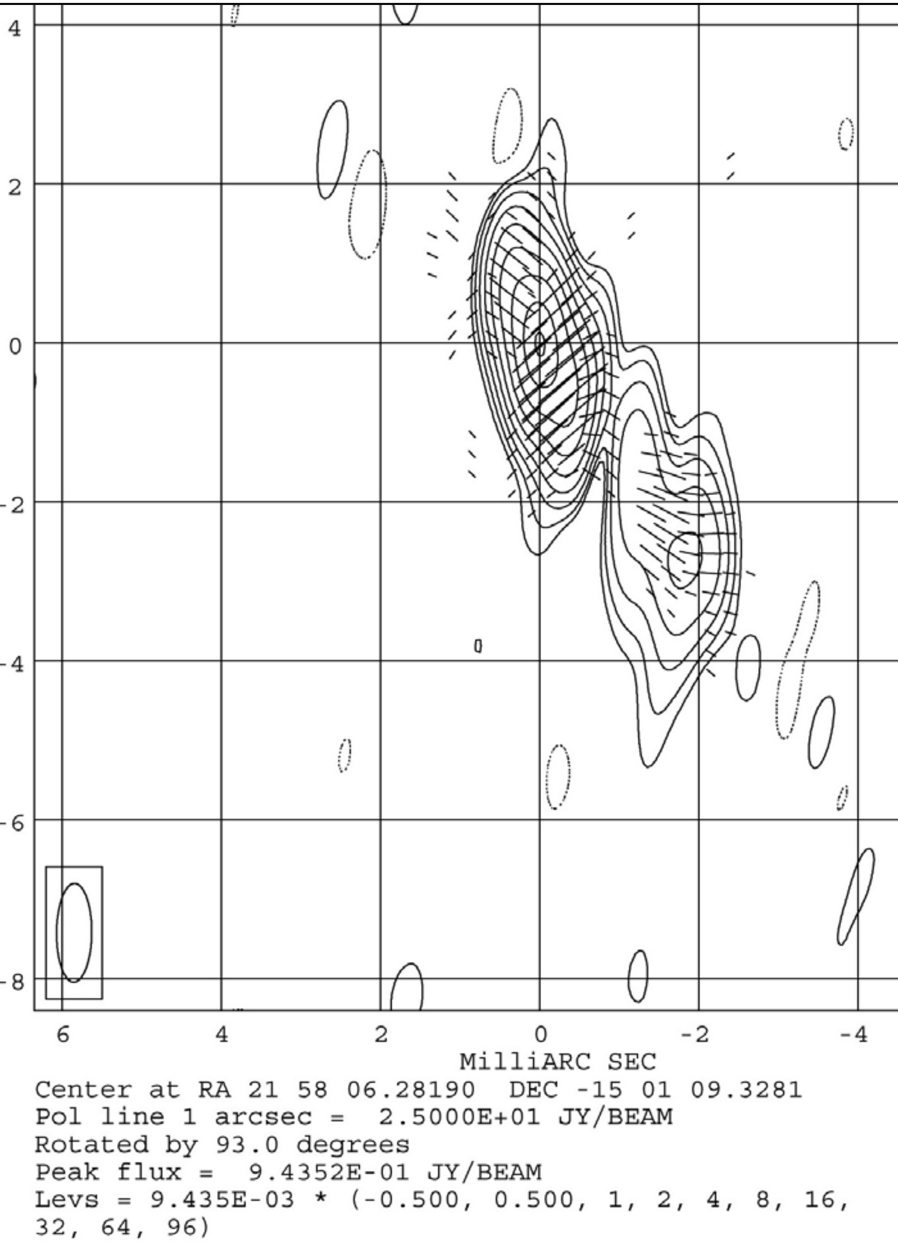
43135.459 MHZ (May 2002)



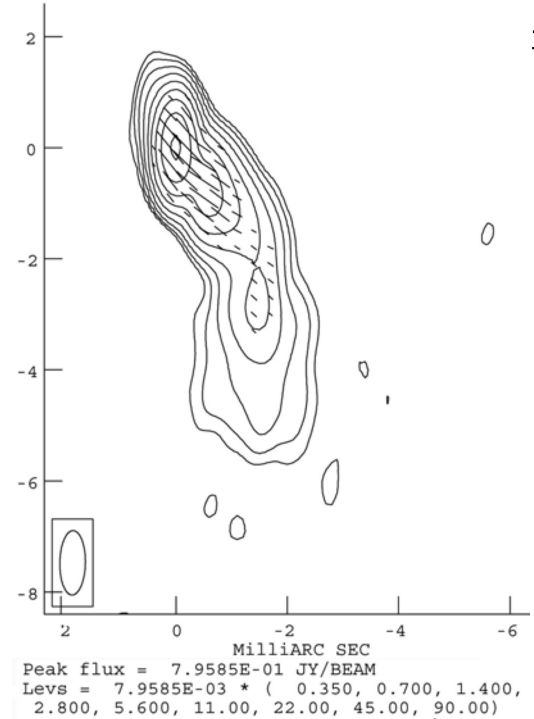
Center at RA 07 48 36.10928 DEC 24 00 24.1102
Pol line 1 arcsec = 2.5000E+01 JY/BEAM
Rotated by 96.0 degrees
Peak flux = 3.1845E-01 JY/BEAM
Levs = 3.184E-03 * (-1, 1, 2, 4, 8, 16, 32, 64, 96)

2155-152

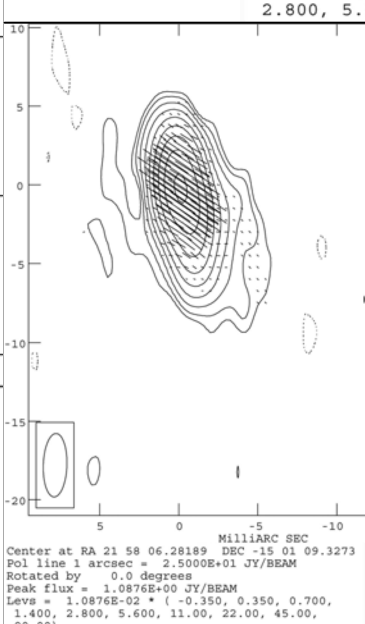
15285.459 MHZ (May 2002)



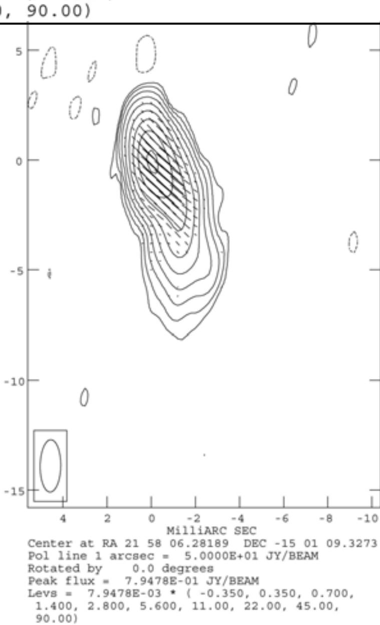
15285.459 MHZ (February 1997)



4971.490 MHZ (February 1997)

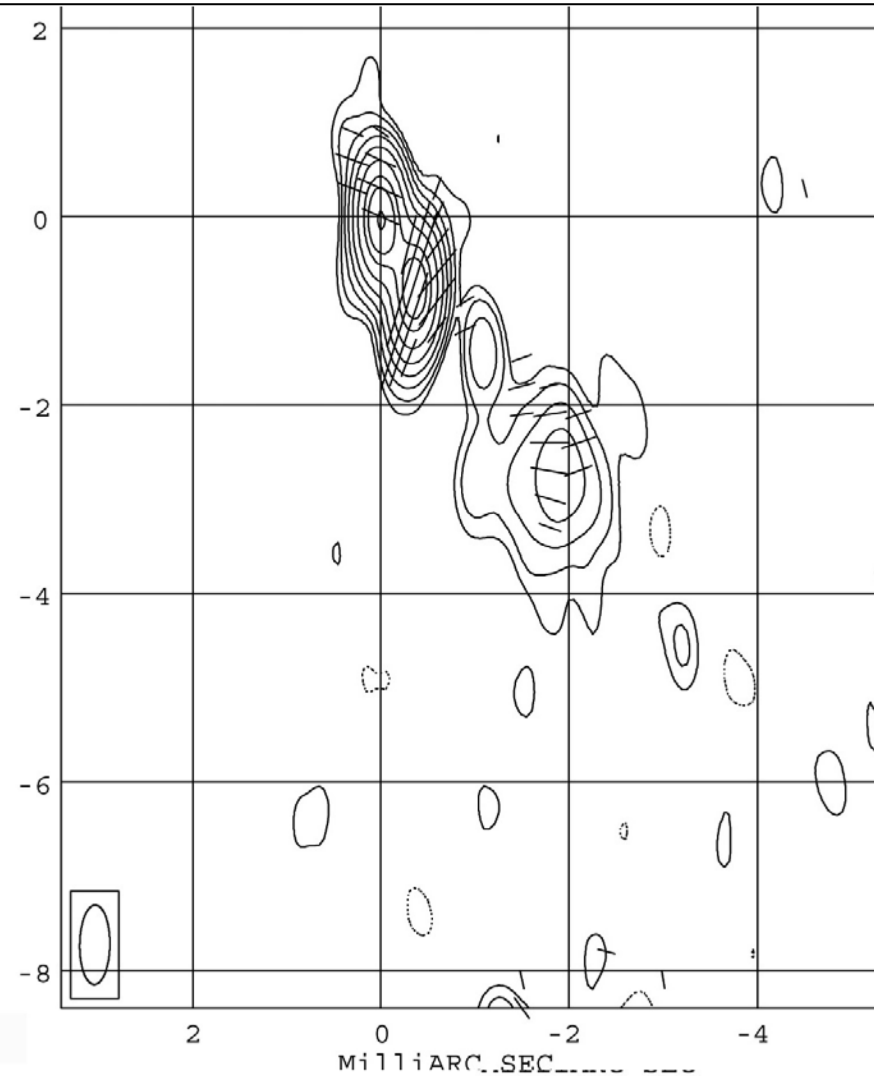


8405.490 MHZ (February 1997)



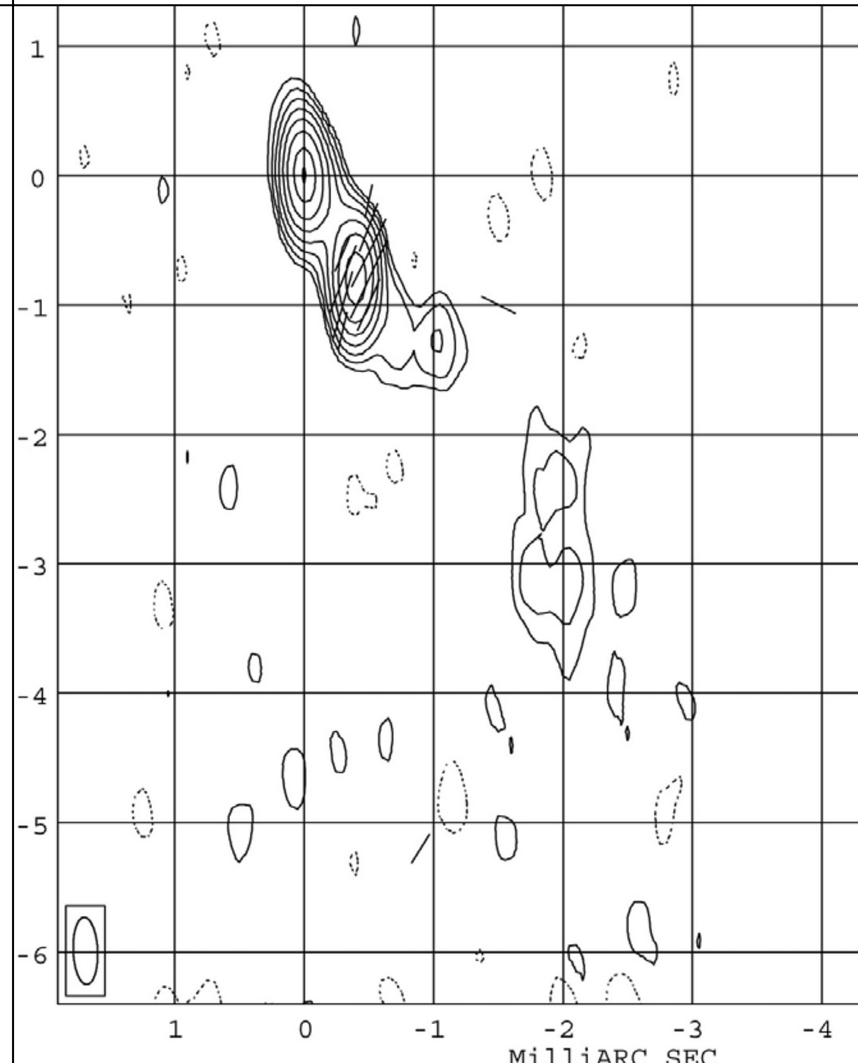
2155-152

22235.459 MHZ (May 2002)



Center at RA 21 58 06.28190 DEC -15 01 09.3281
Pol line 1 arcsec = 1.6667E+01 JY/BEAM
Rotated by 25.0 degrees
Peak flux = 5.8296E-01 JY/BEAM
Levs = 5.830E-03 * (-0.700, 0.700, 1.400, 2.800, 5.600, 11, 23, 45, 64, 96)

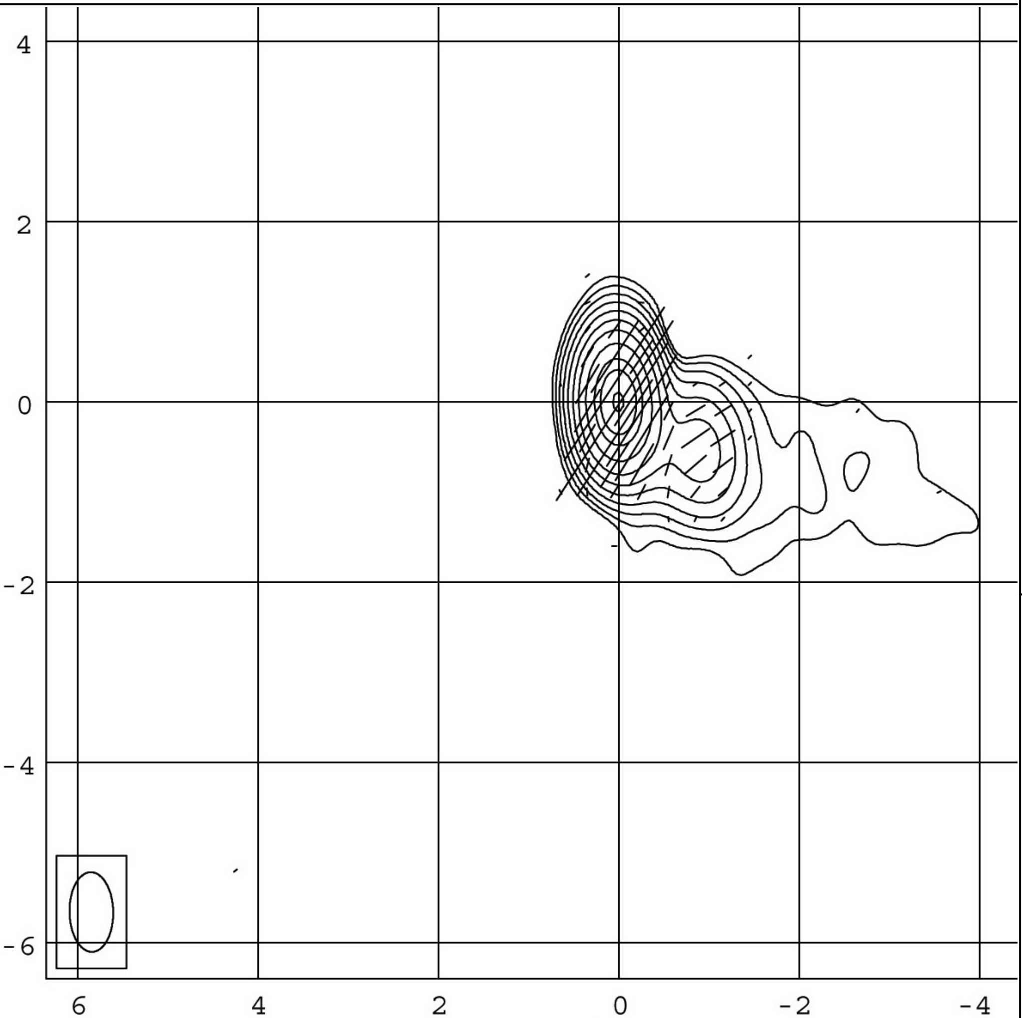
43135.459 MHZ (May 2002)



Center at RA 21 58 06.28190 DEC -15 01 09.3281
Pol line 1 arcsec = 1.6667E+01 JY/BEAM
Rotated by 96.0 degrees
Peak flux = 3.4838E-01 JY/BEAM
Levs = 3.484E-03 * (-1, 1, 2, 4, 8, 16, 32, 64, 96)

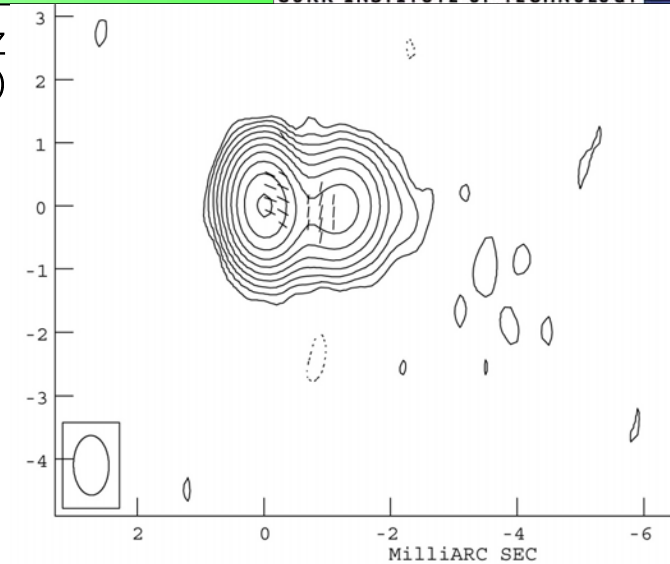
OJ287 (0851+202)

15285.459 MHZ (August 2004)

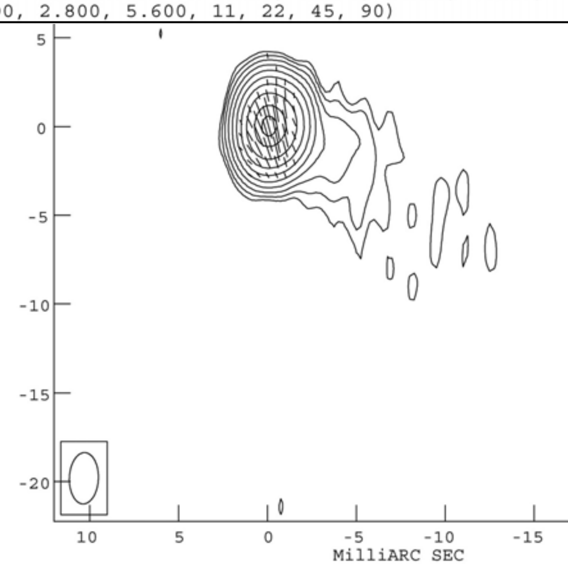


Center at RA 08 54 48.87492 DEC 20 06 30.6409
Pol line 1 arcsec = 5.0000E+01 JY/BEAM
Rotated by 93.0 degrees
Peak flux = 2.4172E+00 JY/BEAM
Levs = 2.417E-02 * (-0.170, 0.170, 0.350, 0.700, 1.400, 2.800, 5.600, 11, 23, 45, 64, 96)

15285.459 MHZ
(February 1997)



Center at RA 08 54 48.87493 DEC 20 06 30.6415
Pol line 1 arcsec = 5.0000E+01 JY/BEAM
Peak flux = 9.9563E-01 JY/BEAM
Levs = 9.956E-03 * (-0.170, 0.170, 0.350, 0.700, 1.400, 2.800, 5.600, 11, 22, 45, 90)



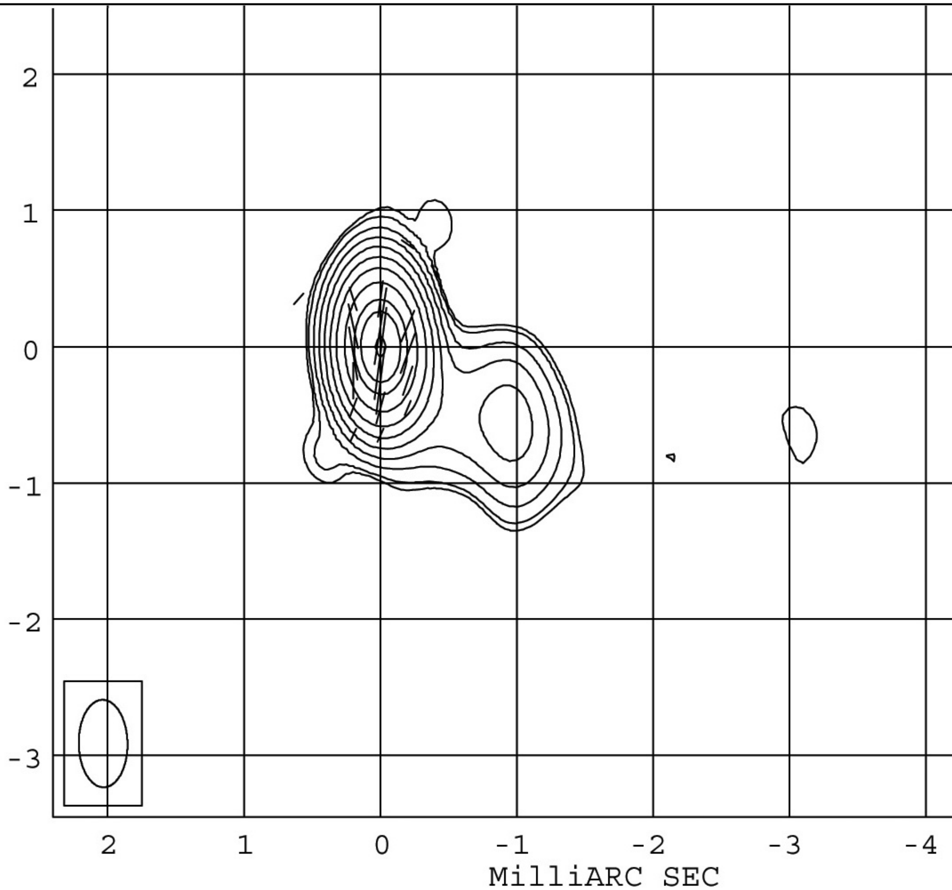
Center at RA 08 54 48.87493 DEC 20 06 30.6415
Pol line 1 arcsec = 1.0000E+01 JY/BEAM
Rotated by 0.0 degrees
Peak flux = 9.2895E-01 JY/BEAM
Levs = 9.2895E-03 * (0.250, 0.500, 1.000, 2.000, 4.000, 8.000, 16.00, 32.00, 64.00,

4971.490 MHZ
(February 1997)

OJ287 (0851+202)

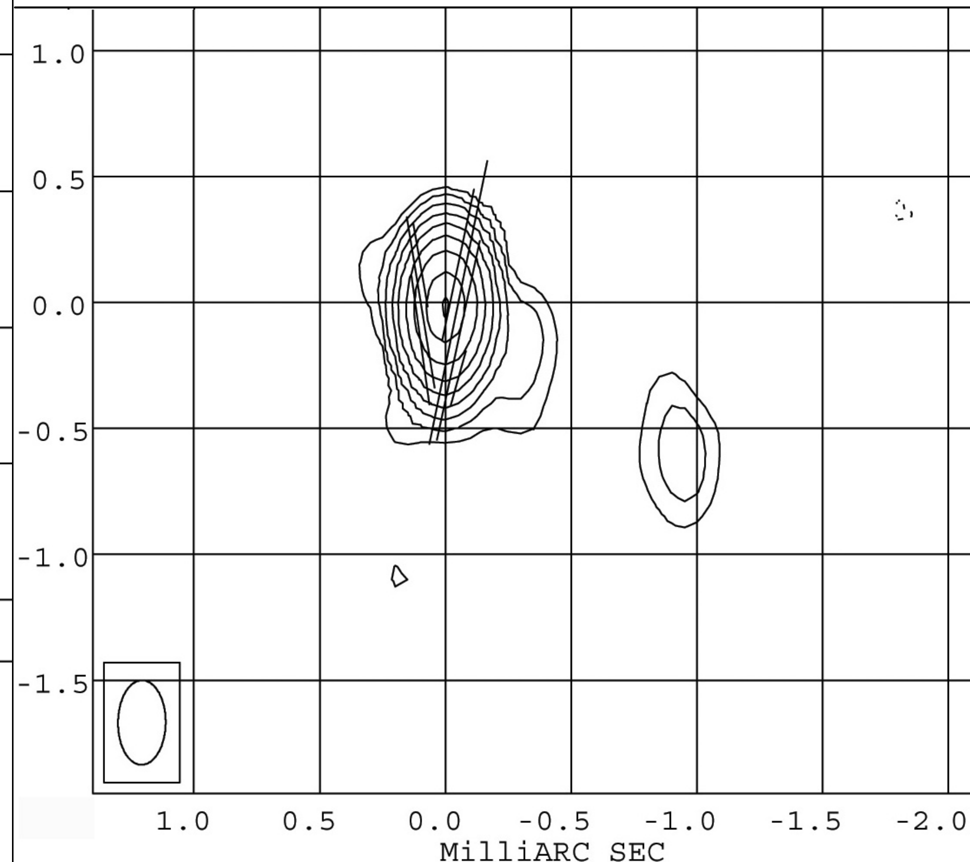
CORK INSTITUTE OF TECHNOLOGY

22235.459 MHZ (August 2004)



Center at RA 08 54 48.87492 DEC 20 06 30.6409
Pol line 1 arcsec = 2.0000E+02 JY/BEAM
Rotated by 60.0 degrees
Peak flux = 2.9933E+00 JY/BEAM
Levs = 2.993E-02 * (-0.250, 0.250, 0.350, 0.700, 1.400, 2.800, 5.600, 11, 23, 45, 64, 96)

43135.459 MHZ (August 2004)



Center at RA 08 54 48.87492 DEC 20 06 30.6409
Pol line 1 arcsec = 1.0000E+02 JY/BEAM
Rotated by 96.0 degrees
Peak flux = 3.6064E+00 JY/BEAM
Levs = 3.606E-02 * (-0.500, 0.500, 1, 2, 4, 8, 16, 32, 64, 96)

1) Finish remaining images and model fit;

2) Joint Analysis of intensity and polarization images at three frequencies.

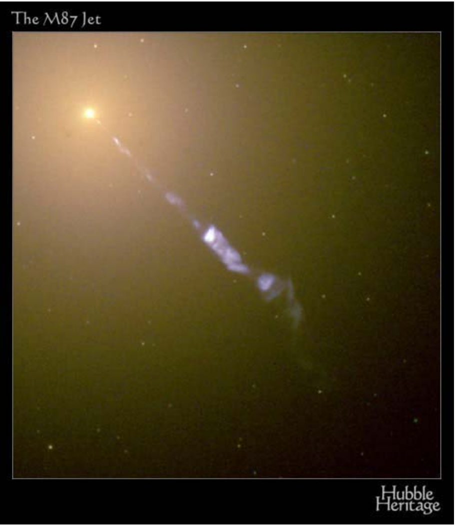
Modeling the Jet of M87

Episode 4: Magnetohydrodynamic models

José Gracia, IASA Athens
Kanaris Tsinganos, Univ Athens
Sergei Bogovalov, Moscow Ing. Phys. Institute

Enigma Meeting, 14-15 June 2005, Bornmühle

The M87 jet



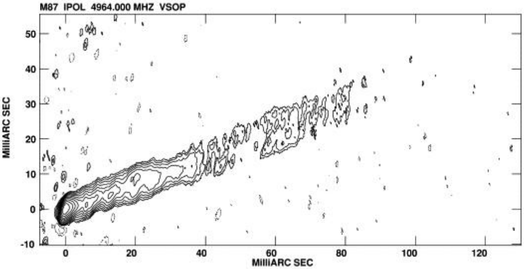
knot A: 14" $\sim$ 900pc $\sim 3 \times 10^6 \mathrm{R_g}$

well-defined jet beam inside of A

increasingly turbulent downstream

influence of environment?
$\longrightarrow$ model inside of A, only

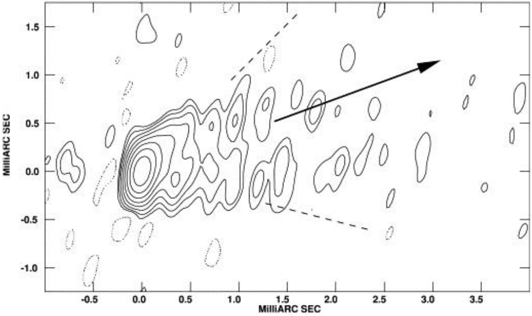
The M87 jet



6cm VSOP
Biretta et al 2002
$10\mathrm{mas} \sim 0.7\mathrm{pc} \sim 2400\mathrm{R_g}$

- "witnessing the initial formation and collimation of the jet" (Biretta et al 2002)
- slowly collimating across a scale of 1 pc

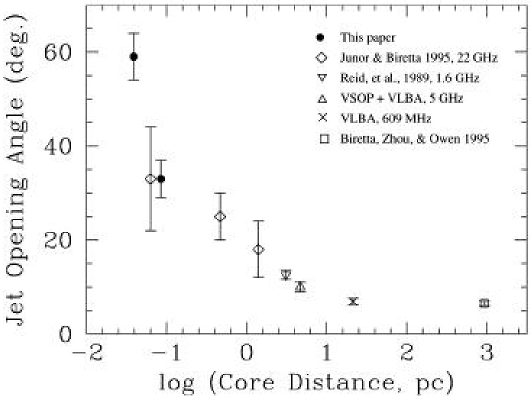
The M87 jet



7mm VSOP
Biretta et al 2002
$1\text{mas} \sim 0.07\text{pc} \sim 240\text{R}_\text{g}$

- some collimation already on 100 Rg scale (0.04 pc)
- jet must be created below 30 Rg

Opening angles



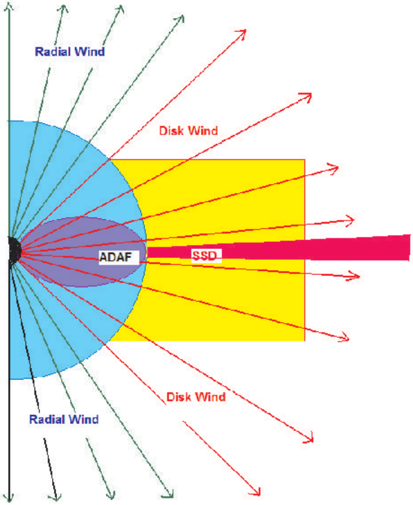
Biretta et al 2002

One-zone models

- disk wind (Blandford & Payne)
  - cold, non-relativistic MHD outflow
  - *pro*: efficient collimation (magneto-centrifugally)
  - *con*: low Γ-factors
- relativistic outflow
  - hot, relativistic MHD outflow
  - *pro*: arbitrary Γ-factors
  - *con*: inefficient collimation

How to combine advantages of both types?

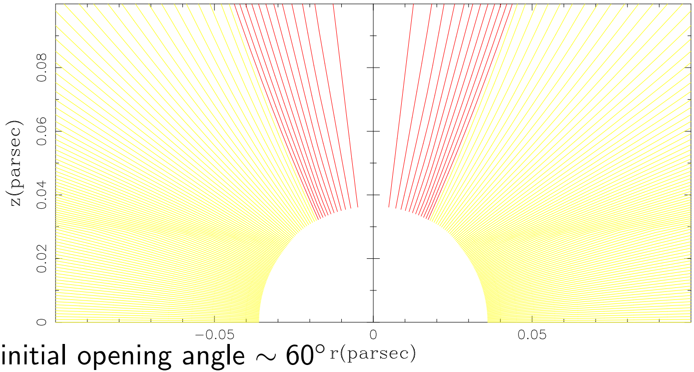
A two-zone model



Tsinganos & Bogovalov 2004

- outer cold, non-relativistic disk wind
- inner hot, relativistic outflow
- inner outflow confined by disk wind
  $\longrightarrow$ collimation

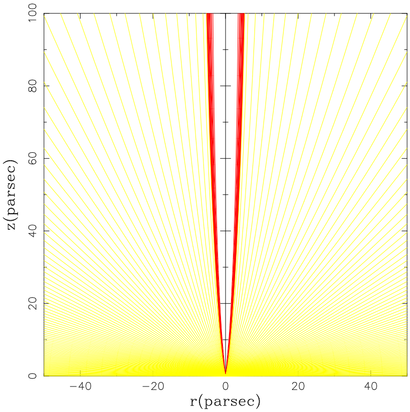
Collimation by confinement 1



initial opening angle $\sim 60^\circ$

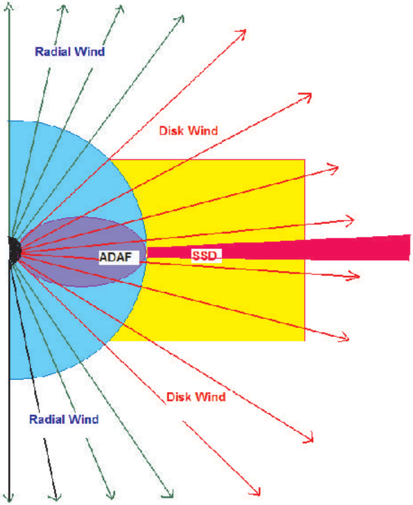
equilibrium between confiment due to disk wind pinching and inertia/pressure of inner outflow

Collimation by confinement 2



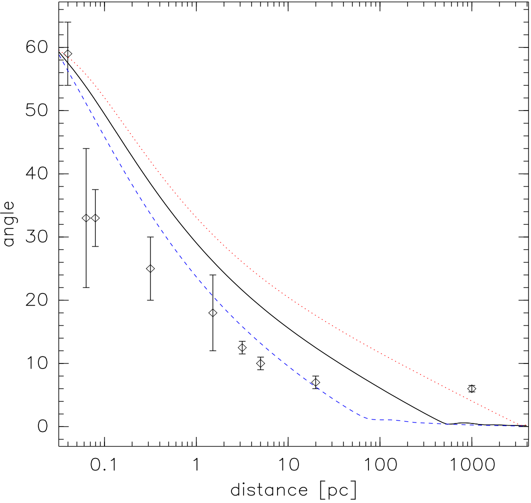
opening angle decreases over few 10 pc

Parameters of the model



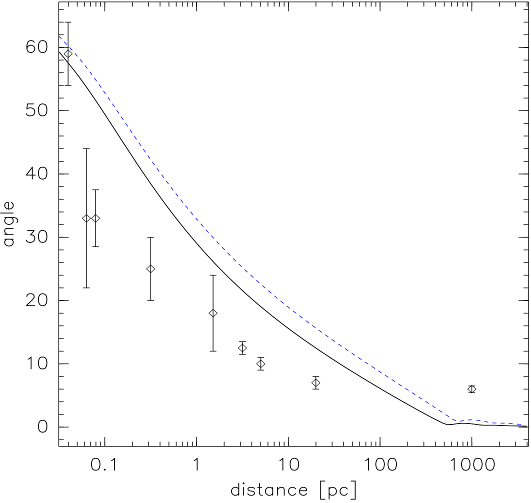
- opening angle, $\alpha = 30°$
- jet temperature, $T_{\rm jet}$
- jet velocity, $u_{\rm jet}$
- angular momentum, q_{jet}
- magnetic field, B_0
- disk wind velocity, $u_{\rm d}$

Jet temperature



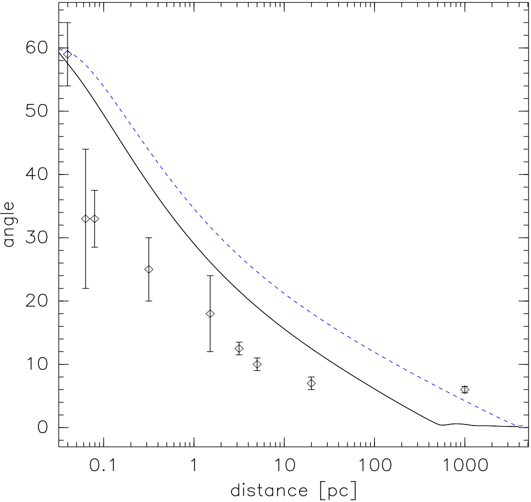
$T_{\rm jet}$:
rotation around a pivoting point at 60°
similar effect for angular momentum, $q_{\rm jet}$

Magnetic field strength



B_0:
shift along x-axis

Jet velocity



u_{jet}:
rotation and shift
superposition of T_{jet} and B_0

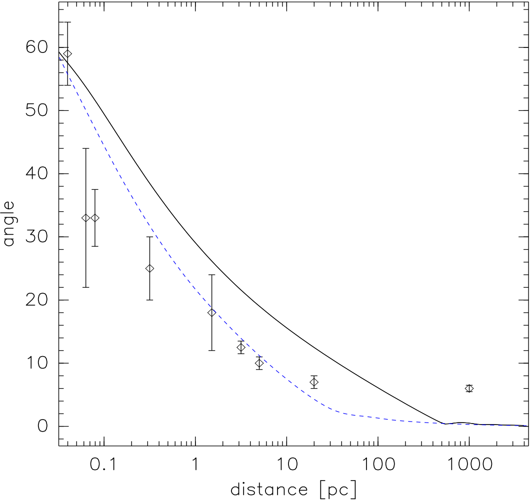
Independent parameters

In principle only 2 independent parameters

- rotation around pivoting point ($T_{\rm jet}, q_{\rm jet}, u_{\rm jet}$)
- shift along x-axis ($B_0, u_{\rm jet}$)

It seems very difficult to change the curvature

The "best fit"

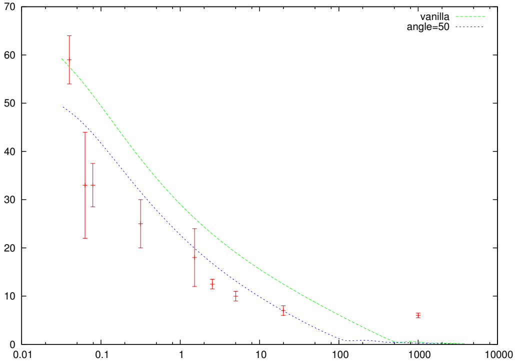


moderately relativistic:

$T_{\mathrm{jet}} \sim 1.5mc^2$

$u_{\mathrm{jet}} = 1.3c$

A better "best fit"?



change of opening angle shifts along y-axis,
formally better fit

Summary

- two-zone MHD models can fit opening angle of the M87 jet
- outer, cold disk wind
- inner, moderately relativistic outflow

But: definition of jet width

- observations: drop in brightness
- model: a specific fieldline

Comparing apples with pears?
$\longrightarrow$ need for emission maps

Outlook

- Episode 5: emission maps, polarization (thermal electrons)?
- Episode 6: non-thermal electron distribution (?)

- Episode 1-3: including the underlying accretion disk, origin of magnetic field, coupling

Stochastic particle acceleration and synchrotron self-Compton emission in TeV blazars

Krzysztof Katarzyński

Osservatorio Astronomico di Brera (OAB, Italy)

Outline

- stochastic particle acceleration as the diffusion process - momentum-diffusion equation
- stationary solution - thermal and quasi-thermal energy spectrum
- evolution without escape and injection of the particles
- influence of the injection and simultaneous escape for the evolution
- synchrotron self-Compton emission of Mrk 501
- number of free parameters in the model

The momentum-diffusion equation

Stochastic acceleration process can be described as the diffusion in the particle momentum space, where the evolution of the isotropic, homogeneous phase-space density ($f(p,t)$) is described by the momentum-diffusion equation

$$\frac{\partial f(p,t)}{\partial t} = \frac{1}{p^2}\frac{\partial}{\partial p}\left[p^2 D(p,t)\frac{\partial f(p,t)}{\partial p}\right],$$

where $p = \beta\gamma$ is the dimensionless particle momentum, $D(p,t)$ is the momentum-diffusion coefficient, γ it the particle Lorentz factor and β is the particle velocity in units of c.

Transformation of the equation

The particle number density (N [cm^{-3}]) is directly related to the phase-space density

$$N(p,t) = 4\pi p^2 f(p,t).$$

Thus, we can rewrite the equation into a following form

$$\frac{\partial N(p,t)}{\partial t} = \frac{\partial}{\partial p}\left[-A(p,t)\,N(p,t) + D(p,t)\frac{\partial N(p,t)}{\partial p}\right],$$

where

$$A(p,t) = \frac{2}{p}D(p,t),$$

describes the acceleration process.

Three more terms in the equation

In order to describe the radiative cooling and possible escape or injection of the particles we have to introduce three more terms

$$\frac{\partial N(\gamma,t)}{\partial t} = \frac{\partial}{\partial \gamma}\left[\Big(C(\gamma,t) - A(\gamma,t)\Big)N(\gamma,t) + D(\gamma,t)\frac{\partial N(\gamma,t)}{\partial \gamma}\right] - \frac{N(\gamma,t)}{t_{\rm esc}} + Q(\gamma,t).$$

Note that for the relativistic particles ($\beta \simeq 1$) the particle momentum becomes equivalent to the Lorentz factor ($p \equiv \gamma$).

The stationary solution

The stationary ($\dot{N} = 0$) analytic solution of the equation in a simplified form

$$\frac{\partial}{\partial \gamma}\left[\Big(C(\gamma) - A(\gamma)\Big) N(\gamma) + D(\gamma)\frac{\partial N(\gamma)}{\partial \gamma}\right] = 0,$$

according to Chang and Cooper (1970), is given by

$$N(\gamma) = x \ \exp\left[-\int^{\gamma} \frac{C(\gamma') - A(\gamma')}{D(\gamma')} d\gamma'\right],$$

where x is the integration constant. Note that the above equation requires that the initial energy distribution $N(\gamma, t = 0) \neq 0$

Thermal spectrum

Assuming a constant synchrotron cooling

$$C(\gamma) = C_0 \gamma^2,$$

and Fermi-like constant acceleration process

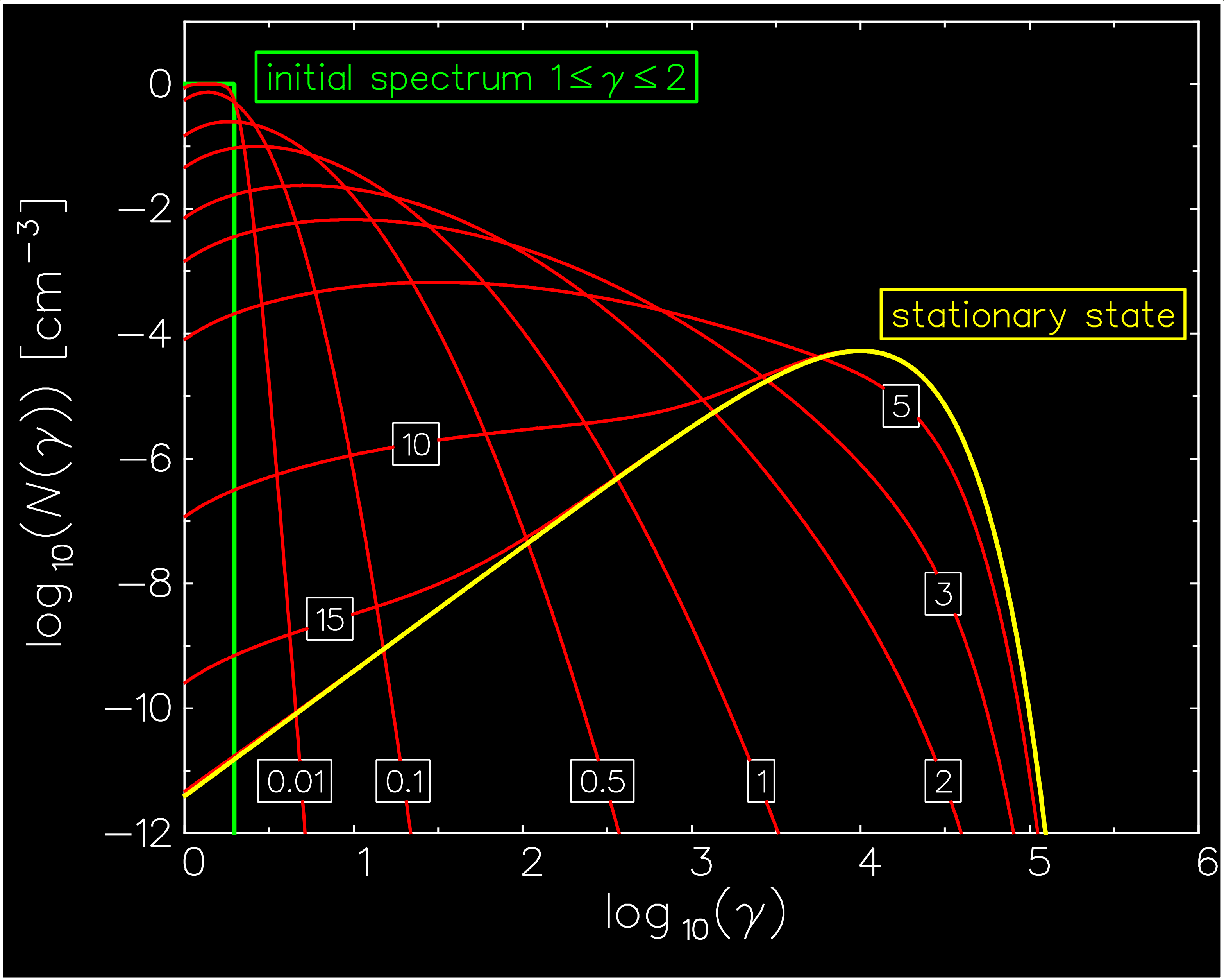
$$D(\gamma) = \frac{\chi}{2}\gamma^2 = \frac{\gamma^2}{(2t_{\mathrm{acc}})} \quad \rightarrow \quad A(\gamma) = \frac{\gamma}{t_{\mathrm{acc}}},$$

we obtain an ultrarelativistic Maxwellian distribution

$$\boxed{N(\gamma) = x\,\gamma^2\ \exp\left[-2C_0 t_{\mathrm{acc}}(\gamma - 1)\right]}$$

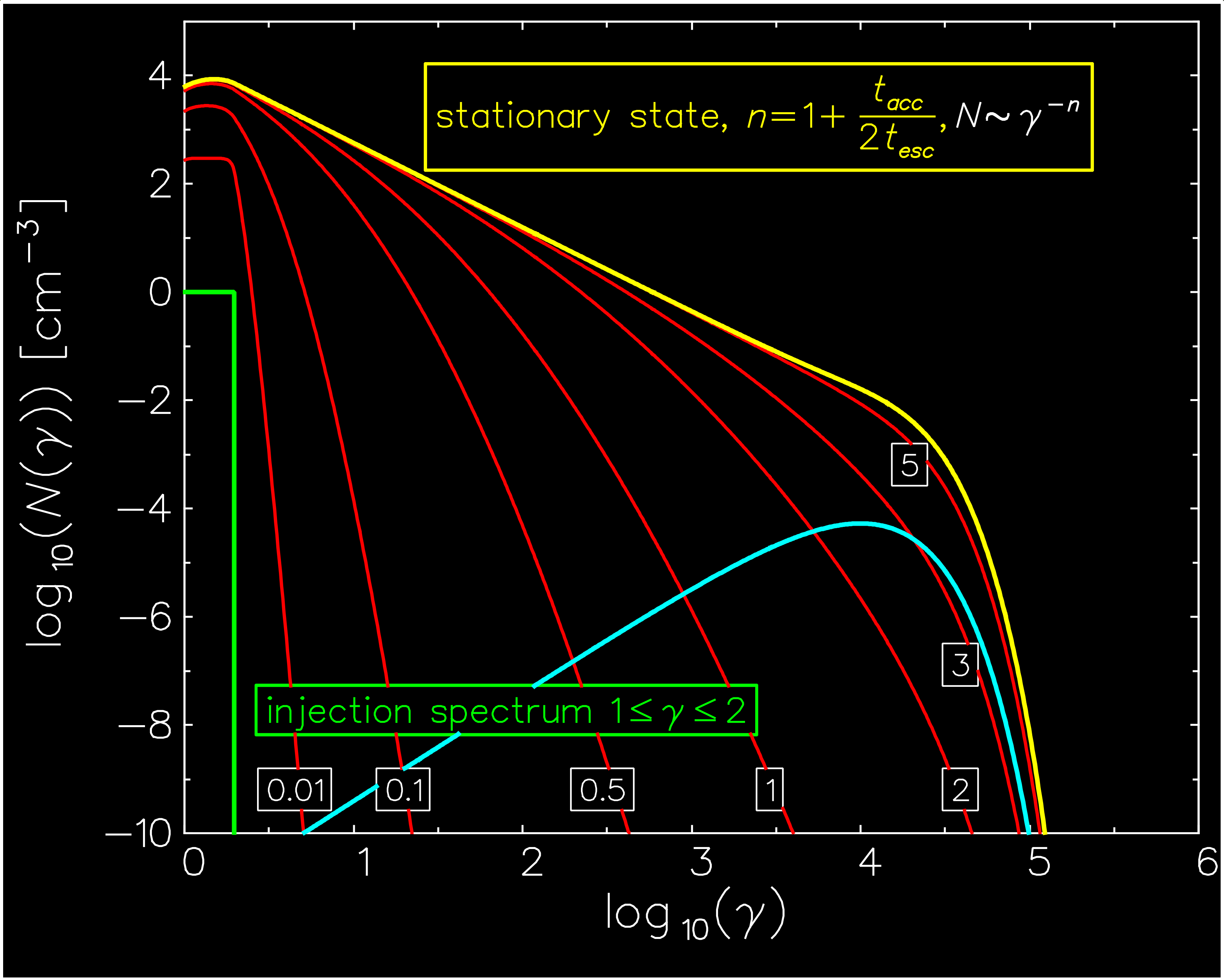
where the maximum appears at the equilibrium between the cooling and heating (Schlickeiser 1984).

Evolution without injection & escape



OAB-Italy

Evolution with injection & escape



Radiative cooling by the SSC emission

The synchrotron and inverse Compton cooling coefficient is given by

$$C(\gamma) = \frac{4}{3}\frac{\sigma_T c}{m_e c^2}\left[U_B + U_{\rm rad}(\gamma)\right]\gamma^2,$$

where

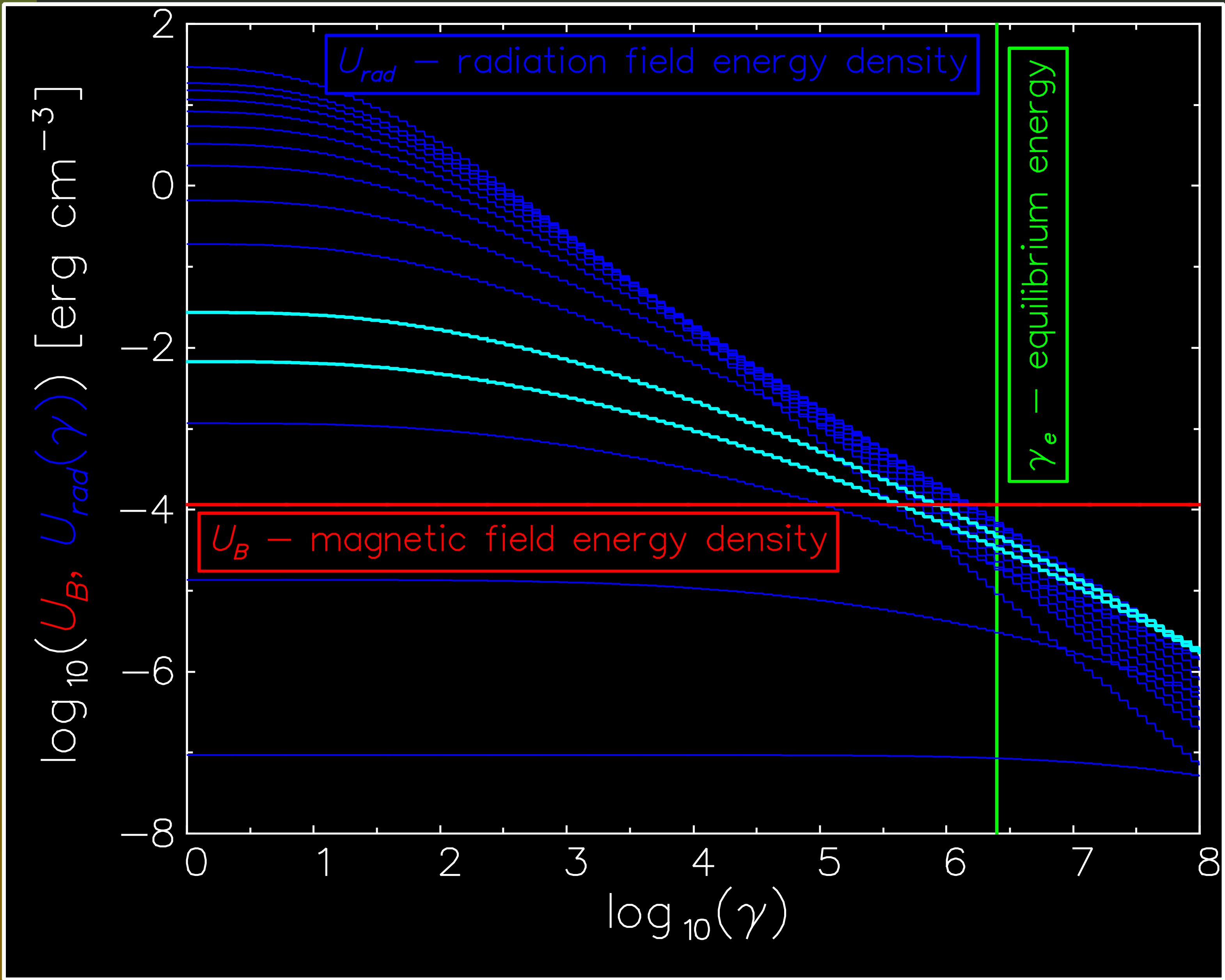
$$U_B = \frac{B^2}{8\pi},$$

is the magnetic field energy density and

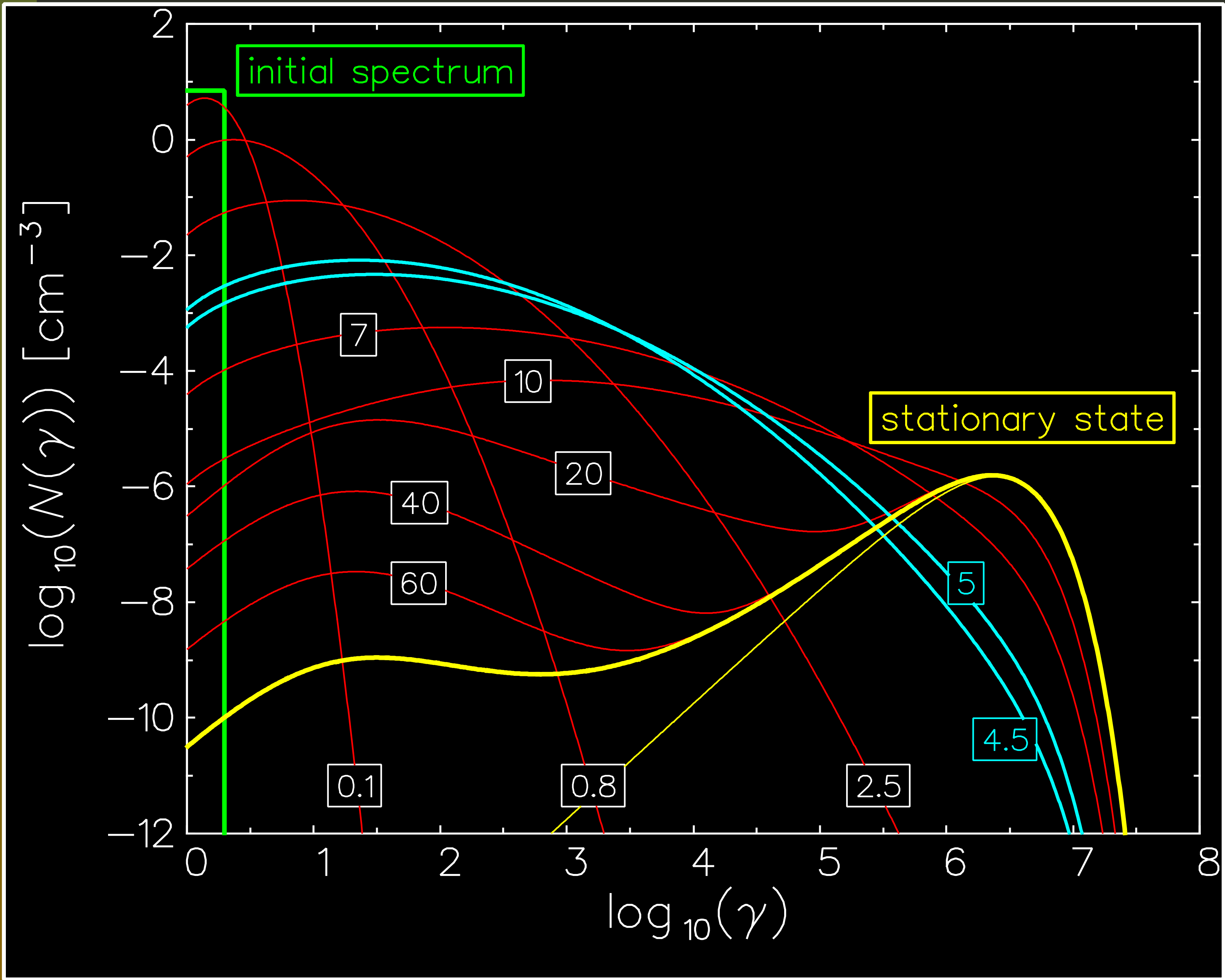
$$U_{\rm rad}(\gamma) \simeq \frac{4\pi}{c}\int_{\nu_{\rm min}}^{\nu_x(\gamma)} I_{\rm syn}(\nu)d\nu \quad \nu_x = \min\left[\nu_{\rm max}, \frac{3m_e c^2}{4h\gamma}\right]$$

is the radiation field energy density.

The radiation field energy density



Evolution of the electron spectrum



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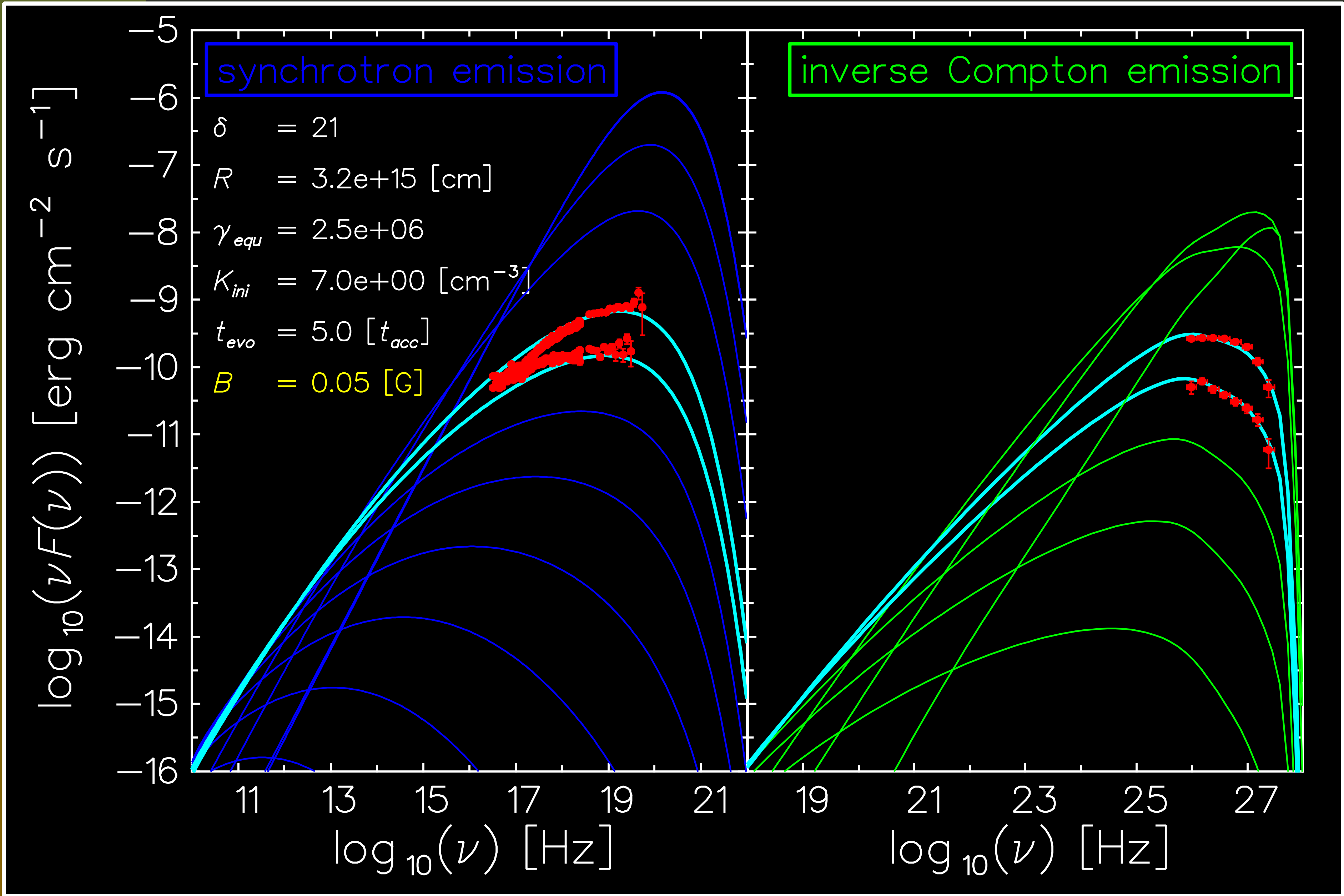
SSC emission of Mrk 501



SSC - number of free parameters

- monoenergetic particle population

$$R, \quad B, \quad K_\gamma, \quad \gamma, \quad \delta \quad \longrightarrow \quad \boxed{5}$$

- power law particle spectrum

$$R, \quad B, \quad K_1, \quad \gamma_{\rm max}, \quad n, \quad \delta \quad \longrightarrow \quad \boxed{6}$$

- broken power law spectrum

$$R, \quad B, \quad K_1, \quad \gamma_{\rm break}, \quad \gamma_{\rm max}, \quad n_1, \quad n_2, \quad \delta \quad \longrightarrow \quad \boxed{8}$$

- our model (no escape and injection)

$$R, \quad B, \quad K_{\rm ini}, \quad \gamma_{\rm equ}, \quad t_{\rm acc}, \quad t_{\rm evo}, \quad \delta \quad \longrightarrow \quad \boxed{7}$$

where R - source radius, B - magnetic field intensity, K - particle density, γ - particle Lorentz factor, n - spectral index, δ - source Doppler factor, $t_{\rm evo}$ - evolution time

... less than seven parameters?

If for the equilibrium energy

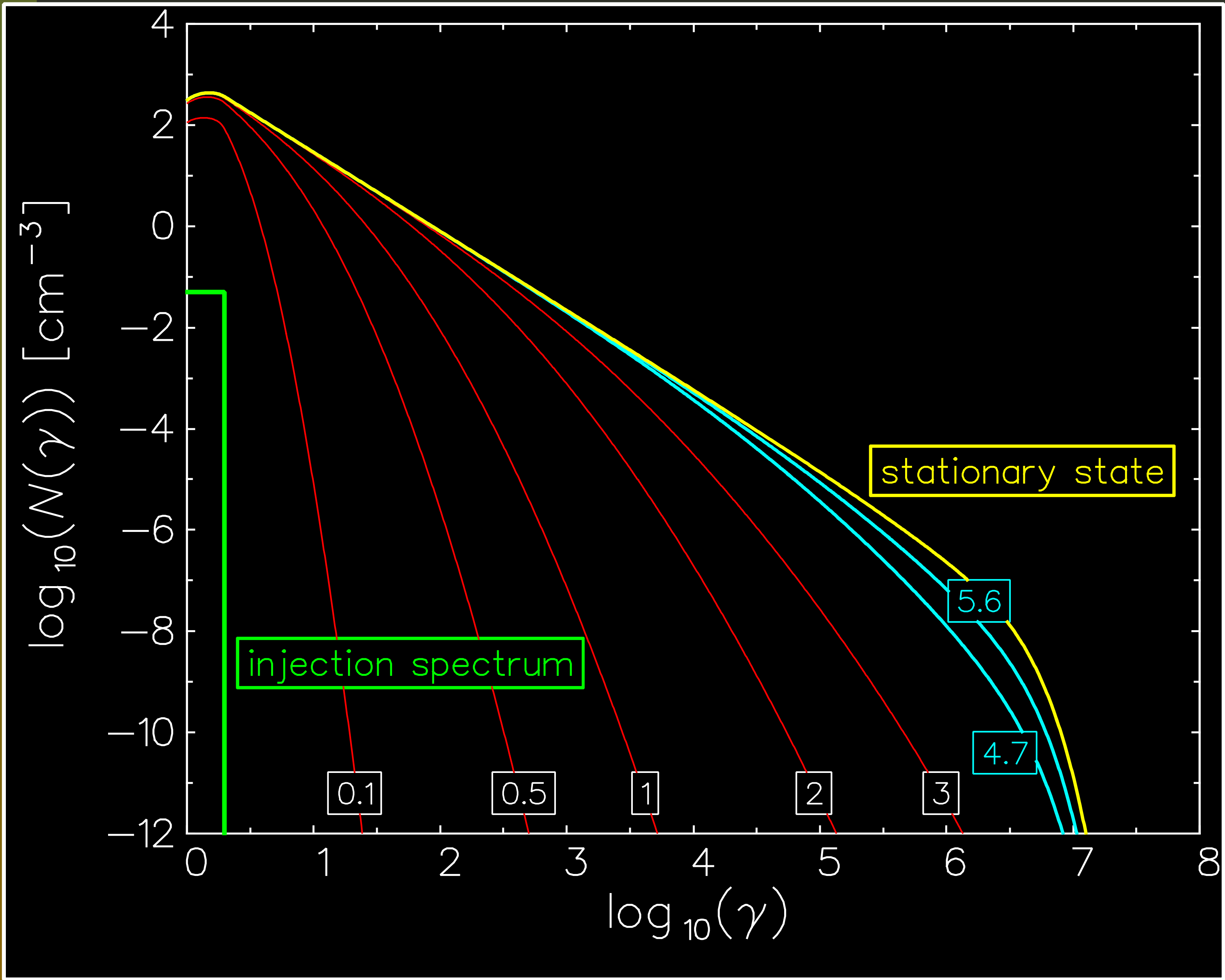
$$U_B \gg U_{\rm rad}(\gamma_{\rm equ})$$

then the value of the magnetic field intensity can be derived from the other model parameters

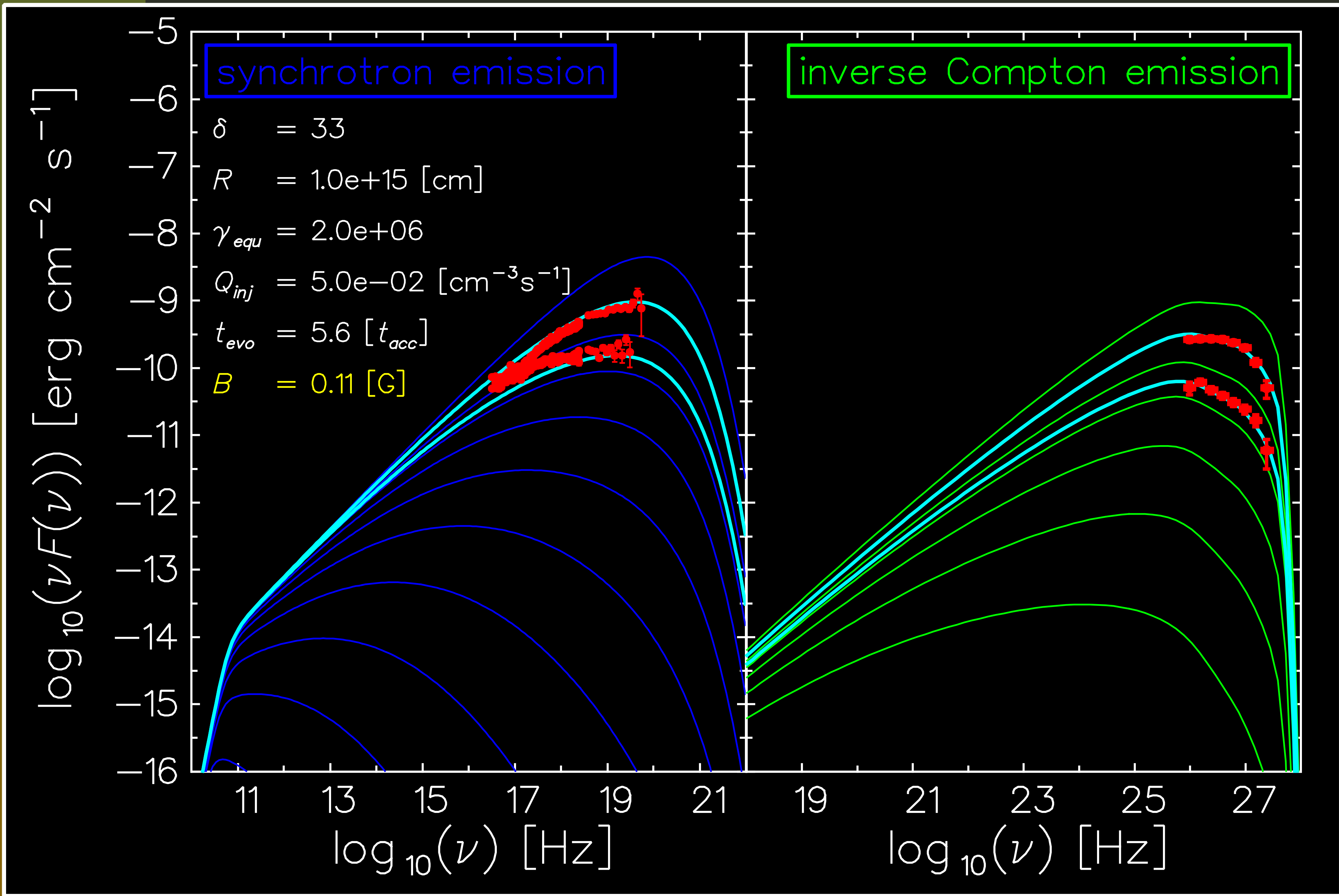
$$B(\gamma_{\rm equ}, t_{\rm acc}) = \sqrt{\frac{6\pi m_e c}{\sigma_{\rm T}} \frac{1}{\gamma_{\rm equ} t_{\rm acc}}} \quad \rightarrow \quad \boxed{7 \rightarrow 6}$$

Moreover, if $t_{\rm acc} \simeq R/c$ then the number of free parameters is reduced to $\boxed{5}$!

Injection & escape scenario



Mrk 501 - injection & escape scenario



free parameters in the inj/esc scenario

In the injection and escape scenario in principle we have eight free parameters

$$R,\quad B,\quad Q_{\rm inj},\quad \gamma_{\rm equ},\quad t_{\rm acc},\quad t_{\rm esc},\quad t_{\rm evo},\quad \delta\quad \longrightarrow\quad \boxed{8}$$

However, we can assume the escape time $t_{\rm esc} \simeq R/c \rightarrow \boxed{7}$. Moreover, since the slope of the spectrum $n = 1 + \frac{t_{\rm acc}}{2t_{\rm esc}}$, the acceleration time $t_{\rm acc} \simeq t_{\rm esc} \rightarrow \boxed{6}$. The magnetic field intensity can be calculated if $U_B \gg U_{\rm rad}(\gamma_{\rm equ}) \rightarrow \boxed{5}$.

Finally, if we observe the source in the stationary state then the $t_{\rm evo}$ can be eliminated $\rightarrow \boxed{4}$!

Conclusions

- Stochastic acceleration of the particles in a competition with the radiative cooling may lead to the thermal or quasi-thermal distribution of the particle energy.
- Continuous injection of the low energy particles with simultaneous acceleration and escape may generate power law distribution with an exponential cut-off.
- Applying those scenarios for the synchrotron self Compton emission of a homogeneous source we can well explain X-ray/TeV spectra of Mrk 501.
- The proposed models provide time dependent description of the emission with the number of free parameters that is comparable with a "static" SSC modeling.

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Kirk, J. G., Rieger, F. M., & Mastichiadis, A., 1998, A&A, 333, 452

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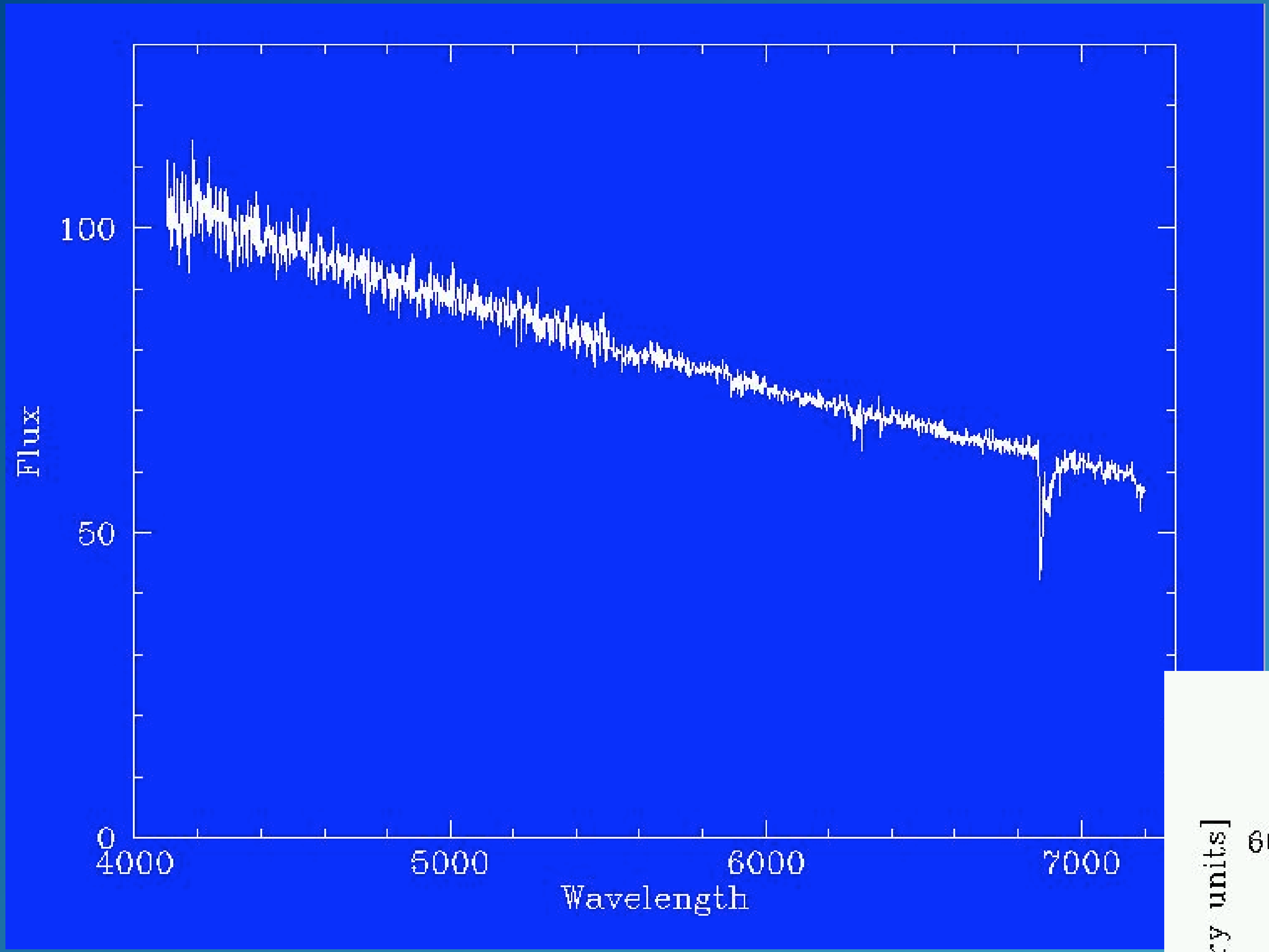
ESO-VLT spectroscopy of BL Lac objects and redshift lower limits

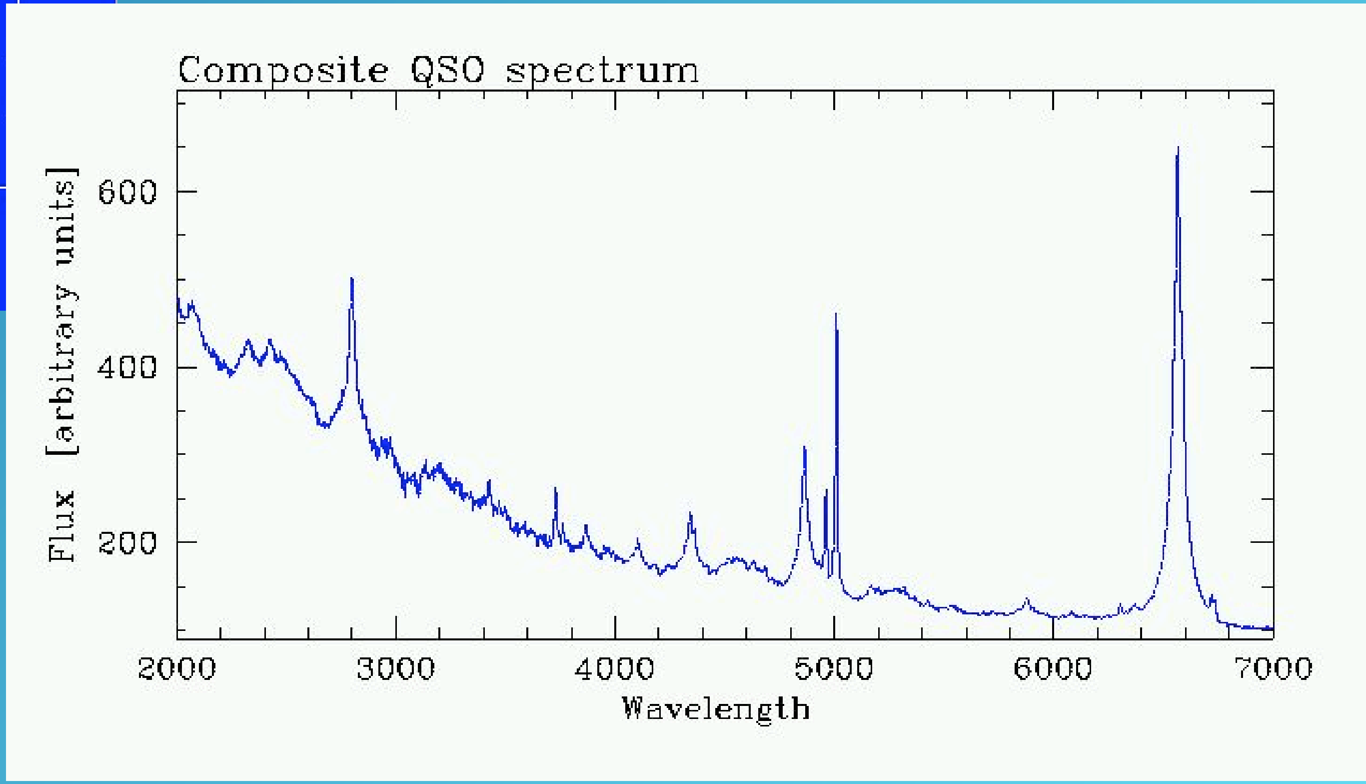
B. Sbarufatti, A. Treves, R. Falomo,
J. Heidt, J. Kotilainen, R. Scarpa

5th ENIGMA MEETING, 13-17 June 2005

Optical spectra of BL Lac objects



BL Lac optical spectra are often dominated by a non-thermal emission from a relativistic jet. Intrinsic spectral features are strongly diluted by the continuum.



Redshift of many BL Lacs are still unknown.

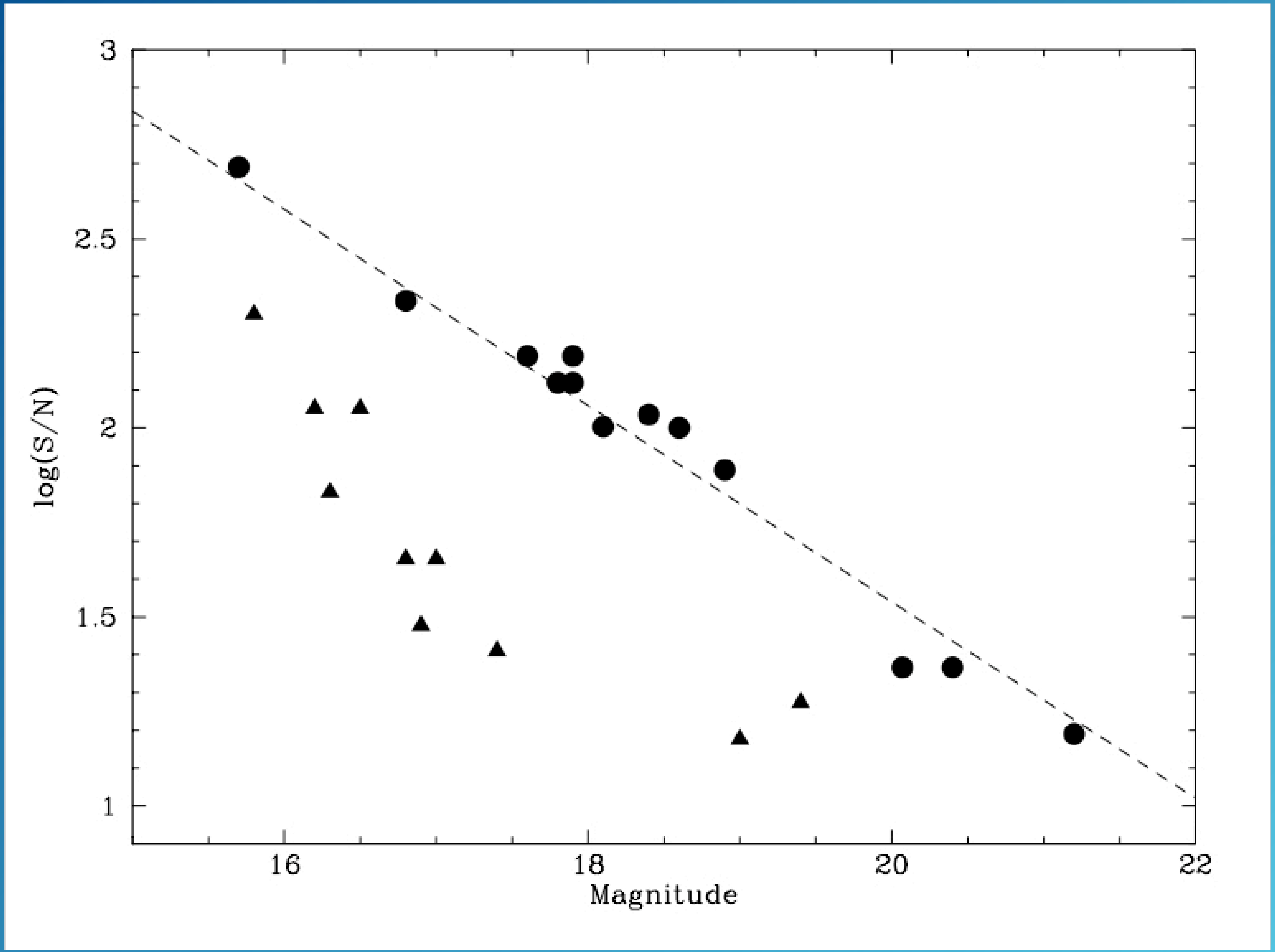
Detection of spectral features

- To detect weak spectral features (EW~ 1 Å or less), high S/N spectra (>100) are required.
- With 4 m class telescopes such a S/N can be reached for objects with $V \leqslant 15$.
- For fainter objects, an 8 m class telescope, is required.

The VLT view of BL Lac spectra

- High S/N (100-400) spectra of ~50 BL Lac with VLT +FORS1; obs. in service mode during poor seeing conditions.
- Selection:
  - BL Lacs and BL Lac candidates from Padovani & Giommi (1995) and Sedentary Survey.
  - Redshift unknown or uncertain.
  - Bright lineless sources are preferred.
- 42 objects observed from April '03 to October '04.

The VLT view of BL Lac spectra



▲ ESO 3.6m

● VLT+FORs1

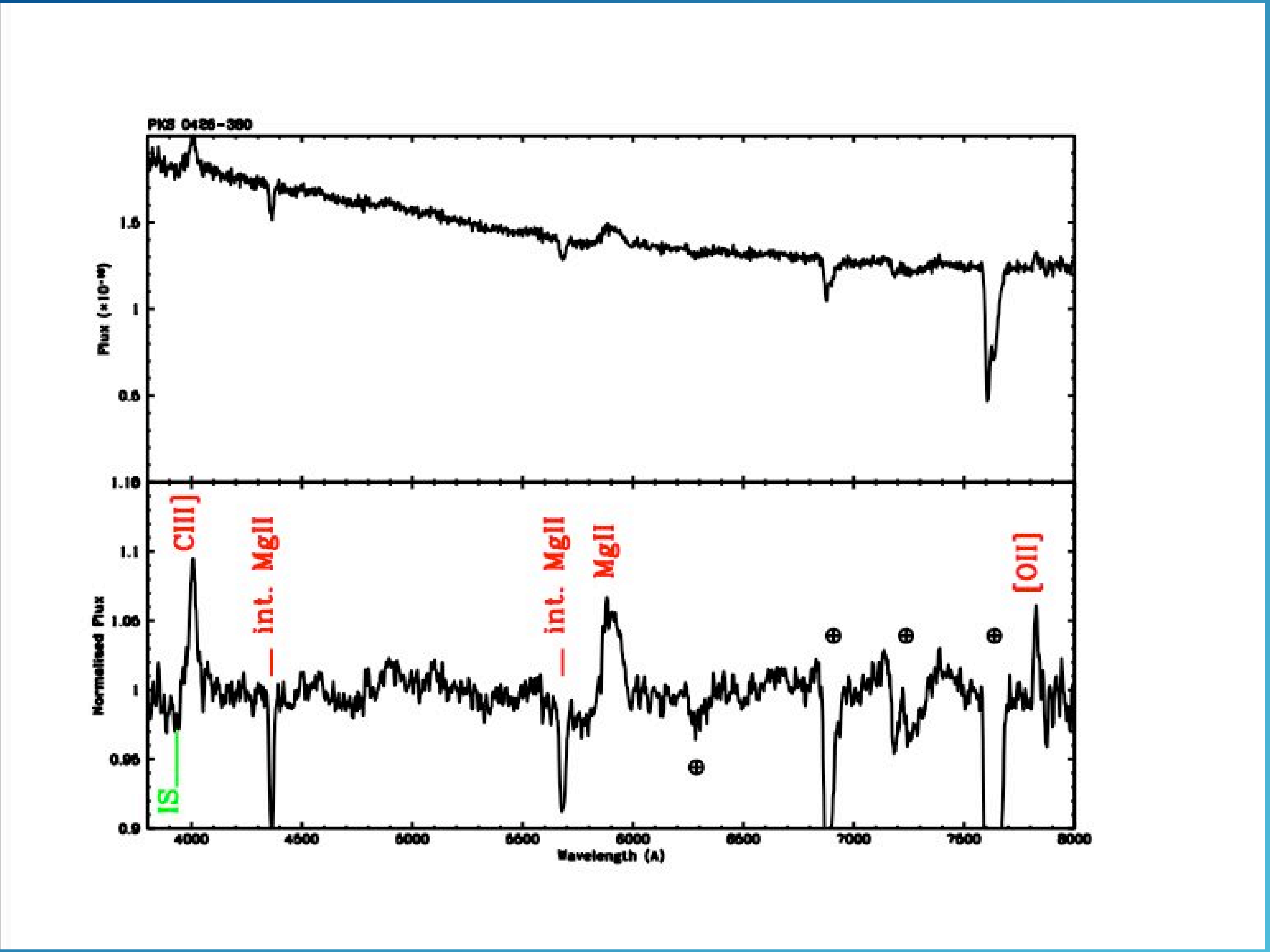
Results

- 16 new redshifts
- 18 featureless objects
- 8 misclassified sources

New redshifts

- 10 redshifts from emission lines (4 cases of broad lines)
- 6 redshifts from absorption lines (host galaxy)
- 2 objects show also intervening absorptions

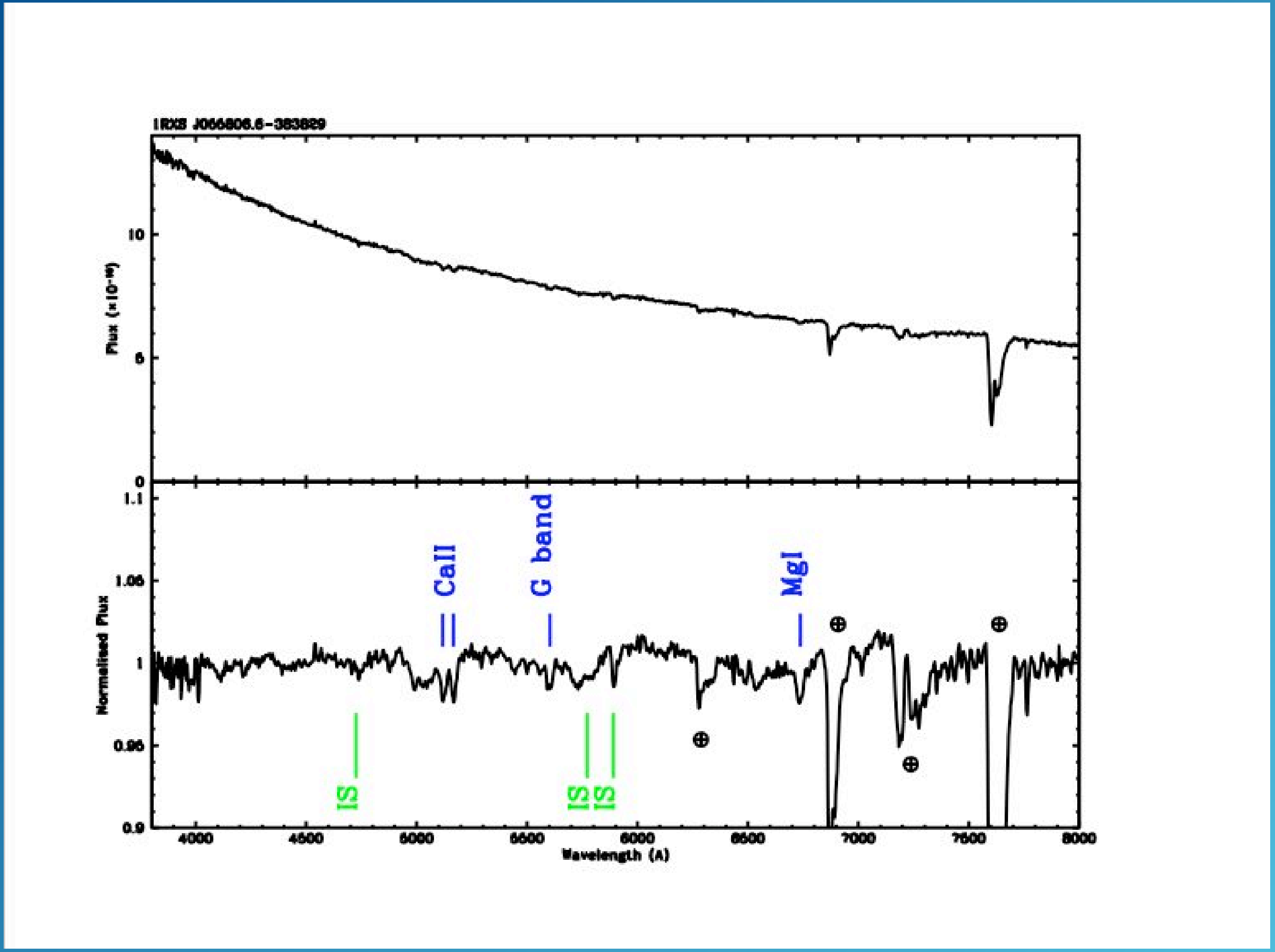
Results: new redshifts from emission lines.



PKS 0426-380

- S/N = 100
- z_{em} = 1.105
- Intervening absorptions @ z = 0.56, 1.03.

Results: new redshifts from absorption lines.



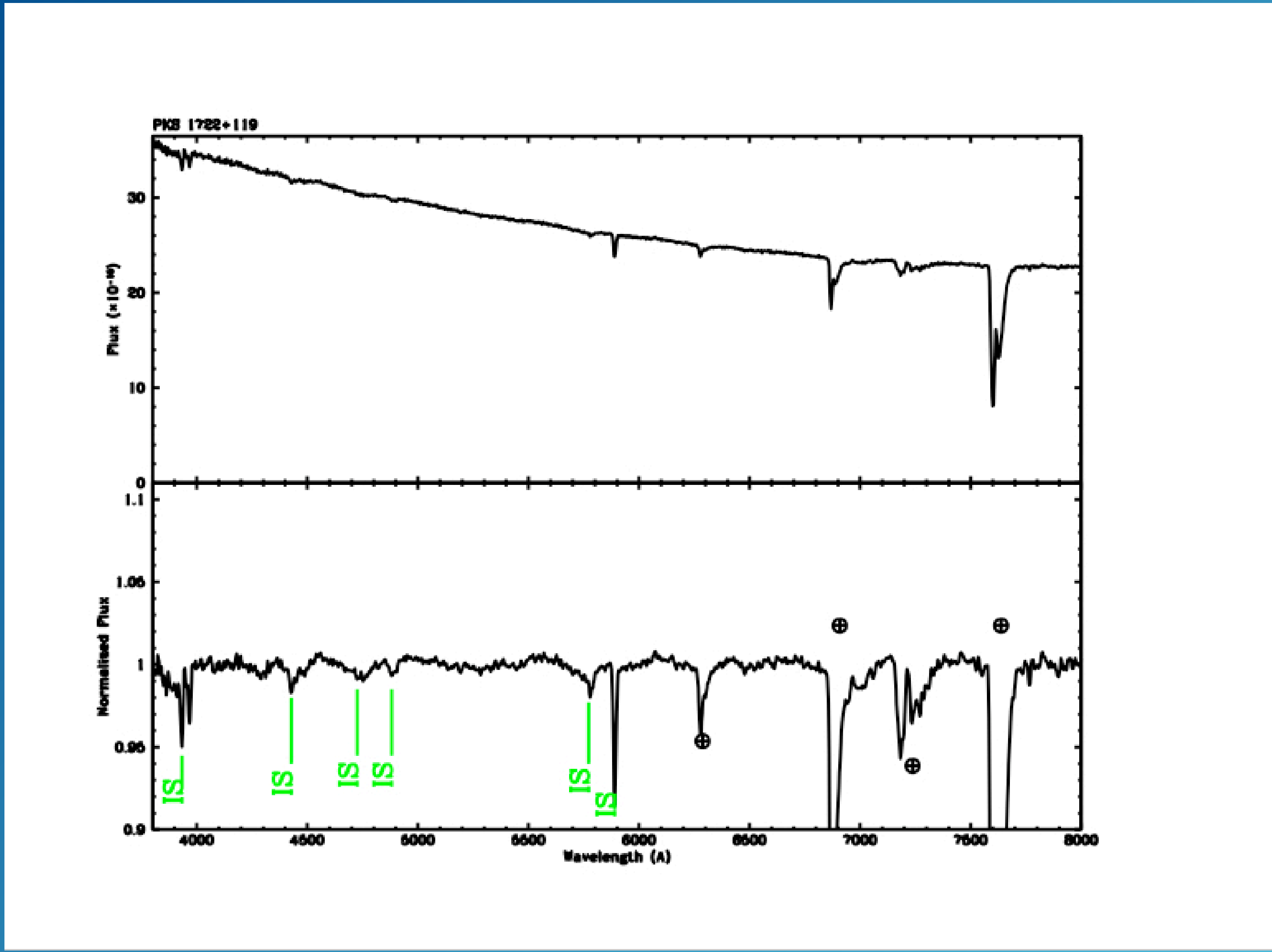
1RXS 055806.6-383829

- S/N = 280
- z_{abs}=0.302
- EW abs lines 0.7-0.9

Featureless objects

- 12 sources with no intrinsic lines
- 2 sources with intervening absorptions
- 8 sources with ISM absorptions (atomic lines and Diffuse Interstellar Bands)

Results: featureless sources

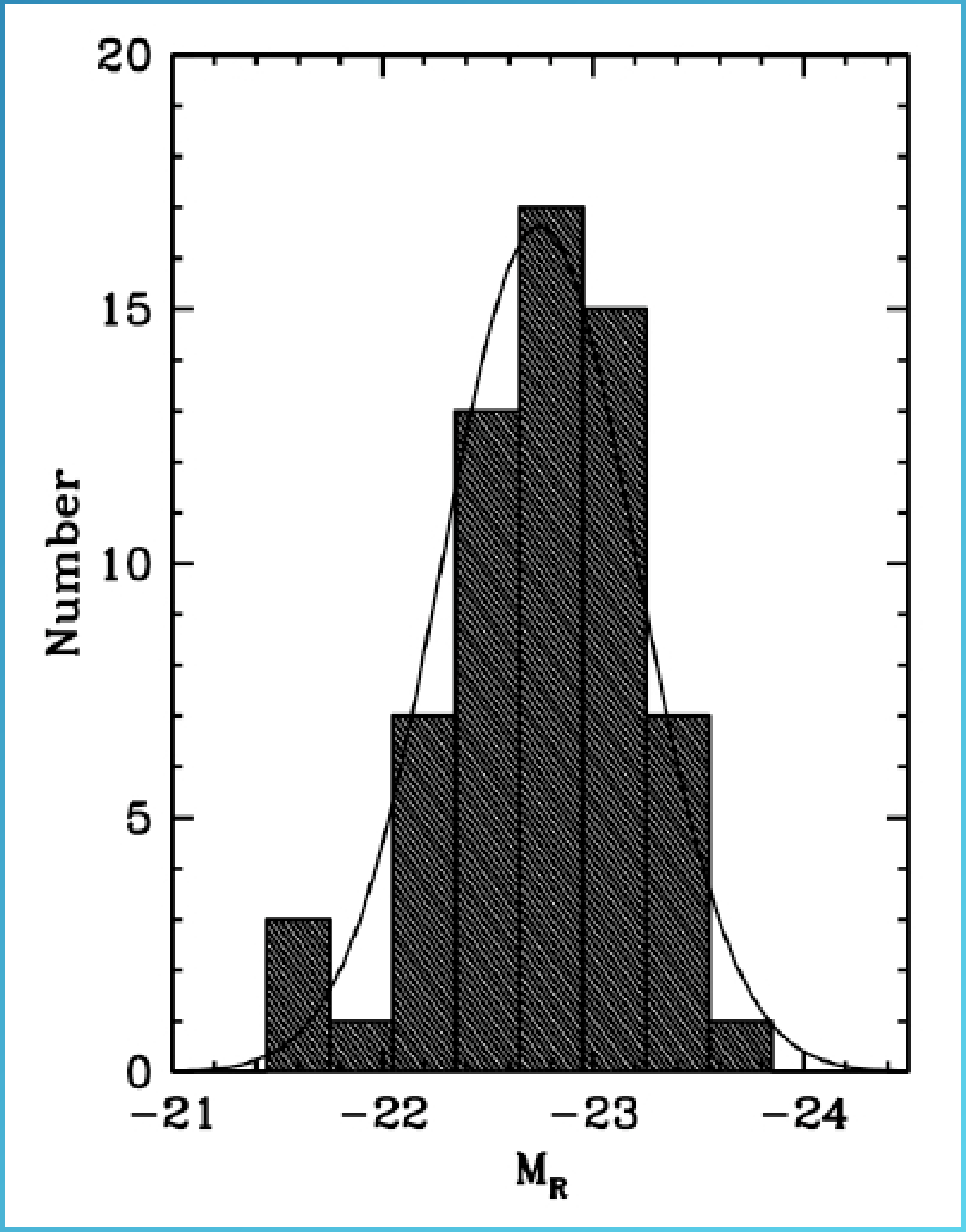


PKS 1722+119

- S/N 340
- EW upper limit on intrinsic features 0.02 Å
- Such an object could be useful to study the ISM, especially the Diffuse Interstellar Bands.

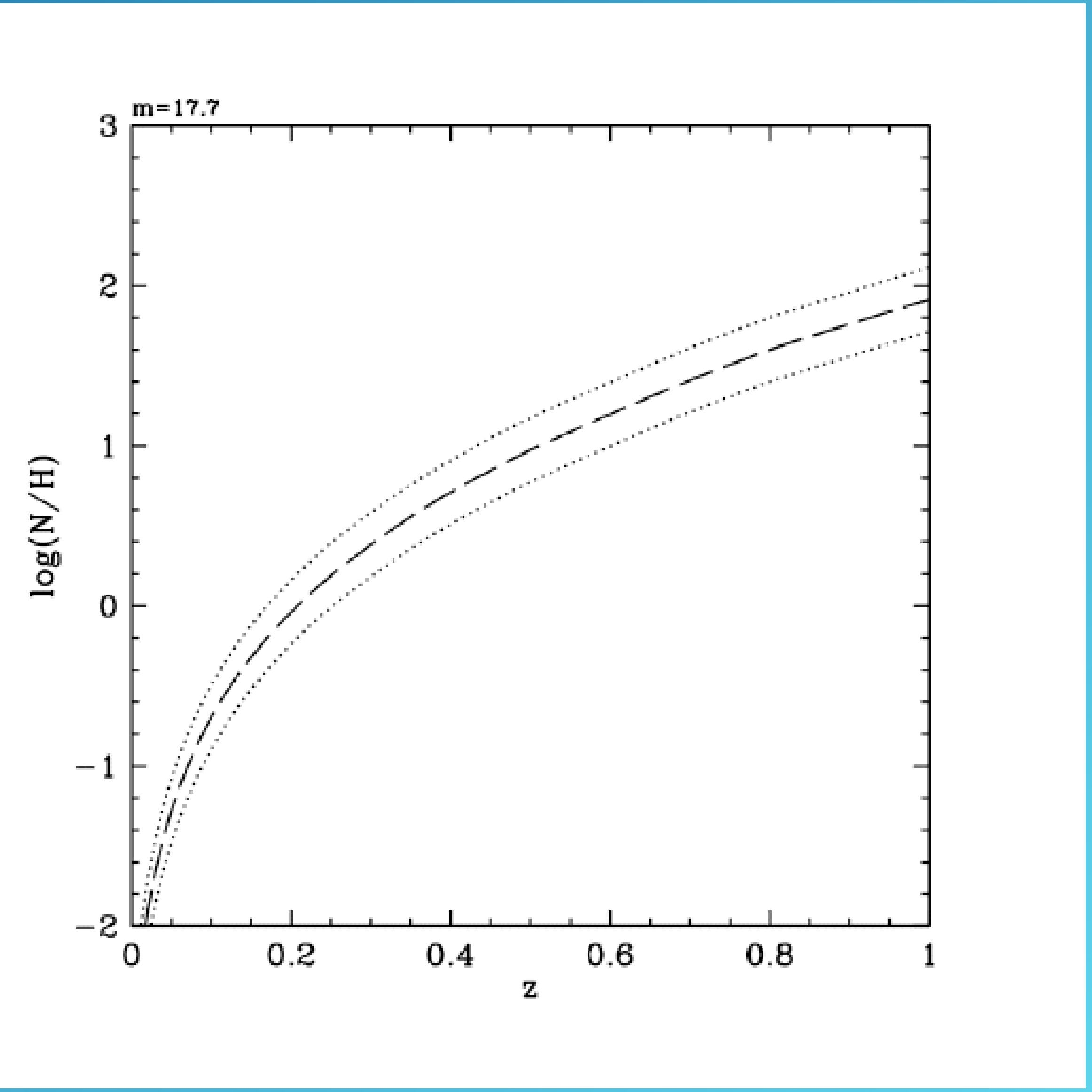
BL Lac host galaxies

- HST snapshot survey (Urry et al. 2000) implies that BL Lac hosts are giant ellipticals.
- M_R^{host}=-22.9±0.5 (H_0=70 km s^{-1} Mpc^{-1}, Ω_m=0.3, Ω_Λ=0.7) (Sbarufatti et al. 2005, submitted)



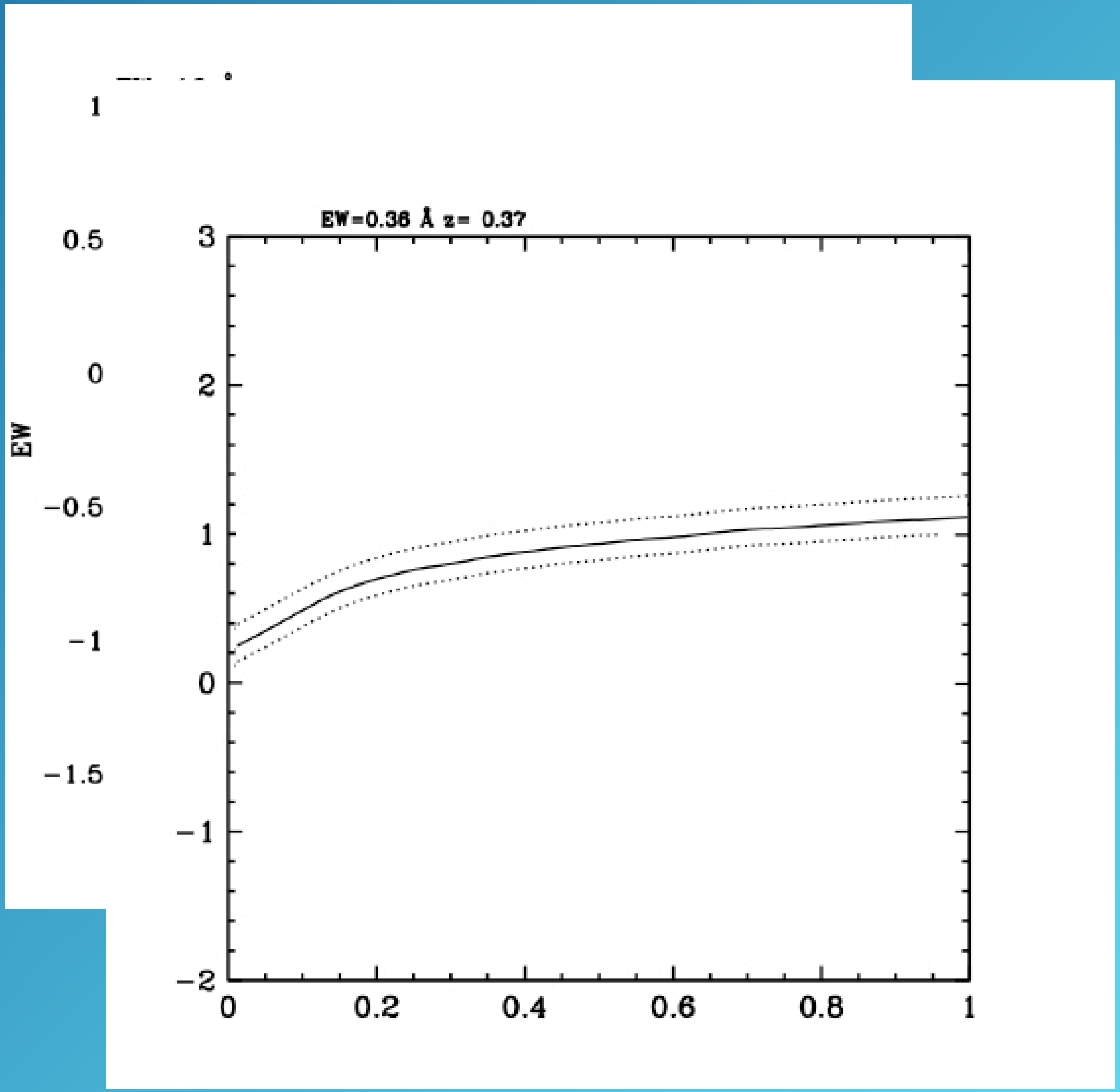
N/H vs z from photometry

- M_R^{host}=-22.9
- $m_R^{nucleus}$ known from photometry
- $\mathrm{N/H} = \mathrm{M}_R^{host} - \mathrm{m}_R^{nucleus} + \mathrm{K}^{nucleus}(z) + 5 - 5\log(z)$



N/H vs z from spectroscopy

- If the host galaxy is a candle, EW of spectral features is reduced by the nuclear contribution: N/H=N/H(EW)
- $EW_{rest\ frame}=(1+z)\ EW_{obs}$
- Assuming a template for the host spectrum (Kinney et al. 1996), N/H=N/H(z) can be computed

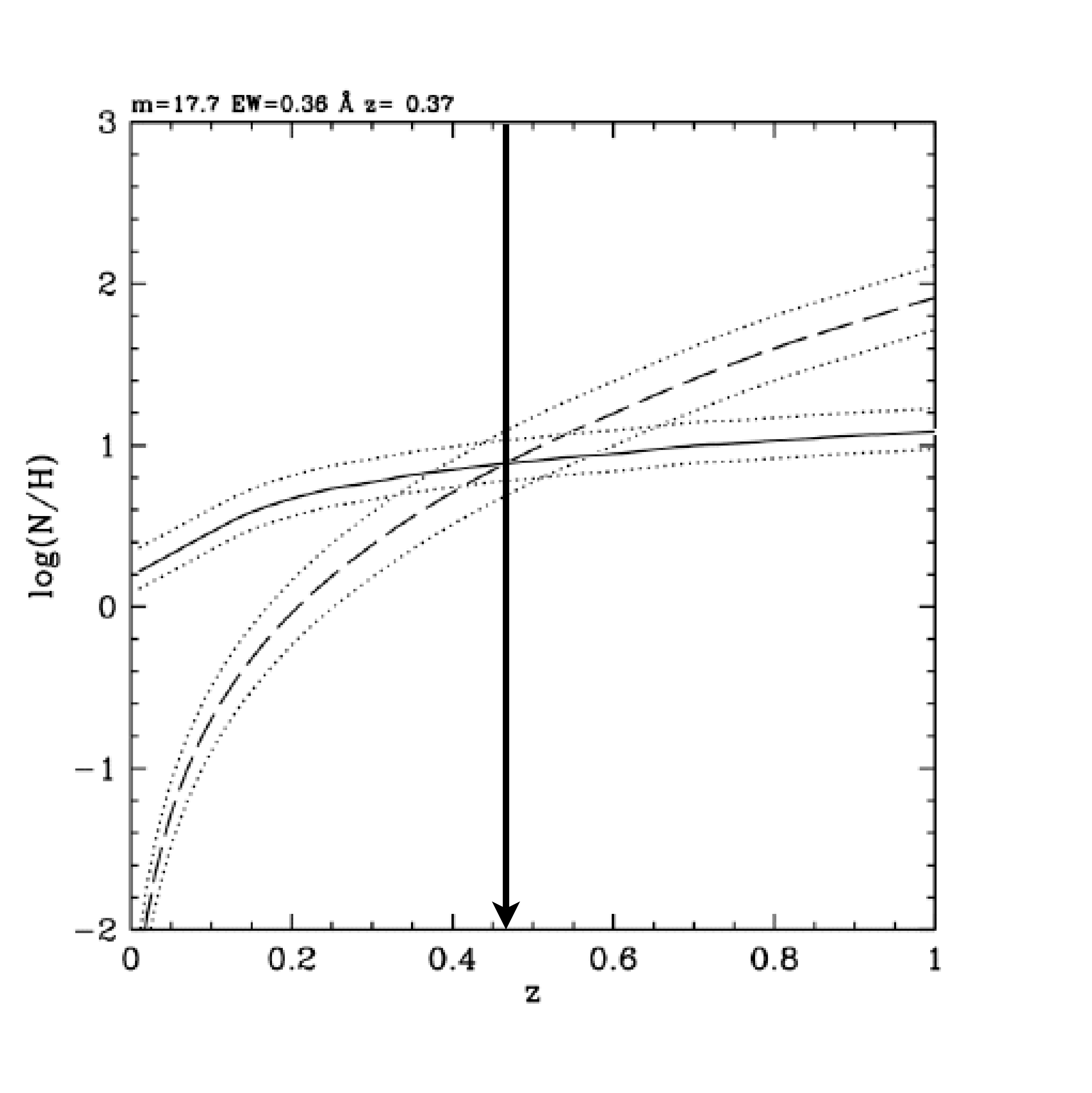


Redshift lower limits

N/H vs z from nuclear magnitude

N/H vs z from EW limits

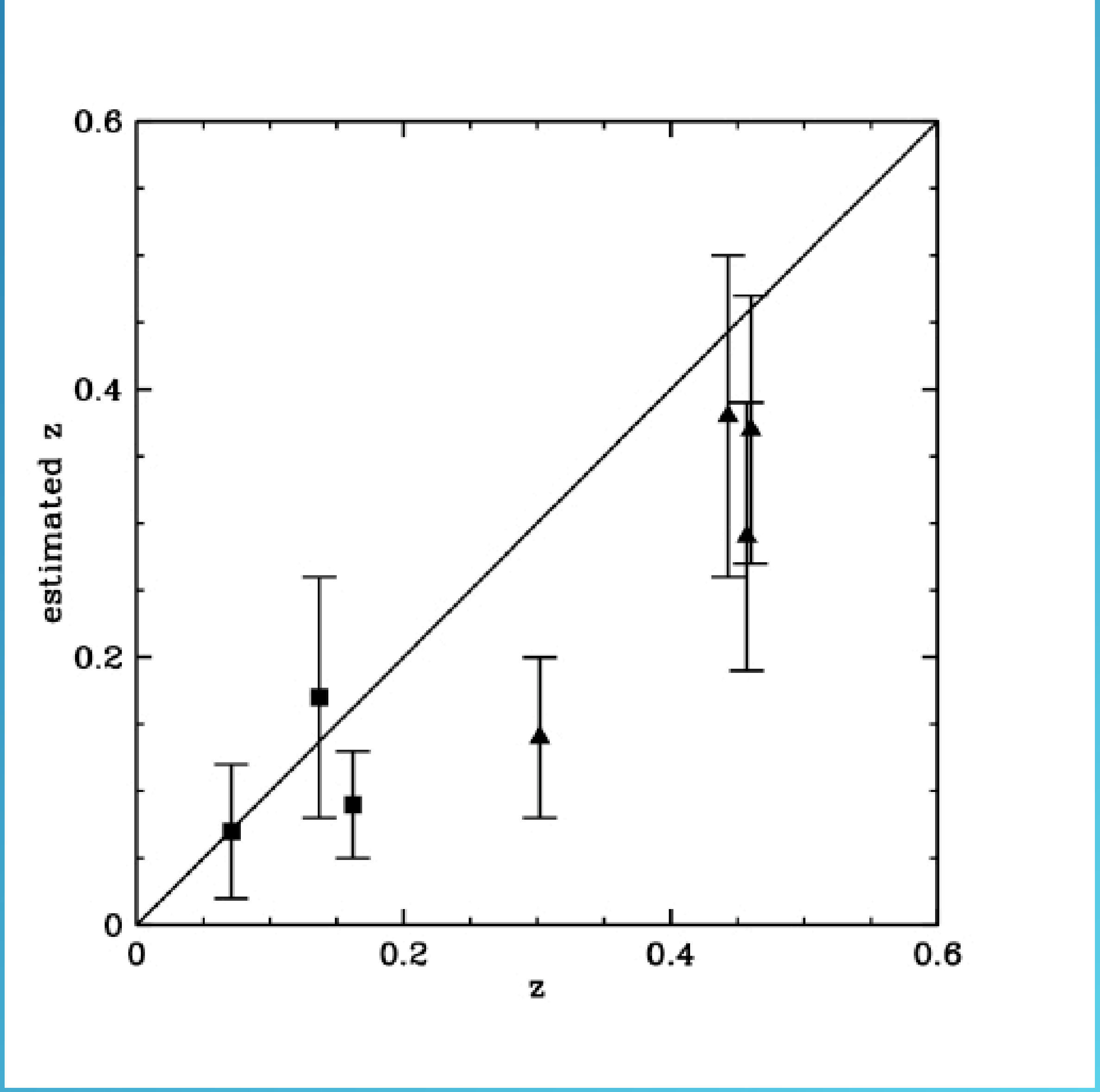
Redshift lower limit for featureless objects



Sbarufatti et al. 2005, in preparation

Redshift lower limits from spectroscopy

- Estimated lower limits are in agreement with spectroscopic measurements.

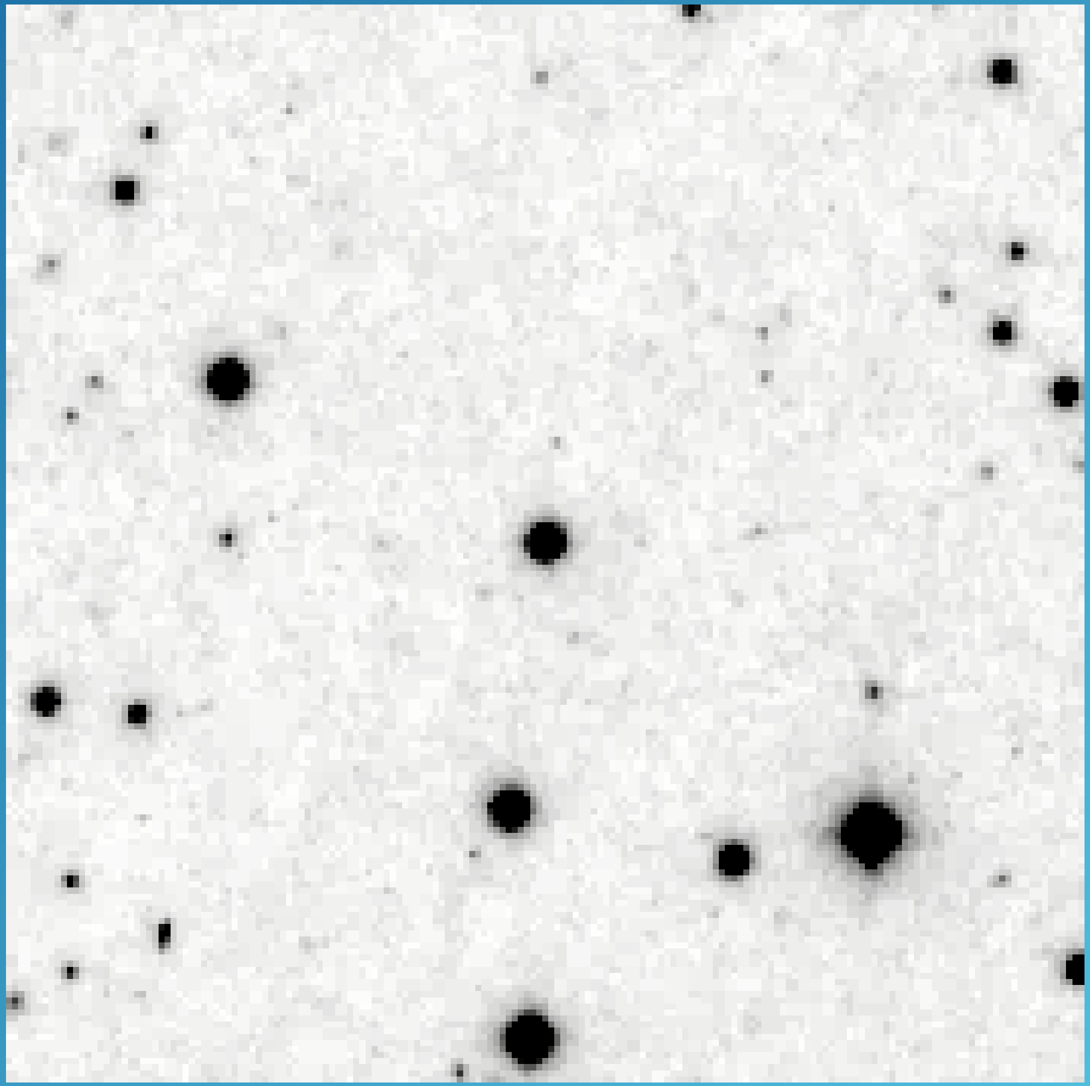


Object name	EWlim	mnucleus	zlim
0047+023	0.36	19.0	>0.8
0048-09	0.22	16.0	>0.3
0422+00	0.25	16.2	>0.3
0627-199	0.92	19.3	>0.6
1349-439	0.31	16.9	>0.4
1445-0326	0.36	17.7	>0.5
1503-1541	0.74	17.8	>0.4
1553+113	0.25	14.0	>0.1
1722+119	0.18	14.7	>0.2
2012-017	0.34	19.3	>0.9
2131-2516	0.32	19.0	>0.9
2133-449	0.36	19.5	>1.0
2136-428	0.24	15.6	>0.2
2233-148	0.43	18.5	>0.7
2254-204	0.25	17.1	>0.5
2310-3719	0.31	19.6	>1.0
2342-1531	1.61	21.4	>1.0
2357-1718	0.16	18.2	>0.9

Conclusions

- 16 new redshift estimates
- 12 redshift lower limits for featureless objects
- 4 weak broad emission lines
- 4 BL Lac with intervening absorptions

A new redshift lower limit for 0716+714



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BL Lac host galaxies

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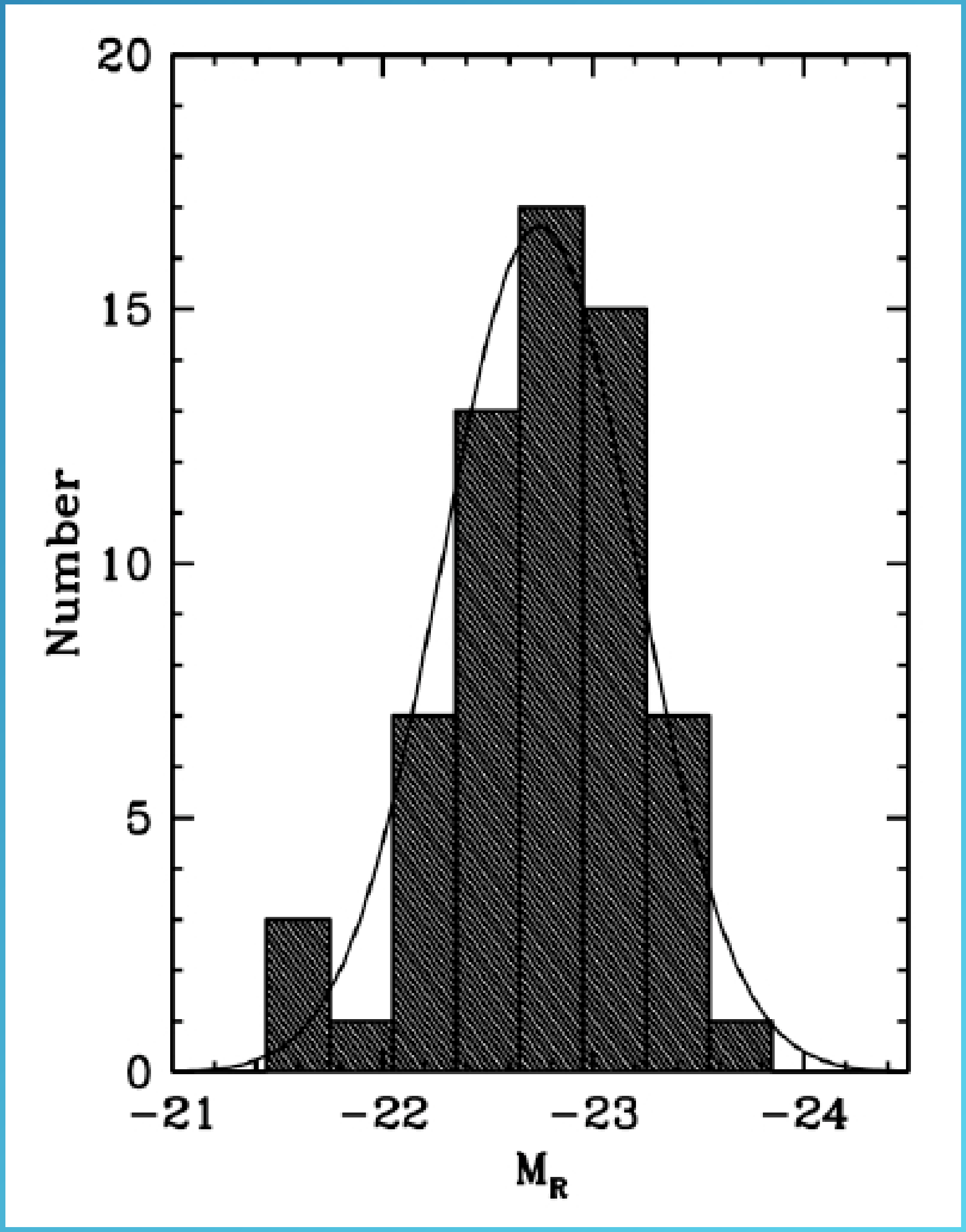
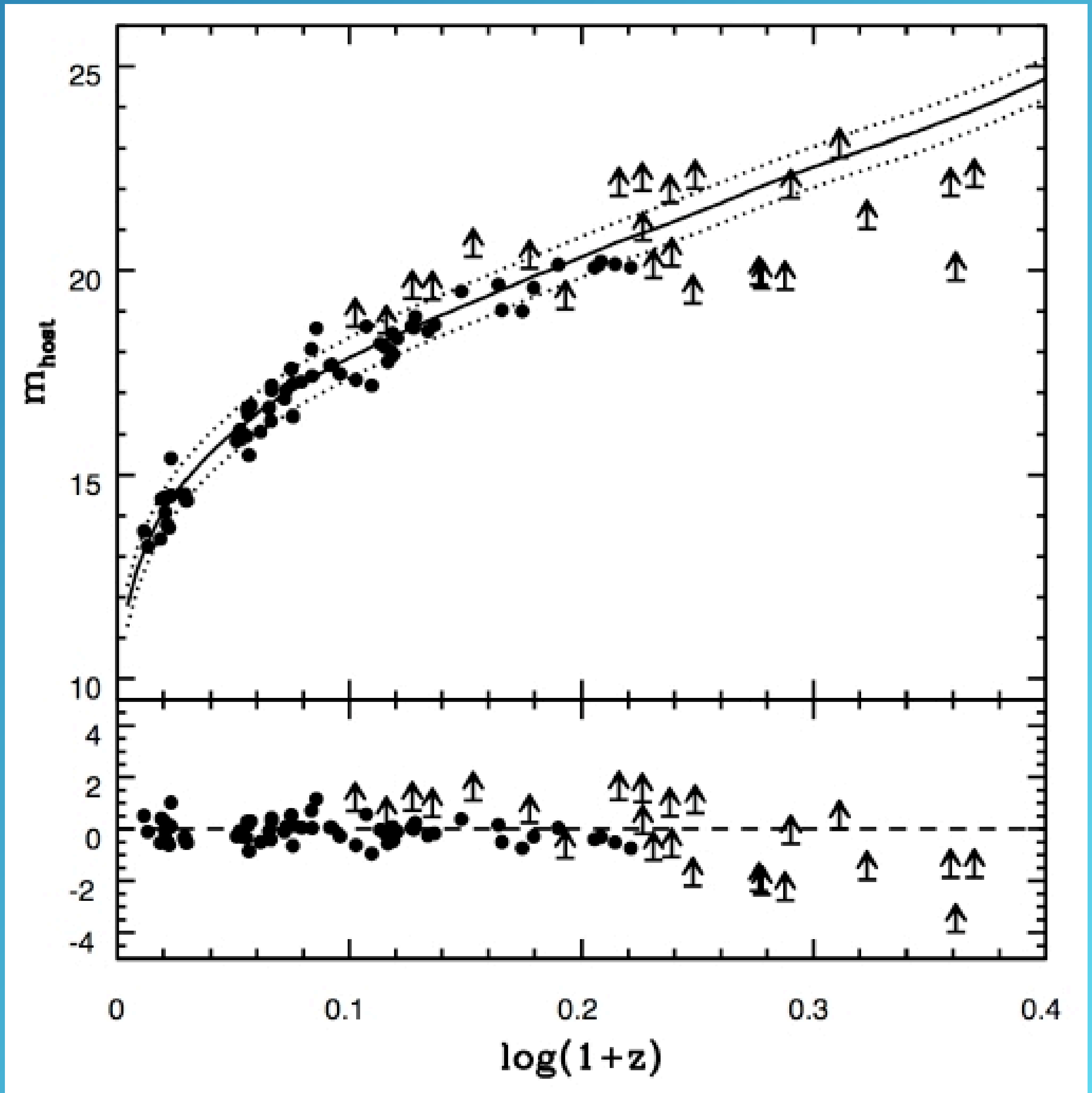


BL Lac hosts Hubble diagram

$$m_R^{host} = M_R^{host} - K(z) + E(z) - 5 + 5\log(d(z))$$

- If BL Lac hosts are candles, the relation can be inverted, giving z as a function of m_R^{host} .
- From lower limits on m_R^{host}, lower limits on z can be obtained.



S5 0716+714

- $m_R^{nucleus} = 14.2$
- $m_R^{host} > 20.0$ → $z > 0.5$

↓

$M_R^{nucleus} < -28.3$

Bibliography

- Sbarufatti, Treves, Falomo, Heidt Kotilainen, Scarpa, 2005, AJ, 129, 599.
- Sbarufatti, Treves, Falomo, Heidt Kotilainen, Scarpa, 2005, in preparation.
- Sbarufatti, Treves, Falomo, 2005, submitted to ApJ.

The 2dF BL Lac Survey

Diana Londish (JPL/Caltech), B. Boyle, S. Croom (AAO), E. Sadler (USyd), J. Heidt (LSW)

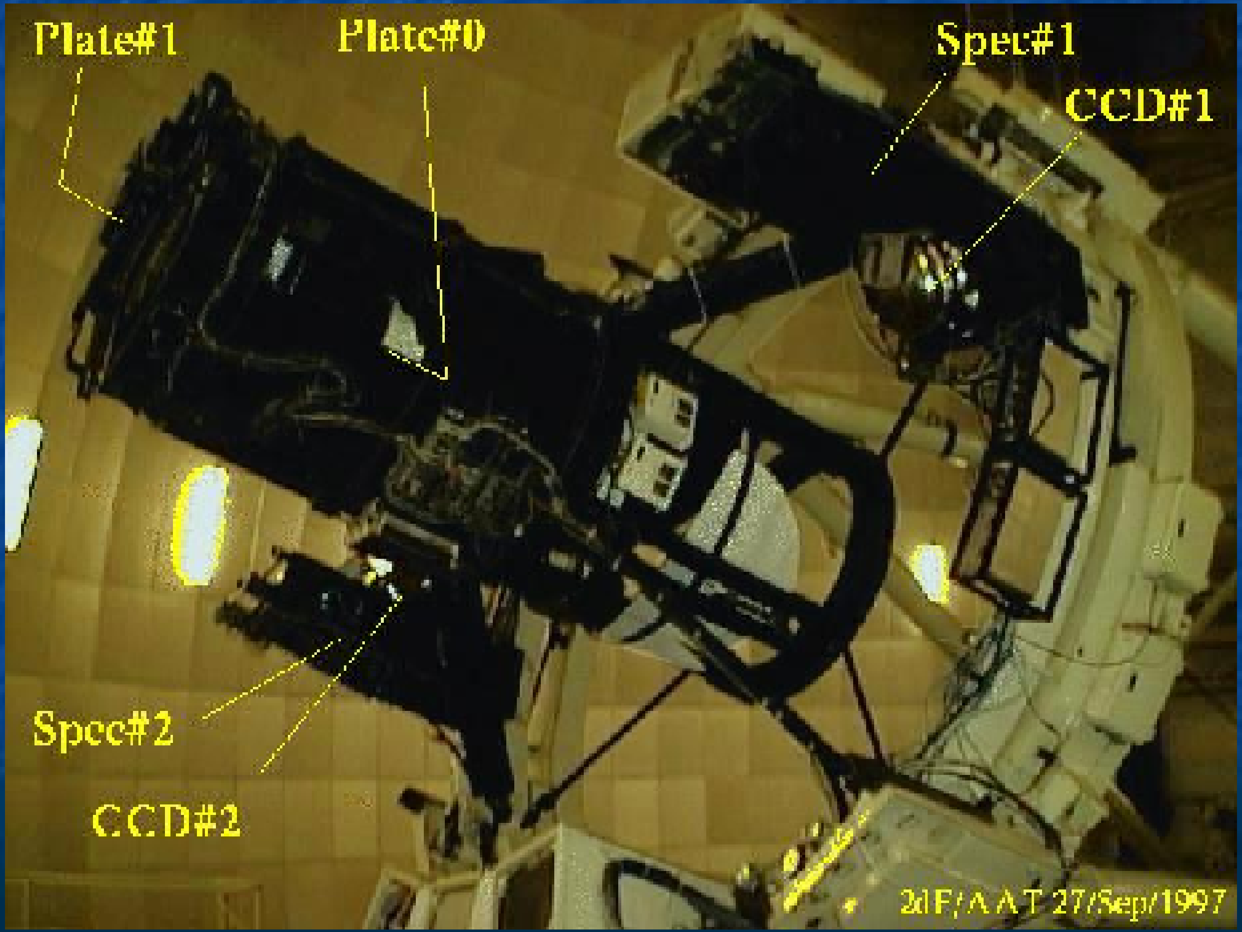
- The 2dF QSO survey

- Why an optically selected BL Lac sample?

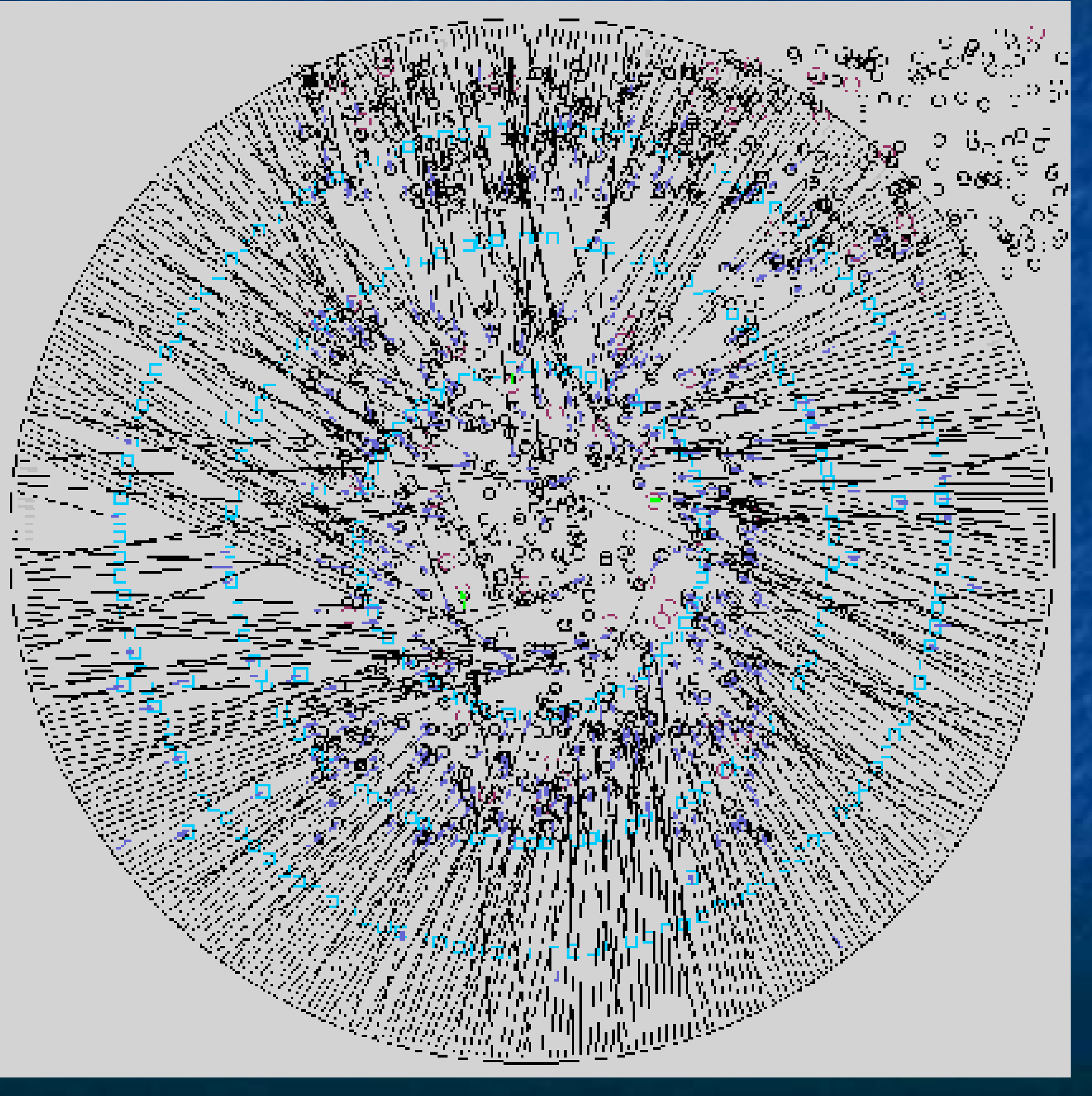
- Selection process

- Current status of follow-up

The 2-degree field instrument at the prime focus of the AAT, Siding Spring Observatory, NSW, Australia



400 fibre multi–object spectrograph with robotic positioner



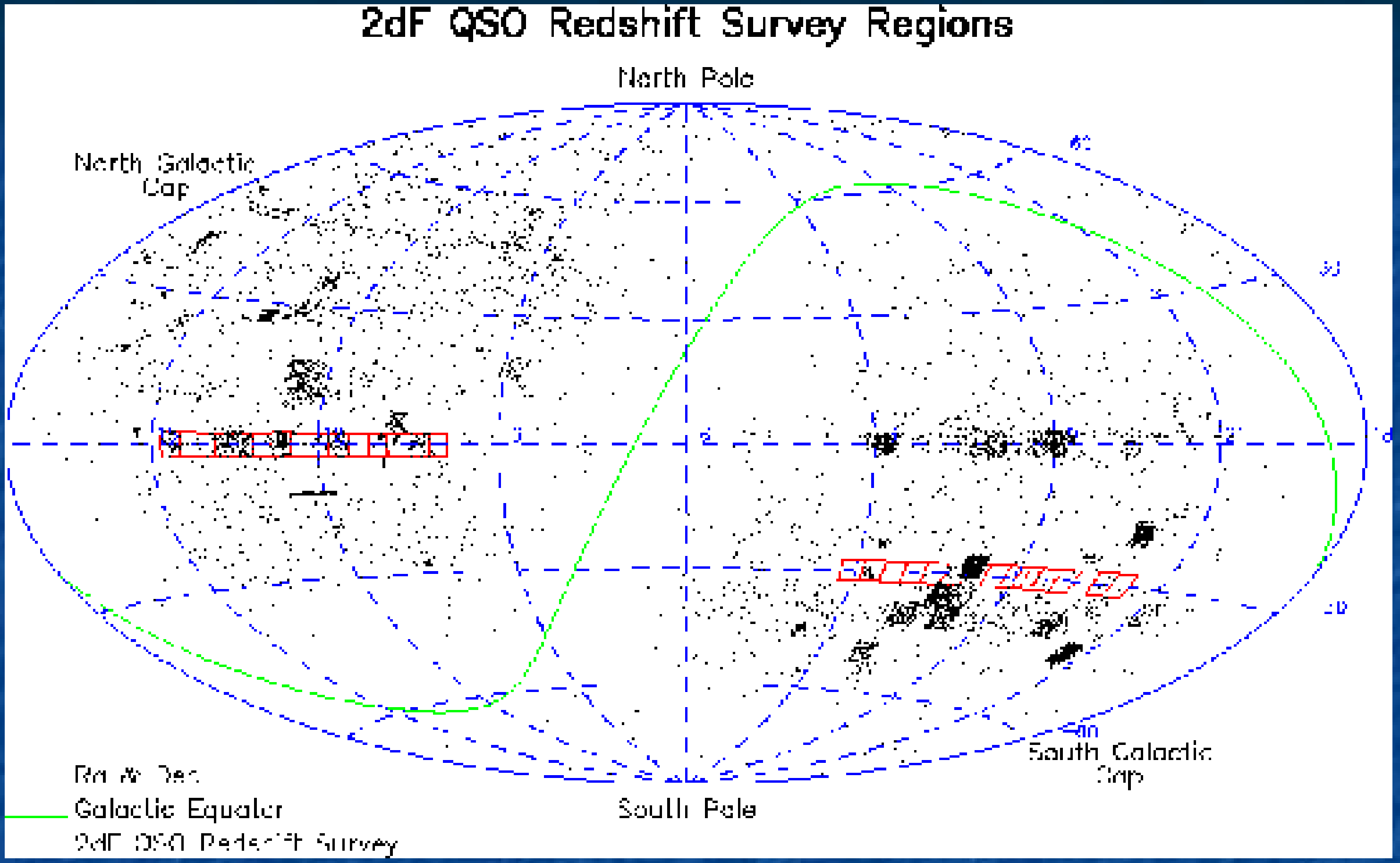
The 2dF QSO Redshift Survey (2QZ)
PI B.J. Boyle

Observations September 1997 – April 2002

~ 23,000 colour-selected* QSOs from UK Schmidt photographic plates (total catalogue of ~50,000 point sources)

*u-b ≤ -0.36, or u-b < 0.12-0.8(b-r), or b-r <0.05

magnitude range $18.25 \leq b_J < 20.85$



two 75° x 5° strips = 740 deg^2

Why an optically selected BL Lac sample?

- RBLs from 1Jy sample
- XBLs from EMSS

Two separate populations?

Not clear: with more sensitive telescopes a population of IBLs also found; LBLs have peak flux at IR wavelengths, HBLs have peak flux in UV/X-ray wavelengths

Two key questions

- Are there relatively more LBLs or HBLs?
- Why are (H)BL Lacs apparently negatively evolving?

Finding the answers – using an optically selected sample from 2QZ

- At optical wavelengths flux levels of both LBLs and HBLs is roughly similar
- No bias from radio and X-ray flux limits
- Look for missing high redshift objects to rectify perceived negative evolution

The 2QZ provides a unique opportunity – spectra 0f ~50,000 point sources .

2BL Selection criteria

- $18.25 \le b_J < 20.0$, blue colors as at 2dF
- Featureless spectra (SNR > 10)
- Reject spectra in fields contaminated by excess scattered light

Result: visual inspection of ~8400 spectra!

- After rejecting objects with detectable proper motion a sample of 52 candidate BL Lacs remained (only ~20% with radio detections)

Follow-up observations

- Radio imaging using VLA and ATCA
- Spectroscopy at Siding Spring, WHT and VLT
- IR observing at Siding Spring, Kitt Peak and Calar Alto
- Variability studies at Mt Stromlo and Siding Spring

Also

- Proper motions from updated Super Cosmos survey
- Online SDSS photometry and spectroscopy

Results

- 31 objects observed at VLA – two detections
- 2 objects observed at ATCA – no detections
- One redshift obtained (from CaII H & K absorption features and G-band) from MSSSO spectroscopy.
- 3 radio-quiet objects with featureless WHT spectra later found to have significant proper motion in updated SuperCosmos catalogue

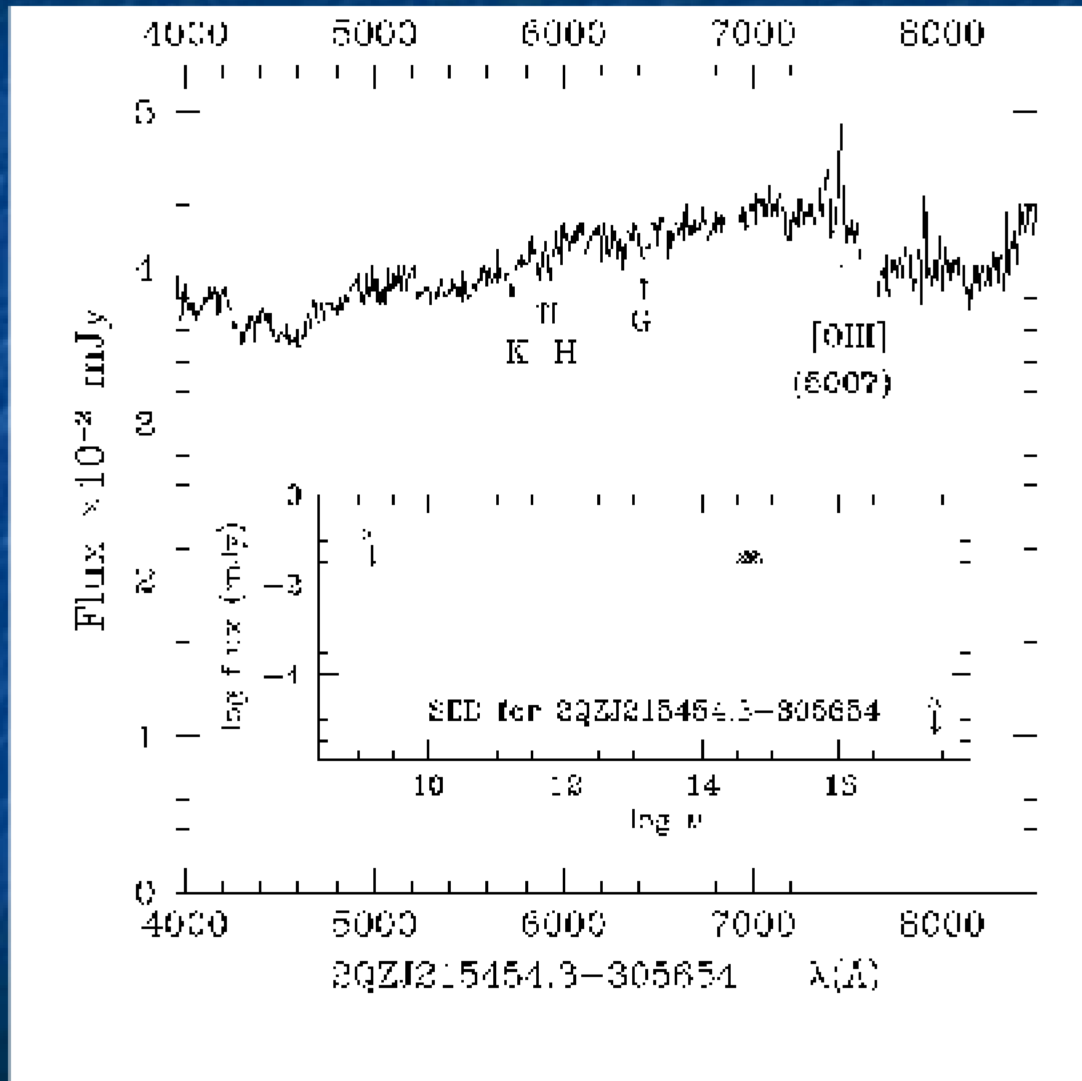
Results (cont`d)

- IR observing at Kitt Peak and plots of SDSS magnitudes confirmed thermal nature of 4 objects, also later found to have significant proper motion in updated SuperCosmos catalogue
- 2 objects have a nonthermal spectrum
- Variability studies found only 3/18 sources to be variable (Δm 0.3)

Results from VLT

- Spectroscopy of 35 objects obtained in 2003/2004 at VLT
- 13 radio-quiet QFOs identified as thermal sources (stars/WDs)
- 8 QFOs (only 2 are radio quiet)
- 14 (weak)-lined AGN – some have definitely varied and as such can still be classified as BL Lacs

A bona fide radio-quiet BL Lac



Analysis of results

- Optical selection of QFOs (*particularly in a blue survey*) is inefficient – too much contamination by featureless WDs and weak-lined AGN in low S/N spectra
- Too few objects to comment on numbers of RBLs vs XBLs, or to compute a luminosity function,
- However . . . . .

We have at least one radio-quiet, X-ray quiet featureless continuum object!

A handful of radio-quiet QFOs have also been found in SDSS