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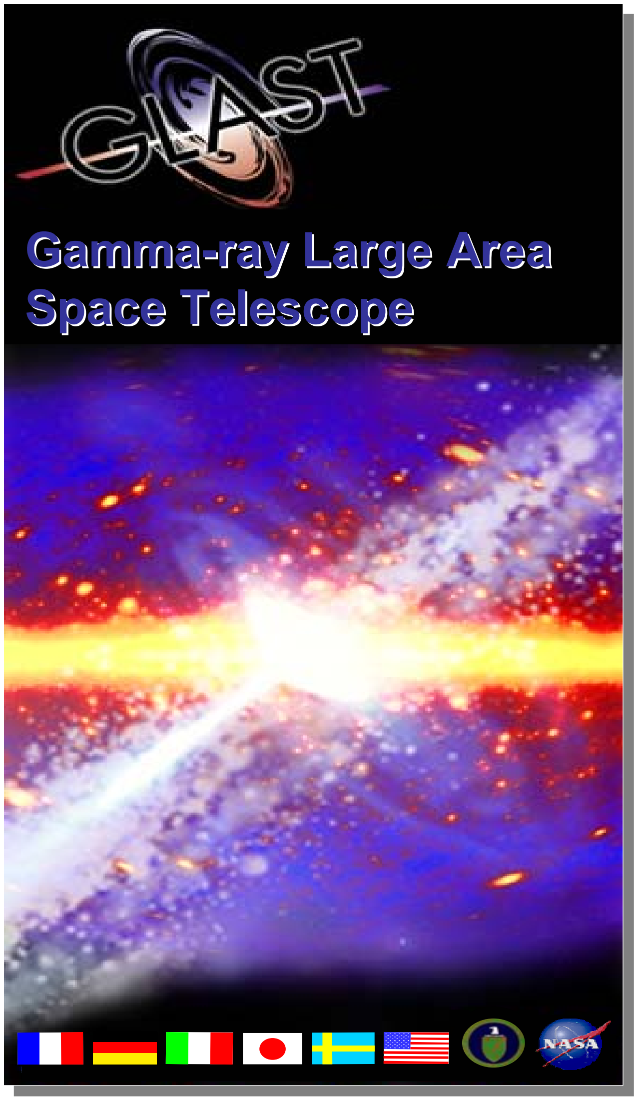


# Blazar Multiwavelenght Activities: Current Status

Stefano Ciprini – INFN Perugia & Univ.

**GLAST AGN/Blazar WG "Face-to-face" meeting**
**SLAC-Stanford, California, USA – March 4, 2006**

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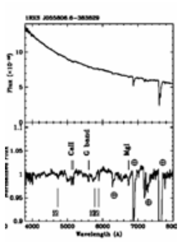
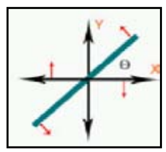
# Summary

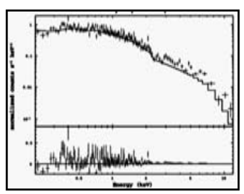
- Spectroscopy



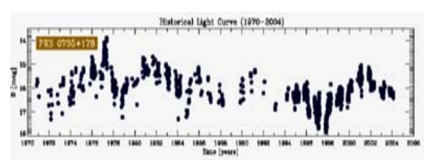
- Polarization



- MW campaign

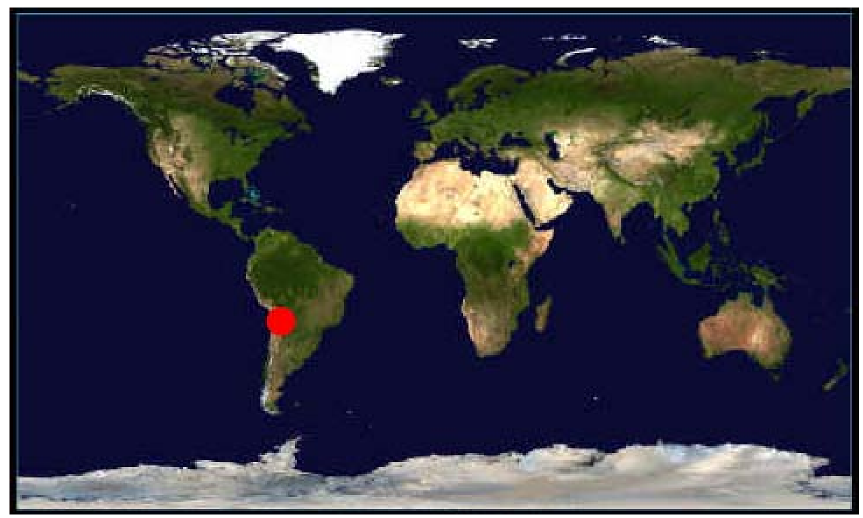


- Variability Monitoring



# ESO VLT high S/N spectroscopy of blazars with unknown redshift

- Redshift z (i.e. distance) of blazars is a fundamental parameter to understand and constraint the physics of relativistic jets, multiwavelength (MW) emission models and the bolometric power emitted in gamma-rays.
- Spectral cutoffs due to gamma-ray absorption produced by the IR-opt-UV extragalactic background light (EBL), can be well studied using blazar-probes at different redshifts.



# ESO VLT high S/N spectroscopy of blazars with unknown redshift

- A first observing program is accepted at the Very Large Telescope (VLT) of the European Southern Observatory (ESO, Cerro Paranal, Chile):
High S/N spectroscopy of 16 sources, (Period 77A, PI: S. Ciprini, COIs: J. Kotilainen & B. Sbarufatti).

- Times: observations (service mode) to be performed in the next southern winter; data release: end of 2006. Expected (prudent) success rate in new redshift determinations: 50%

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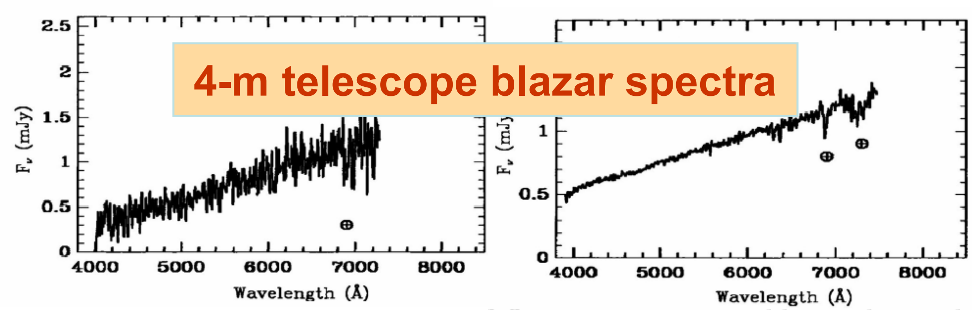
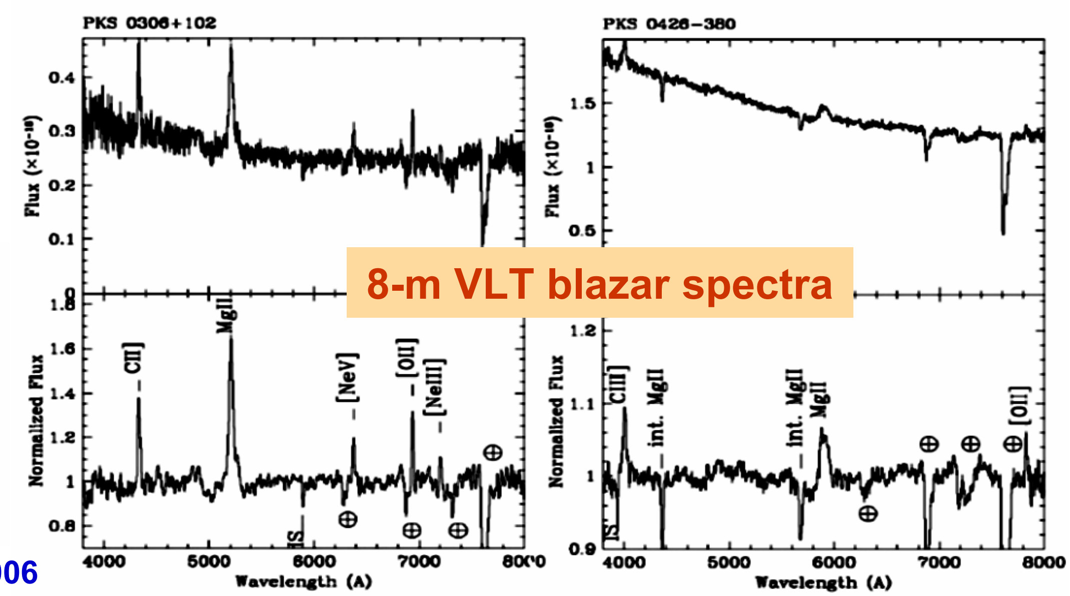
# ESO VLT high S/N spectroscopy of blazars with unknown redshift

**Why the VLT 8-meter (315 inch) "monster" telescopes ?**

- **Especially in pure BL Lacs, the quasi-featureless optical spectra hinders the determination of z, while new catalogues of fainter blazars are being assembled. Moreover currently a squad of well known and monitored blazars have still unknown redshift.**
- **The 4m-telescope class has achieved its limit regarding to such "hard-to-show-features" blazars, and to the new (and fainter) blazar candidates.**
- **High S/N needed in reasonable integration observing times.**



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# ESO VLT high S/N spectroscopy of blazars with unknown redshift

- Critical parameters for detection of spectral features are: (a) luminosity ratio between the nuclear and galaxy components; (b) the S/N of the observed spectrum; (c) redshift value and and the observed wavelength range.

- Criteria adopted in the sample selection: (a) sources classified as blazars (especially BL Lacs) with unknown redshift in the main surveys/catalogs/databases; (b) sources with DEC < +20°, mag(V) < 21; (c) sources with featureless spectra observed in 4-m telescopes; (d) new gamma-ray blazar candidates.

- Previous VLT program results (P71-P73, PI: A. Treves): high S/N level reached (up to 500) and features detected down to line EW = 1 Å.  A total of 42 targets observed: new z determinations for 18 BL Lac objects (12 through emission lines, 5 through host galaxy absorption features, 1 trough both), lower limit to z for 2 objects (through MgII intervening systems), 6 misclassifications, and 18 blazars were found still featureless.  Results published in  Sbarufatti et al. (2005a,b).

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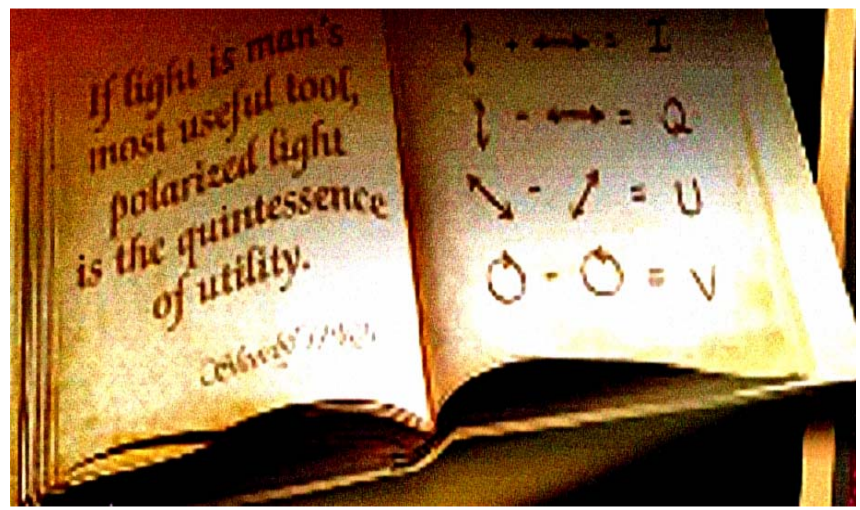
# Optical polarization snapshots of new blazar candidates

- ❑ **High degree (up to 30%) and variability of the optical polarization (OP) is one of the defining properties of blazars (especially the classical BL Lac objects and high-pol quasars HPQ). This means that OP observations are an important element in confirmation of new blazar candidates.**

- ❑ **High degree of OP is an evidence of strong non-thermal (synchrotron) and beamed radiation, and the signature of a population of high-energy (HE) emitting particles (possibly producing also gamma-ray photons).**

- ❑ **Optical telescopes are biased to select optically bright blazars, hence possibly intermediate-energy peaked blazars ( the best candidates to produce HE emission in the GLAST energy bands, i.e. GeV regime following the SSC scenario). The maximum level of information in the optical band is therefore desirable during LAT observations of blazars.**

- ❑ **Optical polarization could be an useful piece of information (both physical and geometrical) in GLAST multiwavelenght (MW) analysis of blazars.**



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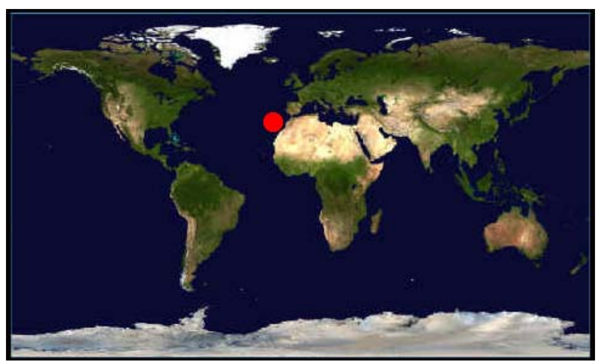
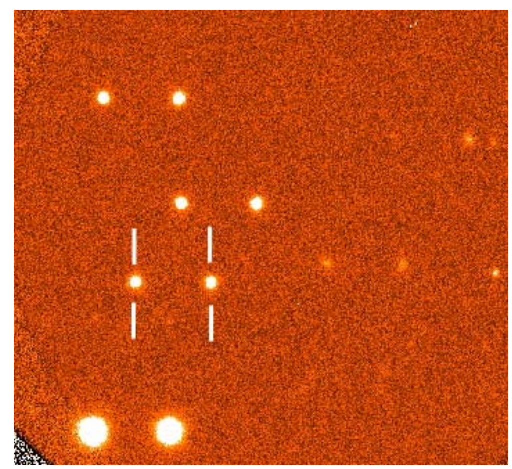
# Optical polarization snapshots of new blazar candidates

- Optical polarization observations of a sample of new blazar candidates is planned.
- Aims: 1) to confirm or not their BL Lac or HPQ status (useful for the GLAST pre-launch catalogs) 2) to have the first (or almost) measures of the optical polarization in such targets.
- Sample: possible, probable, new blazar candidates, and blazar with few or no optical polarization measures. Mag(V): 17-20
- A first run (2 nights at the 2.5m Nordic Optical Telescope, NOT, La Palma, Canary Islands) was performed in Sept.2005 (P31, PI: S. Ciprini, COIs: K. Nilsson & L.O. Takalo).
- About 65% of the granted time lost due to bad weather. Preliminary results: 6 objects can be confirmed as blazars (pol. Degree > 5%).
- Other observing applications are planned for 2-m class telescopes.

NORDIC OPTICAL TELESCOPE



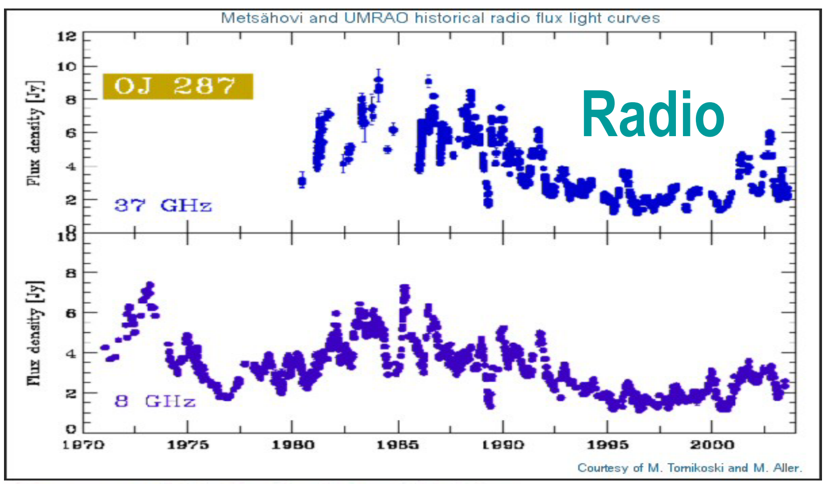


# MW Campaign on OJ 287

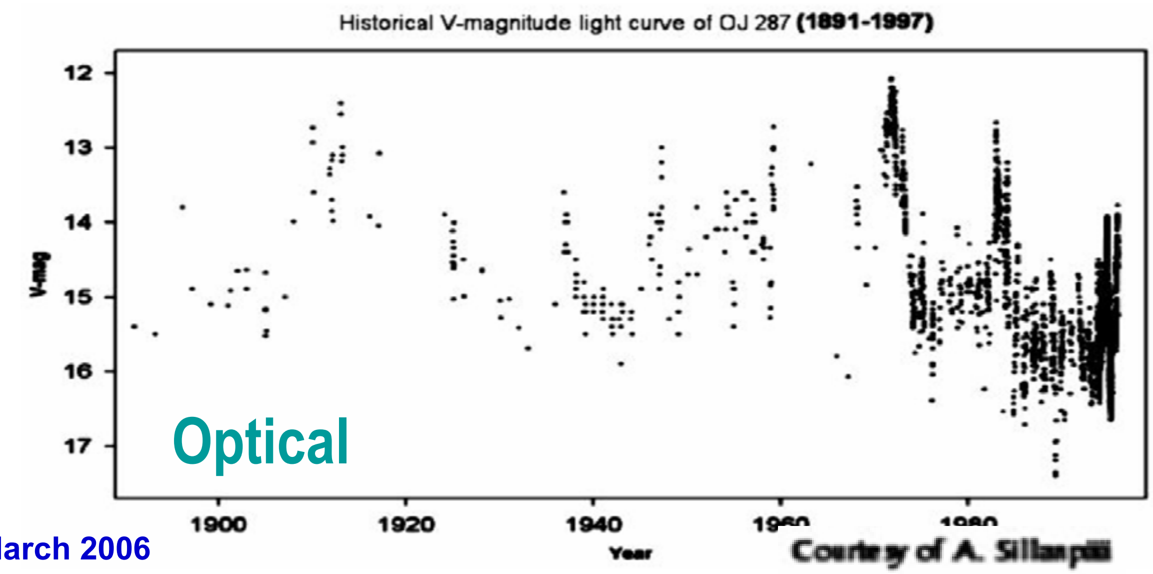
**Motivation**: the peculiar blazar OJ 287 (PKS 0851+202, 3EG J0853+1941, z=0.306) is the only extragalactic source showing a convincing evidence of a major periodical activity in the historical optical light curve, with outbursts occurring every 11-12 years (the last one was monitored by the OJ94 project, period 1993-1997). The next outburst is expected to occur in period 2005-2007. The origin of the supposed periodicity (or pseudo-periodicity, or intermittence, or…?) is unknown, but likely is to hold important clues to blazar variability in general.

OJ 287 2005-2008 Project web-page:

http://www.astro.utu.fi/OJ287MMVI/




Courtesy of M. Tornikoski and M. Aller.



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# MW Campaign on OJ 287

## Some of the ongoing MW programs on OJ 287:

- ❑ Long-term monitoring (OJ 287 2005-2008 Project and ENIGMA Campaign) begun in late 2004 (PM/CM: L. Takalo, A. Sillanpää ).
- ❑ VLBA radio structure/polarization observations in 5 bands: 6 times, 8h for the period 2005-2006 (more obs. planned in 2007-08) (PI: T. Savolainen).
- ❑ VLBA and Global 3mm-VLBI radio-mm structure/polarization observations (as a calibrator, April 4 and 17, 2005, PI: I. Agudo).
- ❑ ESO VLT spectroscopic optical observations (4 epochs, PI: K. Nilsson).
- ❑ XMM-Newton X-ray observations: 2 pointings of about 40 ksec each in cycle AO-4 (April 12, and November 3-4, 2005, PI: S. Ciprini). Another pointing scheduled in November 2006 (AO-5, PI: S. Ciprini).
- ❑ WEBT intensive ground-based MW campaign around the 2 XMM pointing epochs (CM: S. Ciprini) .
- ❑ ToO Effelsberg 100m radiotelescope flux/polarization observations on April 12 and Nov. 8-9-10 (ToO PI: L. Fuhrmann).
- ❑ 4 sessions of Global 3mm-VLBI observations in period Oct.2005-Apr.2007 (PI: E. Rastorgueva, K. Wiik).
- ❑ MAGIC gamma-ray Cherenkov telescope observations in January (10h) and November 2005 (>5h, this last in ToO mode, PI: E .Lindfors).
- ❑ Optical polarization monitoring at NOT (PI: K.Nilsson) and CalarAlto (2006-2008, PI: J. Heidt).

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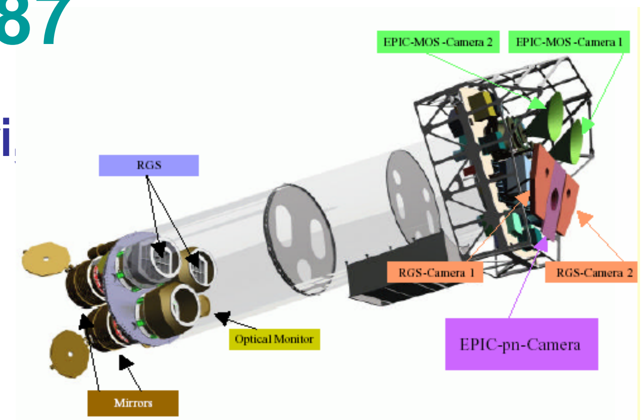
# MW Campaign on OJ 287




**XMM-Newton observations (AO-4, PI:S. Ciprini, COIs: C.M. Raiteri, L.O. Takalo, A. Sillänpää, M. Villata, L. Ostorero, M. Fiorucci), and coordinated WEBT campaign in 2005:**


OJ 287 observed by XMM-Newton twice (April 12, and November 3-4, 2005). Another observation accepted in Nov.2006 (AO-5, PI: S. Ciprini, COIs: C.M. Raiteri, G.Tosti, L.O. Takalo).


WEBT consortium radio-optical and coordinated campaign in April 2005 and October-November 2005 (part 1-2). (CM: S. Ciprini)


**http://www.astro.utu.fi/OJ287MMVI/XMMcampaign.html**

Stefano Ciprini - AGN/Blazar WG "*F2F Meeting*", SLAC, March 2006

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# MW Campaign on OJ 287

## Institutes/Observatories (and contact persons) participating in the MW ground-based coordinated campaign (part-1 only list):

**Optical Observatories:**

- 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)

**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)

# MW Campaign on OJ 287

**Aims of the X-ray and coordinated MW observations:**

- ❑ Study the spectral-temporal behaviour of OJ 287 on both short and long time scales, and in different brightness states (before and during the cyclic outburst).
- ❑ X-ray data likely provide information on the high-energy (inverse Compton, IC) spectral component, while radio-to-optical observations map the behaviour of the synchrotron bump.
- ❑ Possibly to clarify underlying physics, and relevance of geometrical and energetic models.
- ❑ Search for multifrequency correlations.
- ❑ To try out and to challenge a satellite-triggered coordinated MW campaign (in view of the future GLAST MW campaigns).

| 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 |

| Target - PI | RA | Dec | Position_Angle | |
|---|---|---|---|---|
| OJ 287 - S. Ciprini | 08:54:48.87 | +20:06:30.6 | 104:13:22.6 | |
| XMM Obs_Duration | XMM Obs: Start Time | XMM Obs: End Time | Satellite Revolution | IB |
| 51000 sec | 2005-11-03 at 20:59 UT | 2005-11-04 at 11:09 UT | 1081 | E3 |

The 2 XMM-Newton pointings performed in 2005

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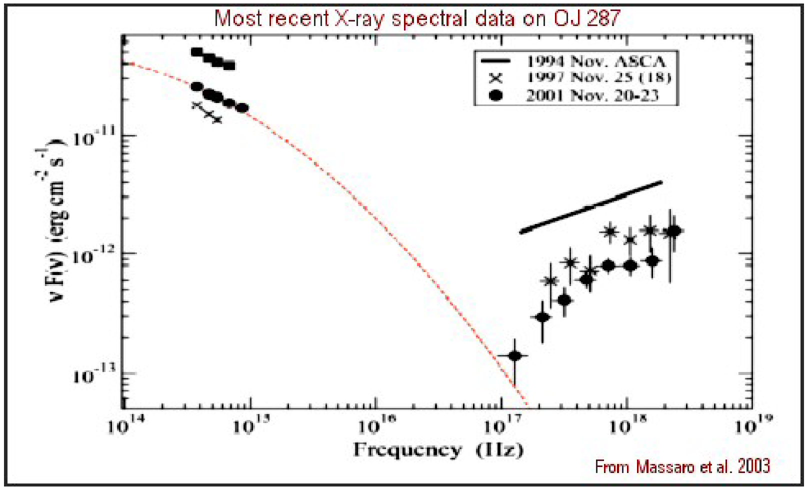
# MW Campaign on OJ 287

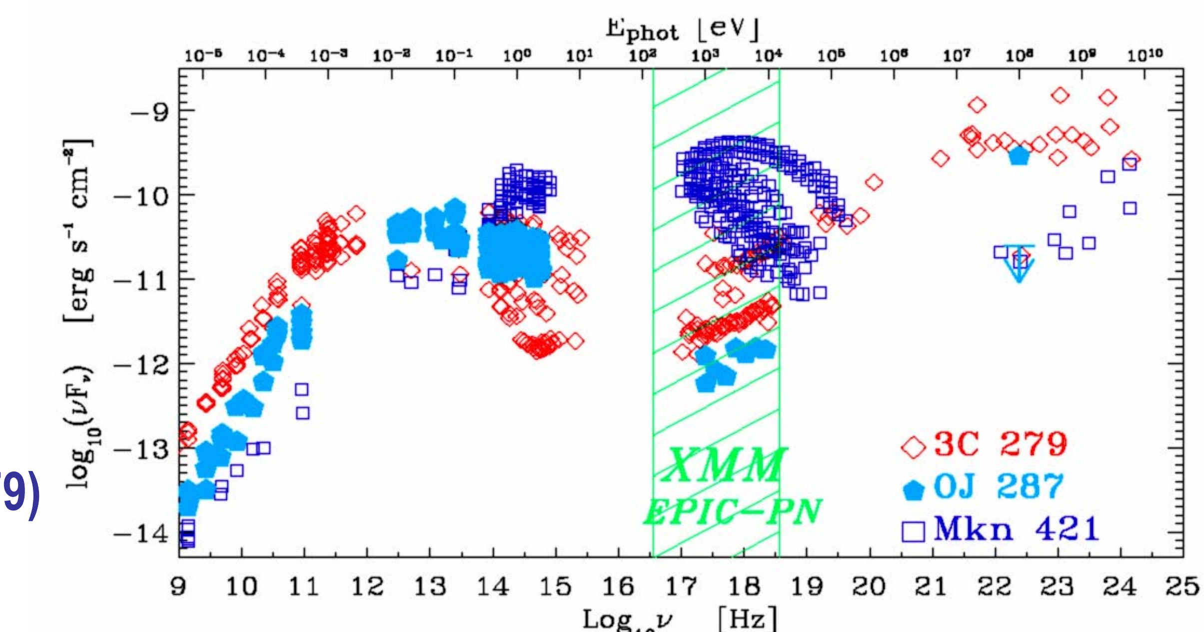



| Source name | Other names | EGRET detection | X-rays past observations | X-rays integral flux [erg cm$^{-2}$ s$^{-1}$] |
|---|---|---|---|---|
| **OJ 287** $z = 0.306$ | PKS 0851+202 PG 0851+202 | YES | Einstein, EXOSAT, ROSAT ASCA, *BeppoSAX* | $1.35\text{-}5.0 \times 10^{-12}$ (2-10 keV) (ASCA, SAX) |

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

| XMM AO-4 source visibility periods | Optical visibility window† |
|---|---|
| 2005.Apr.12 - 2005.May.05 2005.Oct.16 - 2005.Nov.18 | Oct-May |

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

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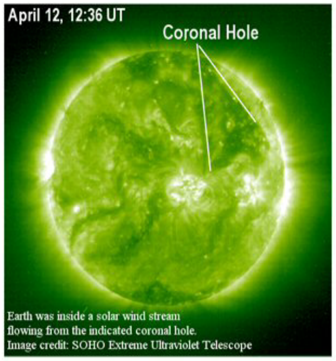
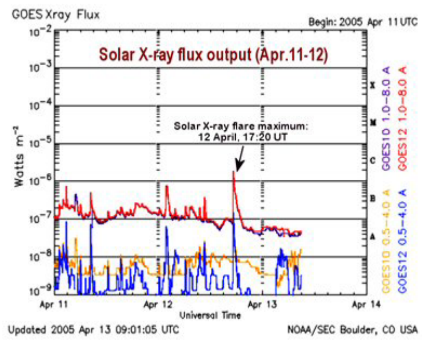
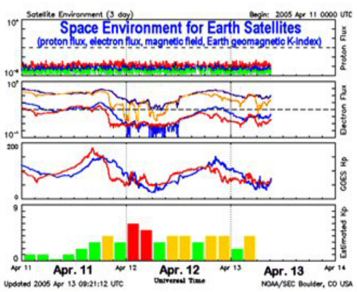
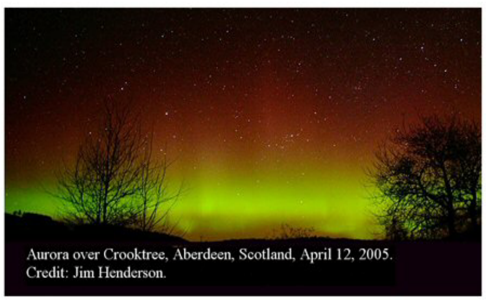
# MW Campaign on OJ 287



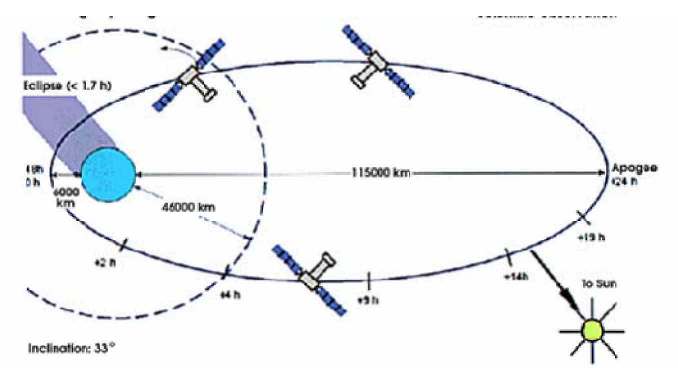



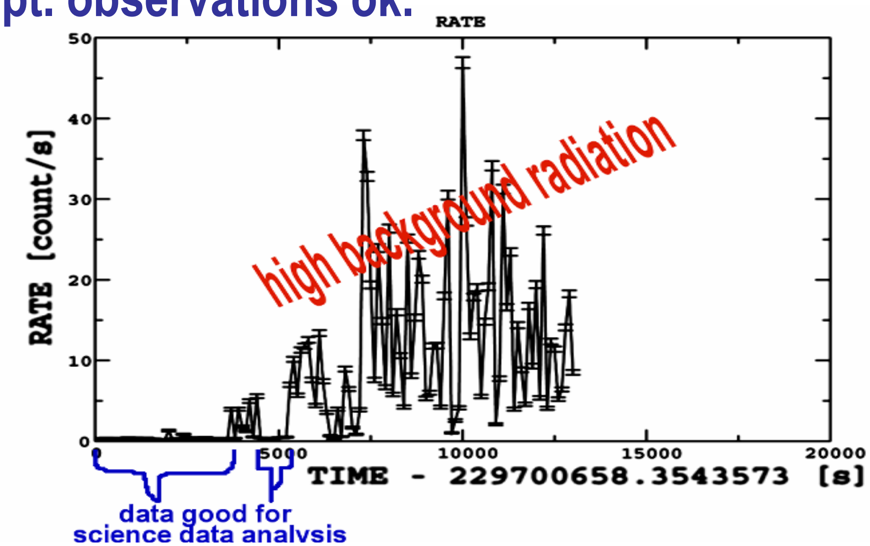

- April 2005 observations heavily affected by high background radiation (due to solar wind and earth proton belt) and stopped. Original 40 ksec granted (with overheads) only about 11 ksec performed and only about 5 ksec useful for science analysis!. Data screening needed. But November 2005 observation better.




- April observation instruments outcome: EPIC pn & MOS detection ok. RGS: no detection. OM: UV-opt. observations ok.

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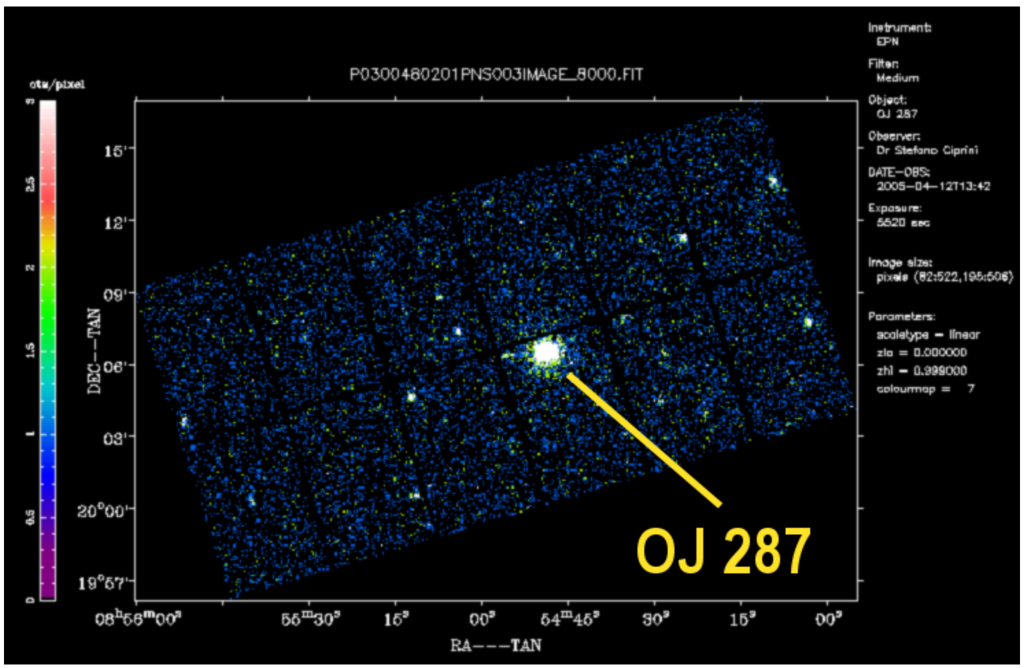
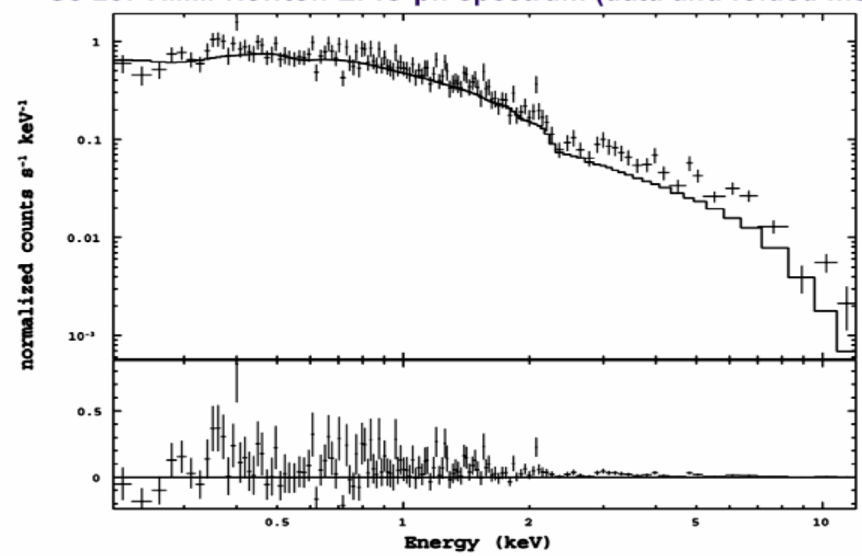
# MW Campaign on OJ 287

**OJ 287 (z=0.306) - Date: April 12, 2005, about 5 ksec data. XMM *EPIC pn* spectrum:**
**Model: single power law + absorption (galactic) in the 0.3-10 KeV range (preliminary).**




OJ 287 XMM-Newton EPIC-pn spectrum (data and folded model)




**Fit example:**

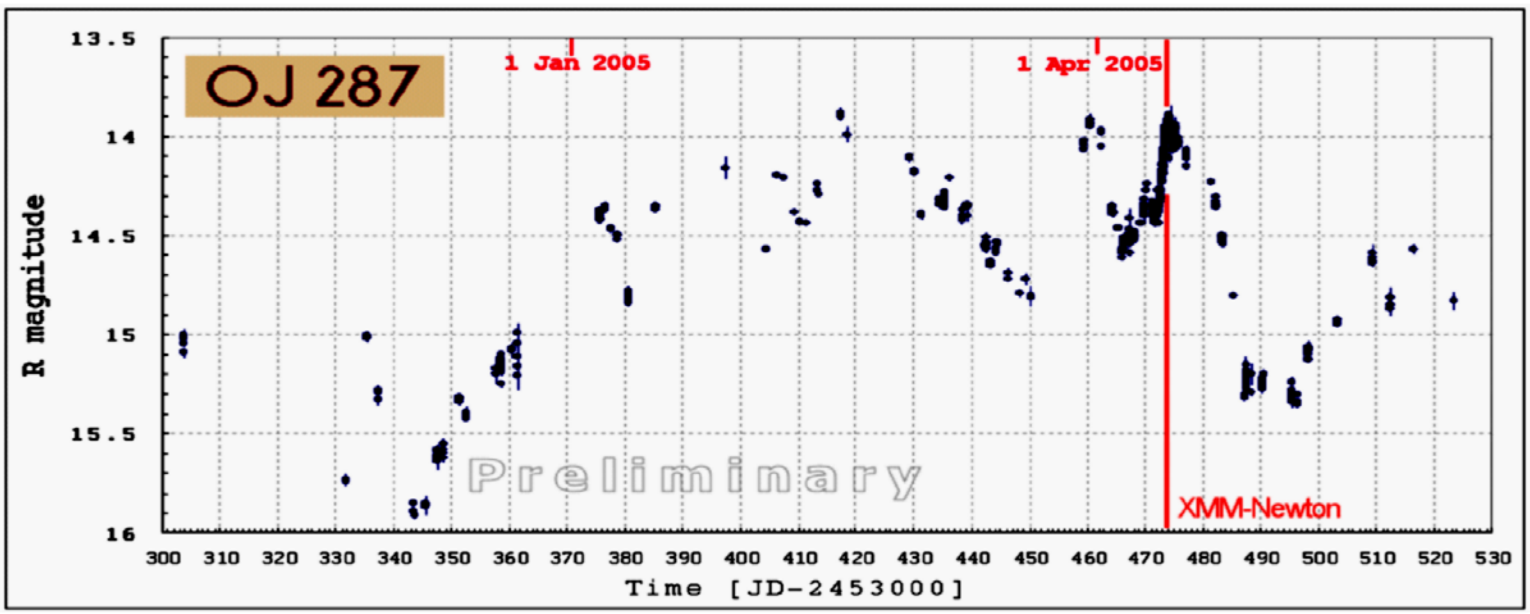
$N_H = 2.53 \times 10^{20}\ cm^{-2}$

$\Gamma = 1.734 \pm 0.010$

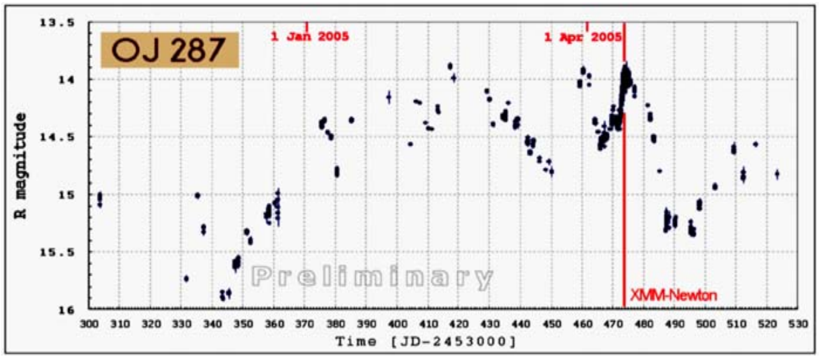
# MW Campaign on OJ 287

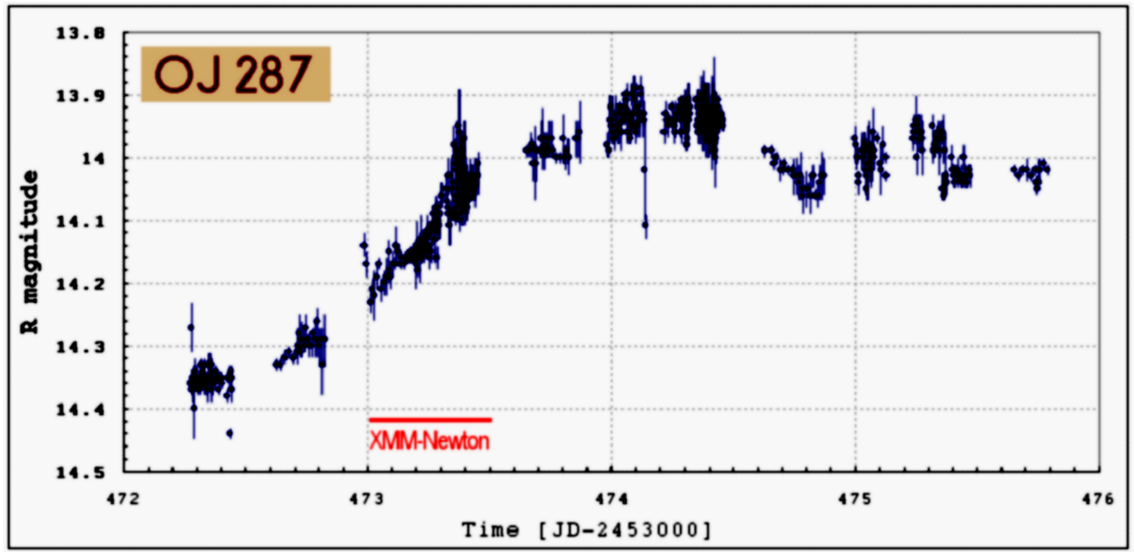
OJ 287 preliminary optical light curves in the previous observing season (Oct. 2004 - May 2005)

- Intermediate brightness level (no faint). Brightness increase of 2 mag in about 2.5 months.
- Mild-level flaring during the XMM-Newton pointing (April 12): increase of ~ 0.8 mag in 8 days, decrease of ~ 1.4 mag in 13 days.
- A more active and flaring state during the XMM-Newton observation of Nov.2005 (preliminary).



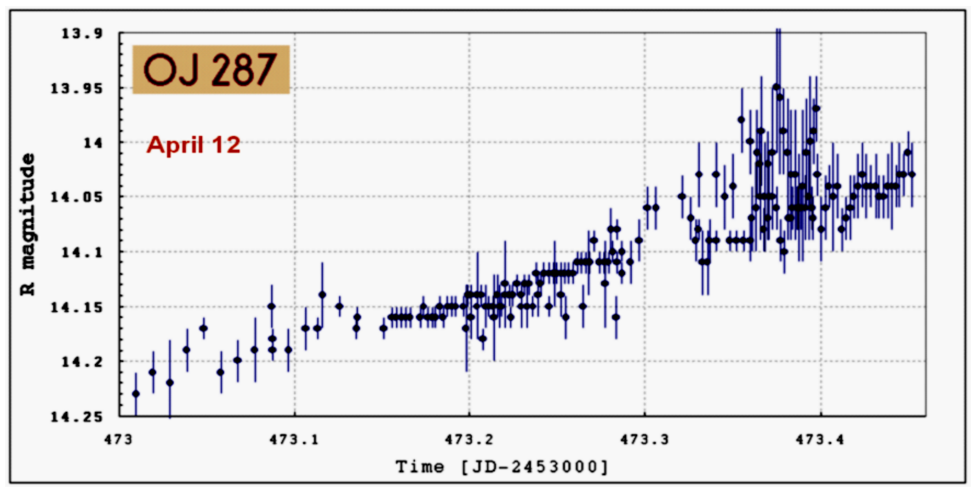
# MW Campaign on OJ 287




Optical light curves around April 12 , 2005 (XMM-Newton 1st pointing):

- ❑ About 0.3 mag brightness increase in less than 9 hours
- ❑ Possible optical Intra-Day Variability (IDV)



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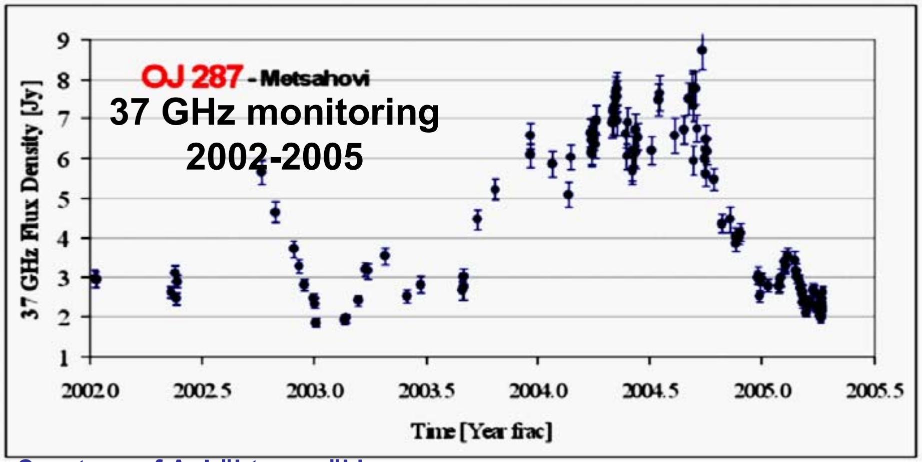
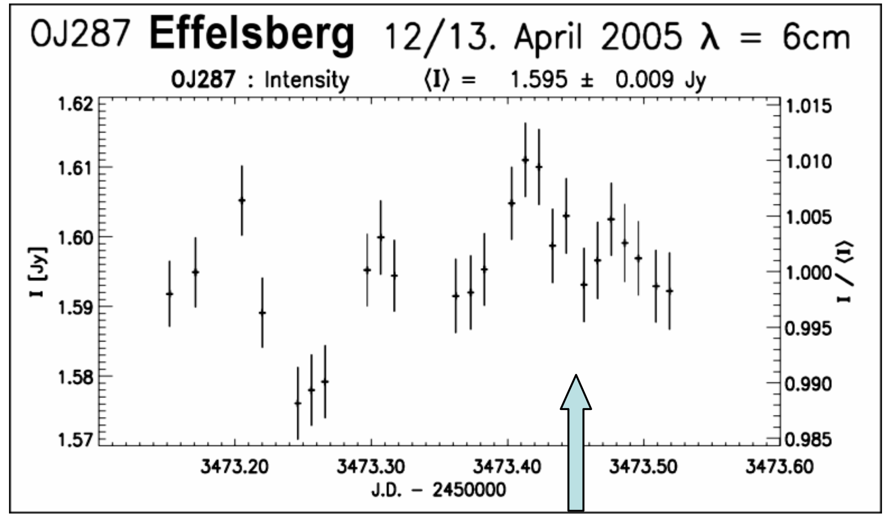
# MW Campaign on OJ 287

## OJ 287: April 2005, radio flux and structure:

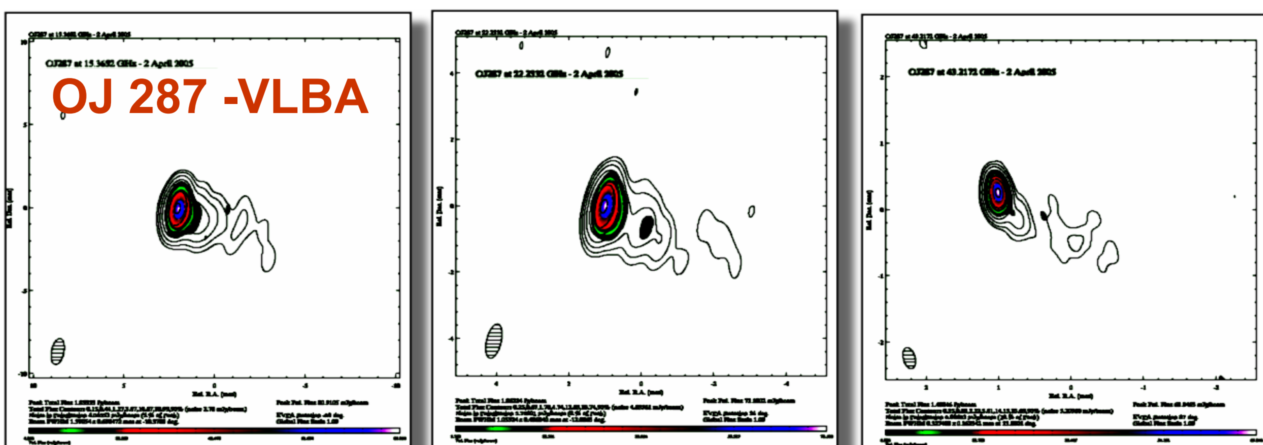



Courtesy of A. Lähteenmäki




Courtesy of L. Fuhrmann

IDV ~ 3%




VLBA radio structure/polarization observations in 3 bands (April 2, 2005).


Courtesy of I. Agudo

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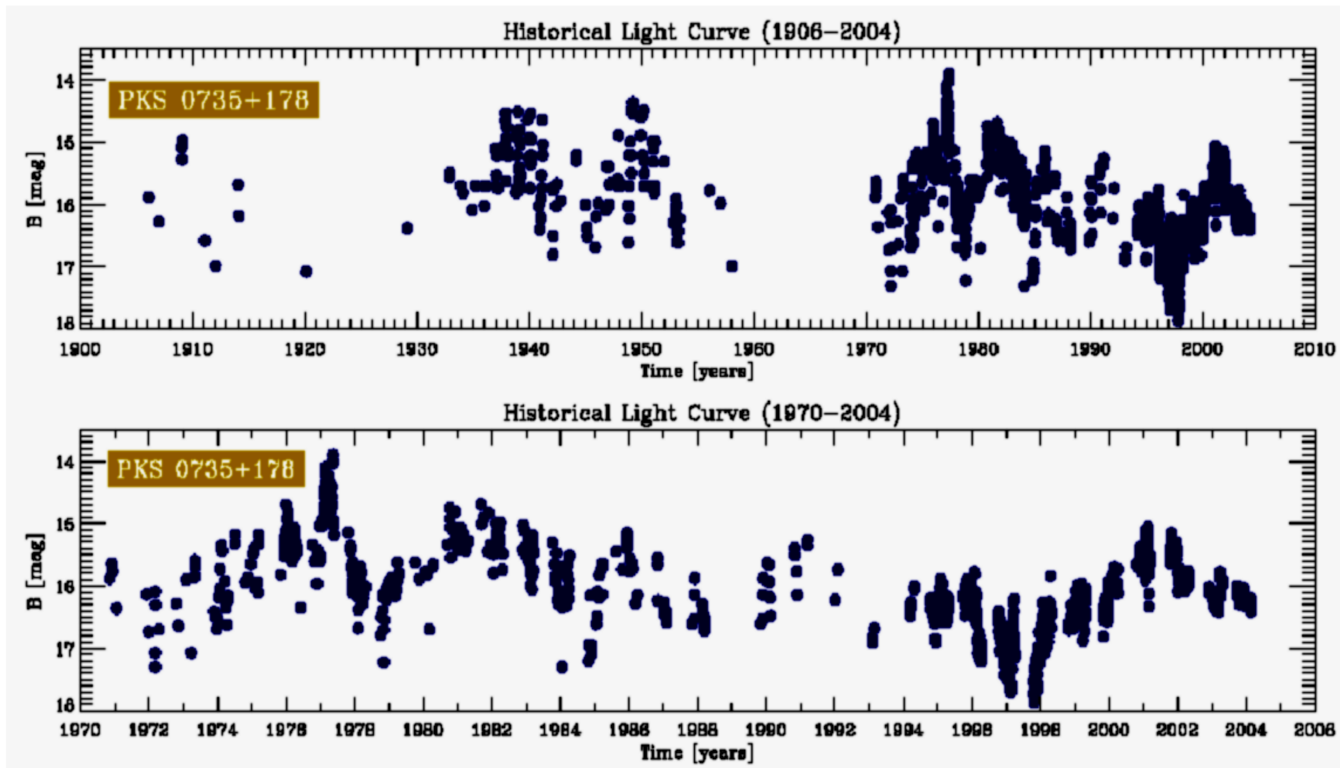
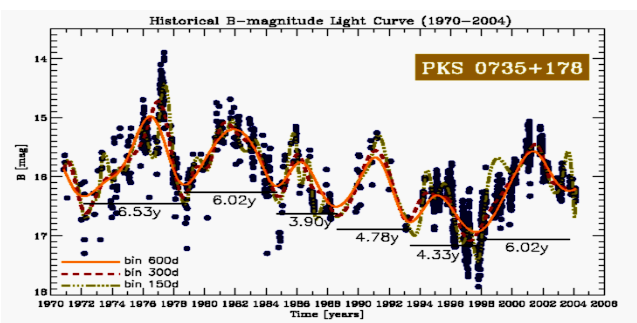
# Optical Variability Monitoring of PKS 0735+178

PKS 0735+178 (OI 158, 3EG J0737+1721, z=0.424) is both a radio and X-ray selected blazar. The source has been extensively studied in the radio. The radio flux appear to vary quite slowly in the radio. Several moving components detected (with VLBA and VLBI techniques). It displays a complex morphology and a twisted jet.

The historical optical data span over about 100 years. Rather good sampling starting from 1970.



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# Optical Variability Monitoring of PKS 0735+178

- 10 years (1994-2004) of unpublished optical monitoring data (*BVRI* bands) on PKS 0735+178 Data from Perugia Univ. Obs. (the bulk of data), INAF-Torino Obs., Tuorla Obs., Sabadell Obs.

- 11 observing seasons, 10 years light curves, 1637 photometric data points, almost 500 nights of observations.

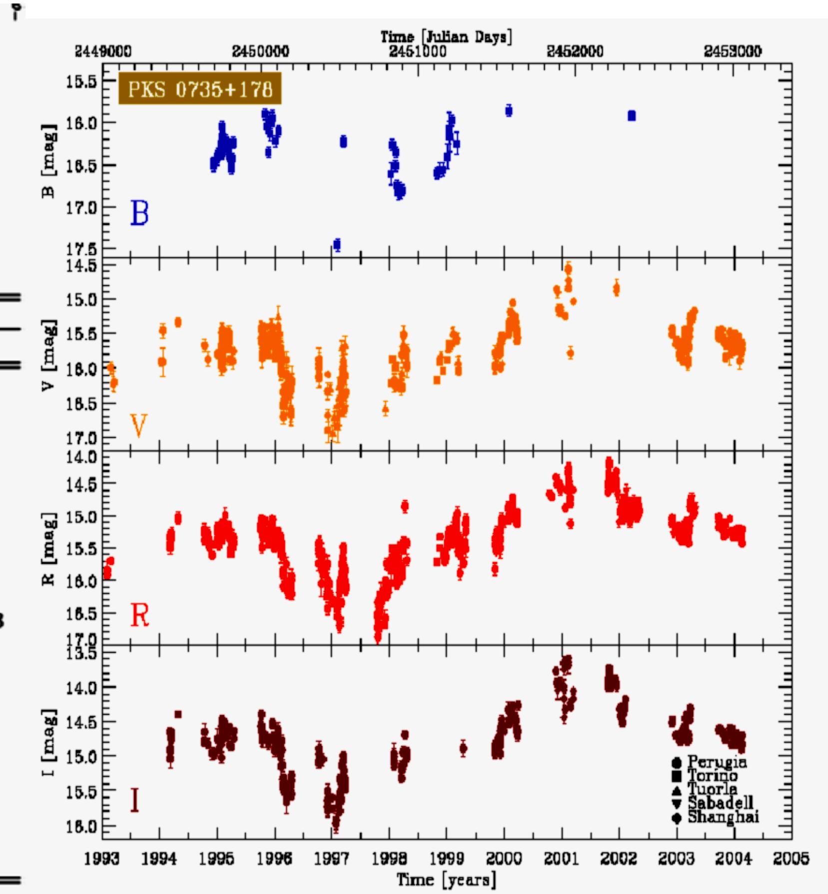
- Rapid optical variations connected to slower variations. General intermediate or low level of activity.

DATA POINTS PER OBSERVATORY

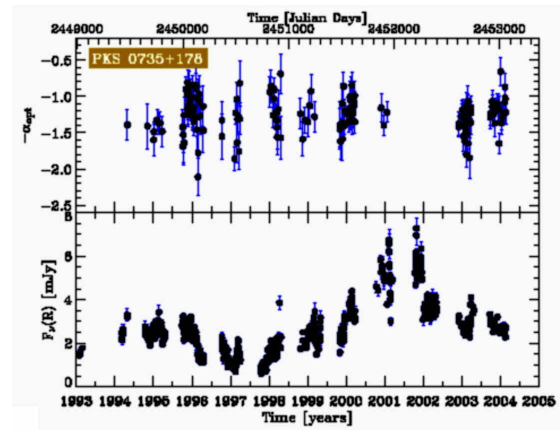
| Obs. | $B$ | $V$ | $R$ | $I$ | Tot. | Period |
|---|---|---|---|---|---|---|
| Perugia | 0 | 226 | 490 | 281 | 997 | Feb1993-Feb2004 |
| Torino | 75 | 38 | 150 | 0 | 263 | Dec1994-Apr2002 |
| Tuorla | 0 | 55 | 0 | 0 | 55 | Oct1995-Feb2001 |
| Sabadell | 0 | 0 | 17 | 0 | 17 | Dec2001-Feb2004 |
| Shanghai | 0 | 115 | 52 | 138 | 305 | Jan1995-Dec2001 |
| Total | 75 | 434 | 709 | 419 | 1637 | |

STATISTICS

| | $B$ | $V$ | $R$ | $I$ |
|---|---|---|---|---|
| Total data points | 75 | 434 | 709 | 419 |
| Start date [JD-2449000] | 698 | 45 | 21 | 420 |
| End date [JD-2449000] | 3354 | 4053 | 4053 | 4053 |
| Total period $N_{tot}$ [days] | 2657 | 4001 | 4032 | 3633 |
| Nights with data $N_{on}$ | 52 | 297 | 459 | 259 |
| $N_{on}/N_{tot}$ fraction | 0.019 | 0.074 | 0.171 | 0.071 |
| Mean num. points × night | 1.44 | 1.46 | 1.51 | 1.62 |
| Total mean gap $\Delta t$ [days] | 35.9 | 9.3 | 5.8 | 8.7 |
| Longest gap [days] | 780 | 352 | 375 | 356 |
| Average brightness [mag] | 16.319 | 15.760 | 15.301 | 14.693 |
| Max brightness [mag] | 15.863 | 14.544 | 14.16 | 13.59 |
| Min brightness [mag] | 17.453 | 16.94 | 16.87 | 15.97 |
| Variab. range $\Delta m$ [mag] | 1.59 | 2.39 | 2.71 | 2.38 |
| Absorption coeff.† [mag] | 0.152 | 0.117 | 0.094 | 0.068 |
| Data standard deviation | 0.256 | 0.368 | 0.515 | 0.453 |
| Data skewness | 1.23 | 0.386 | 0.329 | 0.155 |
| Data kurtosis | 3.791 | 1.087 | 0.019 | 0.400 |
| Max flux [mJy] | 2.21 | 6.1 | 7.3 | 9.9 |
| Min flux [mJy] | 0.51 | 0.67 | 0.60 | 1.1 |

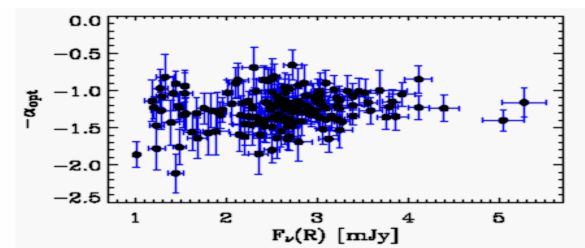


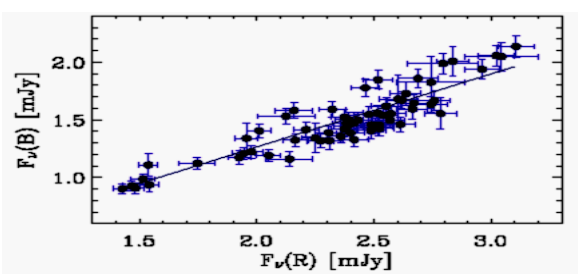
# Optical Variability Monitoring of PKS 0735+178

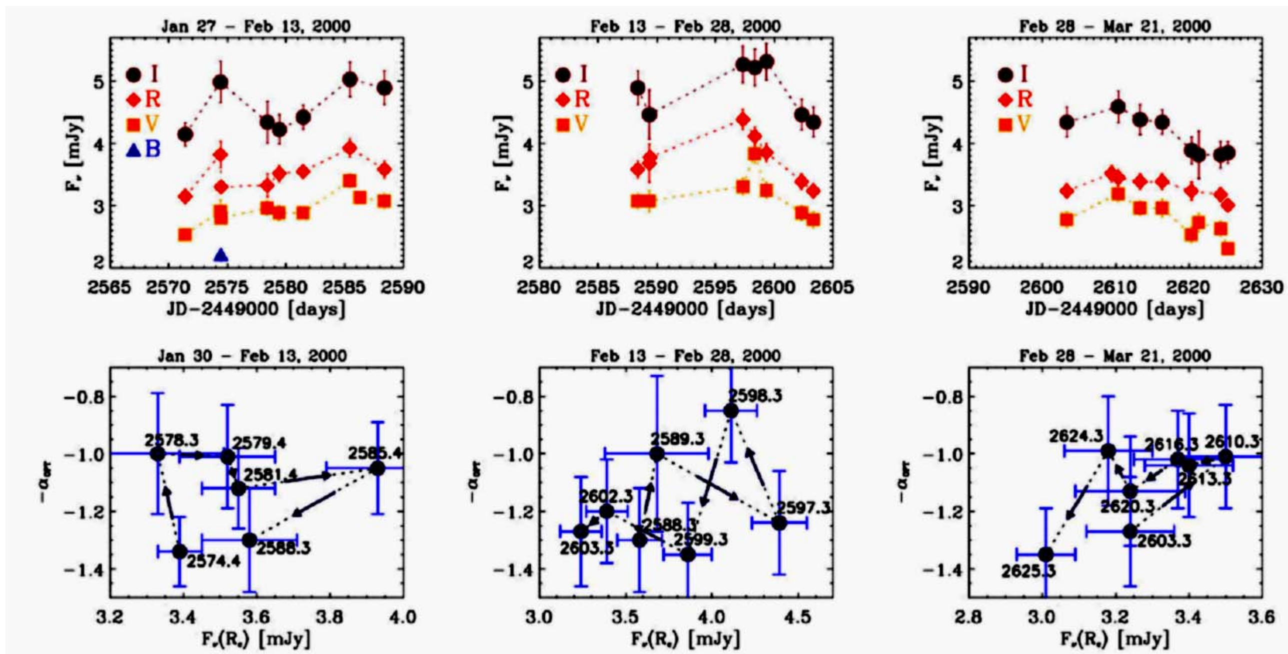



- **Multiband behaviour: Optical spectral indexes calculated and studied on years timescales. Long–term variability is essentially achromatic, whereas flares imply spectral changes.**

- **Evolution of the continuum optical spectrum as a function of the flux during epochs of flickering and moderate flaring activity does not show clear hysteresis loops.**

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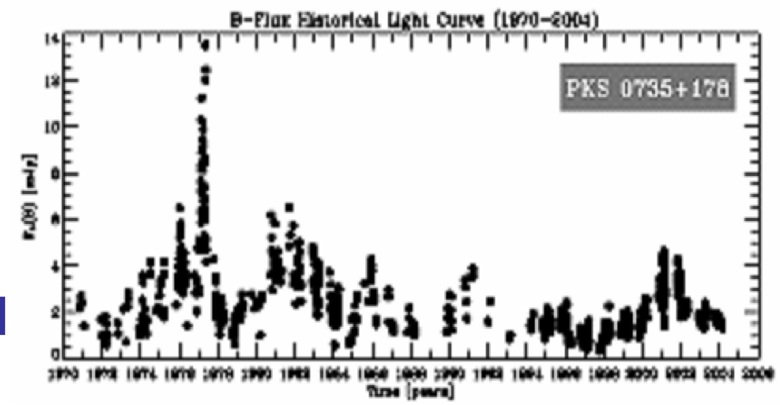
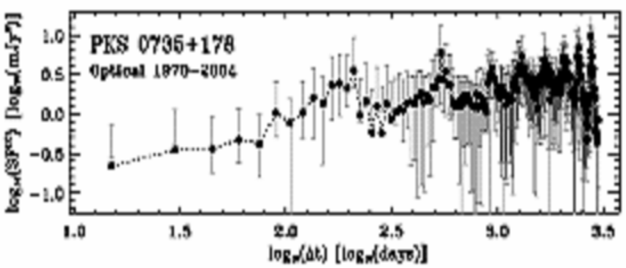
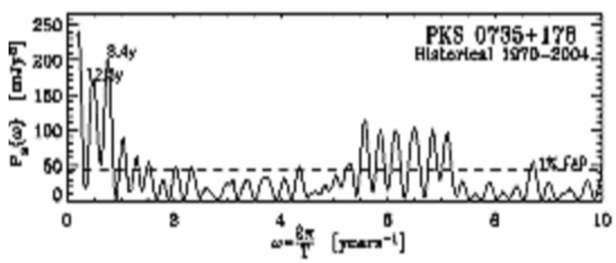
# Optical Variability Monitoring of PKS 0735+178

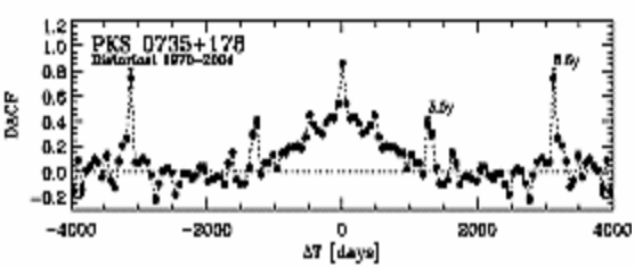
- **Temporal behaviour**: Temporal analysis of the optical variability. To search for coherent structures in the time domain, characteristic timescales and to identify duty-cycles and variability modes .

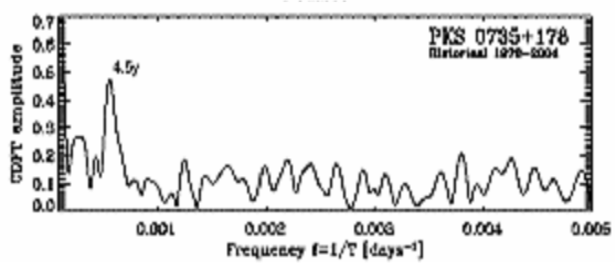
- Several methods applied to the historical light curve and to each single observing season. Long-term (years) and intermediate-term (weeks) timescales investigated.




- Discrete Correlation Function.
- Structure Function SF.
- Lomb-Scargle Periodogram.
- Clean Discrete Fourier Transform.

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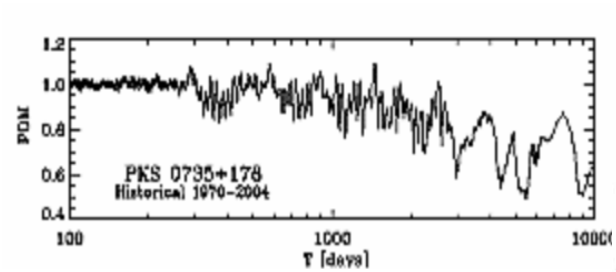


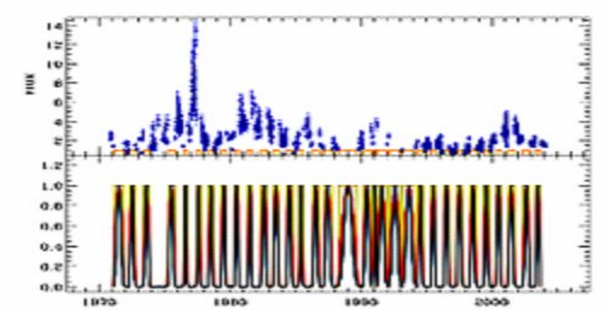

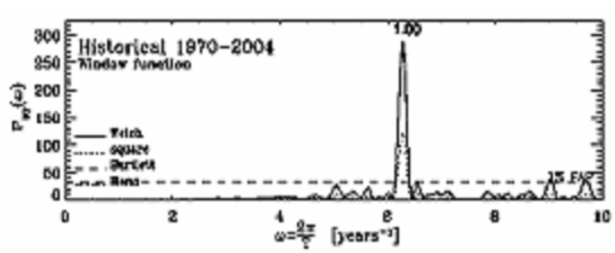


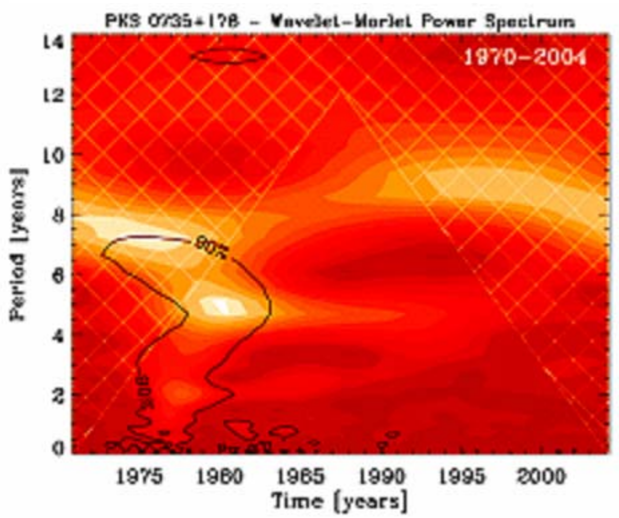


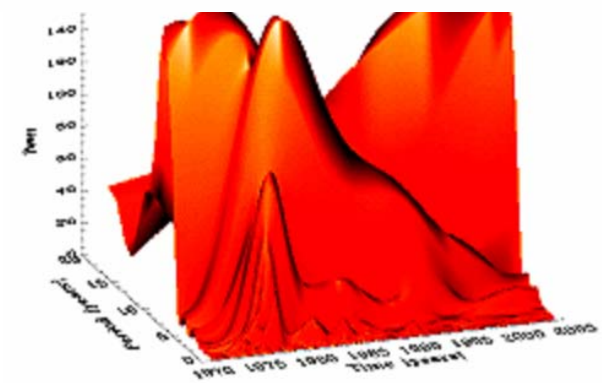

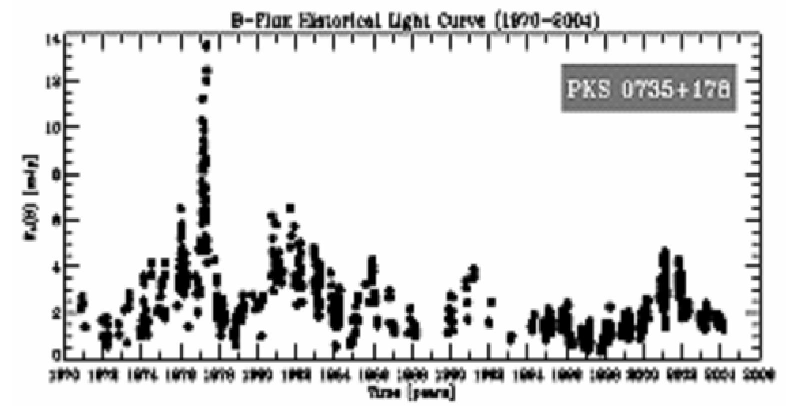


- Phase Dispersion Minimization.
- Gaps Window Function. periodogram GWFP.
- Discrete Wavelet Transform scalogram*.

**Such methods could be applied to LAT lightcurves.**

*: the two-dimensional energy density function DWT(t,T)^2, where DWT is the Discrete Wavelet Transform computed using a Morlet mother waveform, t and T the time and period scale respectively.

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# Optical Variability Monitoring of PKS 0735+178

**Summary of the characteristic timescales* revealed by the timeseries analysis (when possible) performed with the methods cited above. On long timescales some major temporal components, possibly modulating the long term trend are found. On intervals shorter than 200 days (monitored by our seasonal observations), there are not hints of typical recurrent timescales, but signatures of several intermediate (weeks) timescales. Data and results in Ciprini et al. (2006, submitted).**

| Observing season | Duration [days] | $N_{on}$ | $< n >$ | $< \Delta t >$ [days] | $\Delta t_{max}$ [days] | $SF\ T_{dr}$ [days] | $PSD$ slope $a$ | $SF\ T_{to}$ [days] | $DACF\ T_{pe}$ [days] | $LSP\ T_{pe}$ [days] | $CDFT\ T_{pe}$ [days] | $PDM\ T_{dr}$ [days] | $DWT\ T_{pe}$ [days] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $B$ 1906-2004† | 98.1y | 989 | 1.7 | 20.7 | 12.78y | 11.6y,25y, | ... | ... | 8.6y,24.7y | 8.6y,13.2y,33.7y | 34y | 8.2,12.6y,15.2y | 13.7y |
| $B$ 1906-1958† | 52y | 122 | 1.4 | 114 | 8.95y | 12.3y, 18.5 | ... | ... | 11.4y | 5.7y,10.8y | ... | 11.6y | 10.9y |
| $B$ 1970-2004† | 33.3y | 867 | 1.8 | 7.8 | 1.63y | 4.4y,8.1y,11.8y | 1.5,2.0 | 0.6y,1.5y | 3.5y,4.5y,8.6y | 8.4y,12.5y | 4.5y | 8.2y,12.6y,15y | 4.8y,7.4y |
| $R$ III Oct.94-Apr95 | 191 | 43 | 1.8 | 2.5 | 20.8 | 79 | ... | ... | 18 | ... | ... | 18,78 | 25 |
| $R$ IV Sep95-Apr96 | 203 | 62 | 1.4 | 2.3 | 12.9 | 39 | $1.97 \pm 0.25$ | ... | 28 | ... | ... | ... | 34 |
| $R$ V Oct96-Apr97 | 178 | 53 | 1.6 | 2.1 | 17.9 | 50,79 | $1.77 \pm 0.2$ | 36 | ... | 50,77 | ... | 77 | ... |
| $R$ VI Oct97-Apr98 | 189 | 52 | 1.3 | 2.8 | 15.9 | 32,66 | ... | ... | 68 | ... | ... | 33,66,97 | 95 |
| $R$ VII Oct98-May99 | 189 | 51 | 1.2 | 3.0 | 21.0 | 96 | $1.64 \pm 0.09$ | 31 | 54,96 | 53,102 | ... | 30,54 | 48,96 |
| $R$ VIII Nov99-Mar00 | 144 | 36 | 1.4 | 2.7 | 22.2 | 83 | $1.84 \pm 0.12$ | 78 | ... | ... | ... | 25 | ... |
| $R$ IX Oct00-Mar01 | 153 | 20 | 1.4 | 5.6 | 31.2 | 27,56 | ... | ... | 33 | 28 | 28 | ... | 40,76 |
| $R$ X Oct01-May02 | 201 | 62 | 2.3 | 1.4 | 24.8 | 69 | $1.46 \pm 0.17$ | 65 | 41 | 41,54 | 52 | 55,81 | ... |
| $R$ XI Nov02-Apr03 | 144 | 42 | 1.1 | 3.3 | 24.9 | 24,60 | $2.34 \pm 0.12$ | ... | 28 | 28 | 27 | 55 | 40 |
| $R$ XII Sep03-Feb04 | 148 | 33 | 1.0 | 4.6 | 21.0 | 18,55 | ... | ... | 20,42 | ... | ... | 56 | 52 |

† Time scales followed by "y" are expressed in years.

*: characteristic timescale: "the major scale of variability", i.e. where there is more energy in the power spectral density of the signal.