Observations of Mrk 421 with INTEGRAL

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1. Introduction

It was in 1992 that the first AGN, Mrk 421, was detected in the very high-energy domain (>500 GeV = $1.21 \bullet 10^{26}$ Hz) at the 6σ level (Punch et al. 1992). Since then four more AGNs were detected at these high energies. All these objects belong to the BL Lac type of AGNs. They are radio-loud sources with the radio emission originating mainly from a core region and not from lobes and they are characterised by a high polarization at radio (see Figure 5) and optical wavelengths and a strong variability at all wavelengths. The spectral emission characteristics point to non-thermal emission processes at nearly all wavelengths which presumably take place in a relativistic jet pointed at a small angle to the line of sight.

The spectral energy-density distribution of these sources is characterised by two smooth broadband emission components: a low-energy one which reaches a broad peak in the IR/X-ray region and a second one at TeV energies. Both emission components are clearly separated (see the spectrum of Mrk 421 in Figure 1). It is believed that both components are generated by the same electron population, the low-energy one via synchrotron emission, the high-energy one via inverse-Compton scattering of soft photons (for details see next section). This common origin would explain the similarity of the two components (Ghisellini & Maraschi 1996). Hence a similar timing behaviour is expected for both components if this scenario is correct. Such time correlations were indeed observed by previous observations at X-ray and TeV energies (Macomb et al. 1995; Buckley et al. 1996; Catanese et al. 1997). It is the aim of this proposal to study the relative properties in different X-ray bands and between X/γ-rays and TeV-quanta.

So far only few measurements between ~10 keV ($2.41 \bullet 10^{18}$ Hz) and ~1 GeV ($2.41 \bullet 10^{23}$ Hz) exist. COMPTEL has detected Mrk 421 in the 10-30 MeV ($2.41 \bullet 10^{21}$ - $7.24 \bullet 10^{21}$ Hz) range with 3.2σ during one of the cycle VII observations (Collmar et al. 1999). EGRET, however, has detected this source many times above 100 MeV ($2.41 \bullet 10^{22}$ Hz) at various significance levels (Hartman et al. 1999). Nevertheless the transition from the low-energy component to the high-energy one is only poorly known. This transition region falls exactly into the energy range of the two main instruments of INTEGRAL. Thus another intention of this proposal is to gather more information about this interesting region during a long observation of Mrk 421 with INTEGRAL.

2. Emission processes

It is the general belief that the low-energy component is the result of incoherent synchrotron emission of electrons moving at relativistic speed in the jet (Blandford & Rees 1978). The observed polarization at these wavelengths supports this idea (see Figure 5). The high-energy emission is less well understood.

Many different models try to explain this emission component. But a consensus seems to emerge on the basic physical process which is believed to be the inverse-Compton effect. In one scenario the low-energy synchrotron photons are boosted to high energies by the same electron population which creates the synchrotron photons [the synchrotron self-Compton (SSC) models, see e. g. Königl 1981, Maraschi, Ghisellini & Celotti 1992 and Bloom & Marscher 1996]. Although this process must be at work in all blazars, if the synchrotron-emission hypothesis is correct, it may not be the dominant one. In another model the seed photons for the inverse-Compton effect are not internally produced, but enter from outside the jet region [e. g. from the accretion disc or from clouds surrounding the jet (Dermer, Schlickeiser & Mastichiadis 1992; Sikora, Begelman & Rees 1994)]. Apart from these Lepton models the so-called Hadron models were proposed in which the high-energy γ-rays are produced by proton-initiated cascades (Mannheim 1993, Rachen 1999, Mücke & Protheroe 2000, Aharonian 2000).

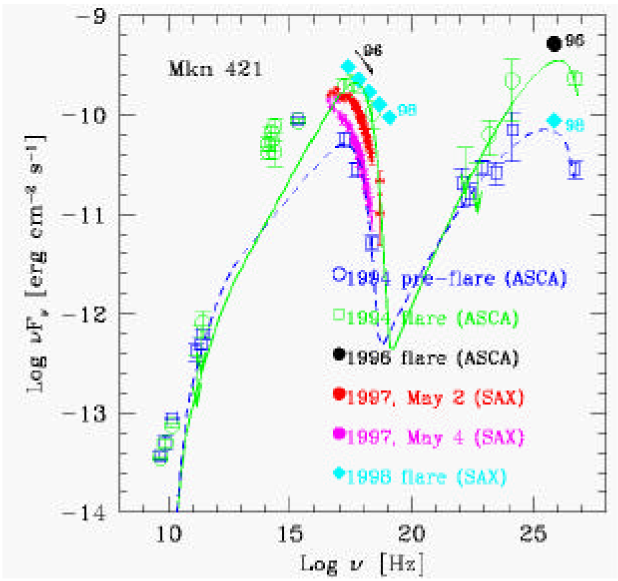

Figure 1: The multi-wavelength spectrum of Mrk 421 as observed by ASCA and BeppoSAX and Cherenkov telescopes.

The SSC model makes very definite predictions about the correlated behaviour of the high-energy end of both the synchrotron and SSC components (simultaneous variability of photons deriving from the same electrons, well defined correlated spectral changes in the medium/hard X-rays and TeV bands). The hadronic models have not been worked out in such detail yet. Several alternatives have been proposed and each needs to be quantified in more detail. However, in general one can say that in the leptonic models synchrotron radiation is "primary" and inverse Compton "secondary" while for hadronic models (at least in one of the versions) it is the opposite: the γ-rays are produced by the "primary" protons through cascades while the X-rays are of synchrotron origin from the "primary" electrons. In this case the relation between the two components can be less tight than for lepton models. Also, in the latter the "cascade" spectra are quite soft (lots of soft γ-rays). This could be constrained with the INTEGRAL observations.

3. Time variability

From observations of AGNs it is known that they are time variable on all different time scales. This holds true also for the TeV blazars. After the first flaring activity of Mrk 421 at these energies was observed in 1994 a systematic monitoring of Mrk 421 was started in 1995 by the Whipple telescope. This long-term monitoring revealed - besides several distinct periods of longer flaring activity - that this source shows also successive short-time variability with time scales of the order of one day or shorter. In May 1996 two fast flares were observed (Gaidos et al. 1996). The first one on May 7 had an intensity which was 10 times higher than the one of the Crab nebula (the highest flux ever observed from this source at these energies) with a time scale of <1 day. The second one on May 15 had an unprecedented time scale of ~30 minutes indicating a very small emission region! Apart from this flaring activity the source can also be in a high state for an extended period, for instance it has been bright practically continuously since the beginning of the year 2000, see CAT light curve for 1999 - 2000 of Figure 2.

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Figure 2: The CAT lightcurve of Mrk 421 at TeV energies from 1999 - 2000.

Among the phenomenological spectral sequence established by Fossatti et al. (1998), the red BL Lac are expected to be the best candidates for optical telescopes, since the synchrotron peak lies in the optical-UV range. Mrk 421 appears to be a blue BL Lac in this sequence. Different multi-wavelength campaigns have not detected strong optical variations during X- and γ-ray flaring events (Tosti et al. 1998 and references therein). However, from SSC we can expect an increase of the averaged optical flux with the global activity of the source. Long-term optical monitoring may also be crucial to link eventual longer-term optical emission to X- and γ-ray flares.

4. Spectral variability and intensity-spectrum correlation

The high flux level of Mrk 421 when it is in its active state allowed the derivation of precise spectra. Their knowledge is important because the shape of the spectrum is the result of the underlying emission process and allows to distinguish between theoretical models. The measurements revealed that the spectrum in the energy range 0.3 - 10 TeV ($7.24 \bullet 10^{25}$ - $2.41 \bullet 10^{27}$ Hz) can be described by a single power law. However the observation showed also that the spectral shape is not constant in time. Whereas during flares in 1996 a spectrum of $\sim E^{-2.5}$ was derived from the Whipple observations, the observation of this source by HEGRA in 1997 and 1998 revealed a remarkably different spectral shape ($\sim E^{-3.1}$). Since the observations with HEGRA were performed at a much lower source flux (~0.5 x the flux of the Crab nebula) than the one by Whipple (up to 10 x the Crab-nebula flux) an intensity-spectral-shape correlation is suggested by the result (i. e. the spectrum steepens with decreasing flux).

5. Multi-wavelength aspects

Most can be learned about a source from simultaneous multi-wavelength observations. Via variability correlations one can relate the different emission mechanisms to each other. Also similarities in the spectral shape can give a clue to the underlying physical processes. So simultaneous multi-wavelength observations are very important and therefore an important part of this proposal. The first clean correlated variability between TeV radiation, γ-rays and lower-energy emission from Mrk 421 was found in 1995 (Buckley et al. 1996, Takahashi et al. 1996). A flare was observed by the Whipple telescope which correlates clearly with the X-ray data of ASCA. Specifically a lag of about 4 ks between soft (0.5 - 1 keV or 1.21 • 10^{17} Hz - 2.41 • 10^{17} Hz) and hard X-rays (2 - 7.5 keV or 4.83 • 10^{17} - 1.81 • 10^{18} Hz) was found which was interpreted as an effect of radiative cooling of the electrons. A correlation with the EUVE and optical data with a smaller significance is suggested by these data, too.

This observation was confirmed by another multiwavelength campaign in 1998 (Takahashi et al. 2000) including telescopes from radio to TeV energies in which it was attempted to observe this source every night for one week. In summary it was learnt from this campaign that Mrk 421 flares daily and that these X-ray variations correlate with the TeV emission supporting the idea that the same electron population is responsible for the emission in both energy bands. They found also an indication for time lags between the 0.5 - 1 keV (1.21 • 10^{17} - 2.41 • 10^{17} Hz) flux and the 4 - 7.5 keV (9.66 • 10^{17} - 1.81 • 10^{18} Hz) flux. But these time lags are claimed to be artefacts of the low-Earth orbit instead of being intrinsic to the source by Edelson et al. (2001), since they were not seen in XMM PV observations of Mrk 421. We hope to prove or disprove the reality of these time lags with our measurements.

The result of measurements between BeppoSAX and Whipple which were performed just prior to the above-mentioned measurements showed that the medium-energy X-ray flare and the TeV flare are simultaneous to within ±1.5 hours (Maraschi et al. 2000). The result of this observation is shown in Figure 3. A more refined analysis of the timing behaviour of the flares (Fossati et al. 2000) revealed a clear correlation of the variability parameter F_{var} (Zhang et al. 1999) with the X-ray energy. They found also that the soft (0.1 - 0.5 keV or 2.4 • 10^{16} - 1.2 • 10^{17} Hz) X-ray band exhibits a slower variability than the hard (0.5 - 6 keV or 1.2 • 10^{17} - 1.45 • 10^{18} Hz) X-ray band. The statistical significance, however, is not overwhelming and needs a confirmation.

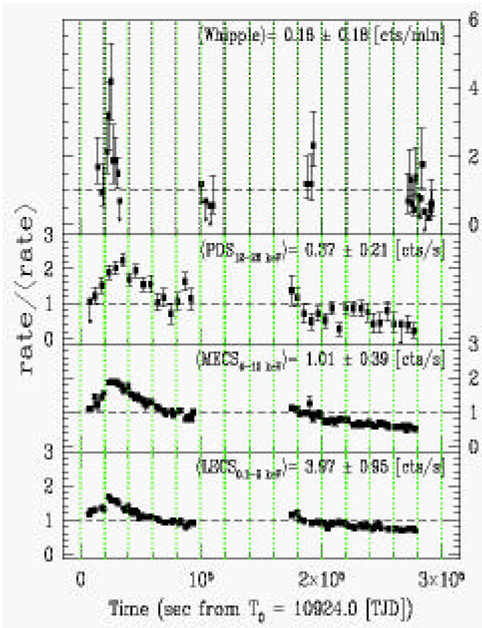

Figure 3: Light curves of Mrk 421 at TeV and X-ray energies (from Maraschi et al 1999).

6. Goal of the proposal

The aim of this proposal is to measure the drop off of the low-energy part of the emission spectrum and the increasing part of the high-energy emission component with INTEGRAL when the source is in its quiescent and in its active state. The spectral shape of the drop off will tell us, if compared with the cut off of the spectrum at TeV energies, something about the origin of the seed photons. If the spectral shapes of the two cut offs are identical then this would be a hint for an internal source of the seed photons. A difference of the spectral shape, however, would favour an external source of the seed photons. This interpretation, however, is only justified when the absorption of the high-energy photons on the intergalactic background light is negligible. For Mrk 421, because of its close distance (z = 0.031), this will be the case. Moreover the shape of this low-energy cut off may yield information about the radiative energy losses. It also traces the maximum energy of the accelerated particles which produce the photons with this cut-off energy thus yielding information about the acceleration processes (Kirk, Rieger & Mastichiadis 1998).

From the variability time scale which we hope to measure with INTEGRAL strong constraints on the particle dynamics can be posed. Since relativistic protons have much larger Larmor radii than relativistic electrons their time scale is much larger than the one of electrons. Our observations will therefore help to distinguish between Hadron and Lepton models.

In order to meet the goal of this proposal simultaneous measurements at all energies are mandatory. Therefore it is proposed to organize multi-wavelength observations at all wavelengths whenever the source is observed by the INTEGRAL instruments. Measurements at X-/γ-ray energies will be performed by the INTEGRAL instruments JEM-X, IBIS and SPI. Measurements at TeV energies will be carried out by CAT and Whipple. Observations at optical wavelengths will automatically be performed by the OMC, but also by several other optical telescopes as described in section 9. In addition measurements in the infrared and at radio frequencies are planned (see also section 9).

7. Technical Feasibility

Here it is estimated if INTEGRAL with its three instruments JEM-X, IBIS and SPI can detect Mrk 421 in its quiescent state and with what significance it is detected when it is active. For our estimation we assume that the energy-density spectrum of Figure 1 in the energy range 3-100 keV ($7.25 \bullet 10^{17}$ - $2.4 \bullet 10^{19}$ Hz) for the quiescent state can be crudely approximated by a power law with spectral index -1.

$$F_{quiescent}[\frac{keV}{cm^2 s}] \approx 3.2 \cdot 10^{-2} \cdot E_{keV}^{-1}$$

Based on this assumption we obtain then the flux values of Table 1.

Instrument	E-range [keV]	E_{mean} [keV]	Energy-density flux at E_{mean} [erg/(cm^2 s)]	Integral flux [cm^{-2} s^{-1}]	Differential flux at E_{mean} [cm^{-2} s^{-1} keV^{-1}]	Observation time for 5σ [s]
JEM-X	3 - 35	5.5	~$9.3 \bullet 10^{-12}$	$1.8 \bullet 10^{-3}$	$1.9 \bullet 10^{-4}$	$1.2 \bullet 10^{5}$
IBIS	25 - 100	40	~$1.3 \bullet 10^{-12}$	$2.4 \bullet 10^{-5}$	$5.0 \bullet 10^{-7}$	$1.0 \bullet 10^{7}$
SPI	40 - 100	57.1	~$9.0 \bullet 10^{-13}$	$8.4 \bullet 10^{-6}$	$1.7 \bullet 10^{-7}$	$7.3 \bullet 10^{8}$
IBIS, SPI	> 100	-	-	-	-	$> 10^{8}$

Table 1: Calculation of the observation time needed for a 5σ detection if the source is in its quiescent state.

The observation times in the last column were calculated for a 5σ detection. They were calculated using for JEM-X the formula given in the JEM-X Observer´s Manual from Orr et al. (2000) and for IBIS and SPI the observation-time-estimator tools of ESA assuming a hexagonal dithering pattern. Table 1 shows that unrealistic long observation times are needed to detect Mrk 421 above 100 keV ($2.4 \bullet 10^{19}$ Hz). Within a reasonable observation time only JEM-X will detect the source at hard X-rays when it is in its quiescent state.

For the active state we took the spectrum of Figure 4 which is close to the one observed with BeppoSAX in 2000. Based on the flux values derived from this figure we calculated the observation times needed for a 10σ (5σ) detection. At low energies (<100 keV) the source can easily be detected within 10^4 s with JEM-X and IBIS. Only at higher energies longer observation times are needed. Since we are not only interested in the hard X-rays, but also in the low-energy γ-rays, we ask for an observation of 10^6 s if Mrk 421 is in its active (or bright) state.

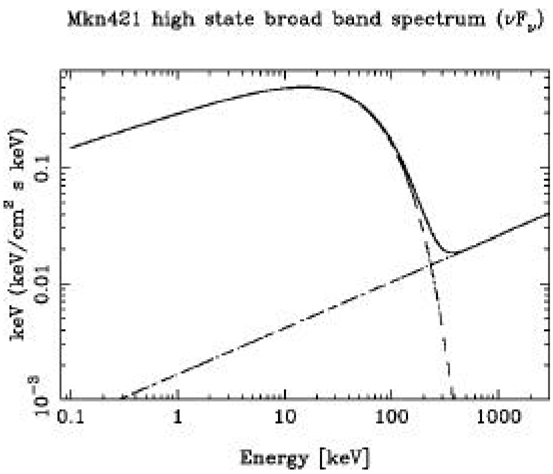

Figure 4: A theoretical high-state broad-band spectrum of Mrk 421.

Instrument	Energy range [keV]	Flux [cm^{-2} s^{-1}]	Observation time for 10σ [s]
JEM-X	3 - 35	0.138	$4.7 \bullet 10^{3}$
IBIS	25 - 100	$1.2 \bullet 10^{-2}$	$4.2 \bullet 10^{5}$
SPI	40 - 100	$4.8 \bullet 10^{-3}$	$2.9 \bullet 10^{7}$
IBIS	100 - 200	$5.2 \bullet 10^{-4}$	$\sim 8 \bullet 10^{4}$
SPI	200 - 500	$7.3 \bullet 10^{-5}$	$3.5 \bullet 10^{6}$ (for 5σ)
SPI	500 - 1000	$2.2 \bullet 10^{-5}$	$3.3 \bullet 10^{7}$ (for 5σ)

Table 2: Calculation of observation time needed for a 10σ (5σ) detection if Mrk 421 is active.

We base our request for such a long observation time of about one month on the following arguments:

1. If one wants to learn something about a source a bare detection at the 3σ level does not really help. Therefore we have chosen a 10σ (5σ for higher energies) level for our observation-time estimation which leads to these long observation times.

2. Our knowledge of the transition region from ~100 keV (~$2.4 \bullet 10^{19}$ Hz) to ~1 MeV (~$2.4 \bullet 10^{20}$ Hz) rests on theoretical predictions only. This region is therefore good for surprises. And even if the source is not detected one can hope to get upper limits which may constrain the theoretical models.

8. Observation strategy

Mrk 421 is visible for INTEGRAL twice per year, from May till June and from October till December. It is proposed here to observe this source when it is in a very active state showing an indication for a very hard spectrum at TeV energies. In order to obtain a trigger for a ToO observation for such an active state an observation program will be initiated with several Cherenkov telescopes (CAT, MAGIC, VERITAS) with the aim to observe this source regularly. Unfortunately the visibility times of Mrk 421 for these telescopes do not match very well with the visibility times of INTEGRAL for this source. In both visibility periods of INTEGRAL Mrk 421 can be observed by the Cherenkov telescopes only at large zenith angles leading to larger thresholds and to lower counting rates. It is therefore planned to perform an extensive TeV monitoring of Mrk 421 only during May and December, because during these months the observation conditions for the Cherenkov telescopes are best. The trigger criterium should be a detection of an intensity increase to ~3 Crabs for 3 successive nights. Since we want to optimize the return from the INTEGRAL observations a measurement of Mrk 421 is only envisaged, when it is in an exceptional hard state (as it was in January 2001, see Börst et al. 2001). Thus it is our intention to measure the spectral index at TeV energies and to derive the quiescent-to-mid-activity TeV index. We would like to trigger an INTEGRAL observation if this index shows a sign of hardening. Such hardness-ratio determinations are possible with Cherenkov telescopes within a couple of days. So in summary we have two trigger criteria:

1. an increase of the source intensity at TeV energies to 3 Crab.

2. an indication for a spectral hardening at TeV energies.

If these trigger conditions are fulfilled we ask for an as-quick-as-possible repointing of INTEGRAL [target-of-opportunity (ToO) proposal]. In this case we would like to observe Mrk 421 for 10^6 s.

Another instrument from which information about the state of Mrk 421 could come would be the all-sky monitor of RXTE. It measures X-rays in the energy range from 2 - 10 keV ($4.83 \bullet 10^{17}$ - $2.4 \bullet 10^{18}$ Hz), the range where the low-energy peak is located. Just recently an enhanced X-ray emission from Mrk 421 was detected by RXTE with its all-sky monitor. This detection triggered an observation by the Cherenkov telescope CT1 of HEGRA which detected very strong TeV activity from this source (Börst, Götting & Remillard 2001). It is the aim of the proposers to establish a similar procedure for INTEGRAL follow-up observations. It is also planned to ask for XMM observation time and to schedule simultaneous observations with INTEGRAL.

Since so far Mrk 421 was not detected in its quiescent state at hard X-rays and only marginal at low-energy γ-rays by COMPTEL (Collmar et al. 1999) a long observation by INTEGRAL of this source would be useful even if it is in this state. From Table 1 it gets obvious that unrealistic observation times are needed for an observation at γ-ray energies. But since nobody really knows the spectral shape at these energies an observation makes sense. Even if only an upper limit can be derived theoretical models could be severely constrained. So we ask for one long observation time of Mrk 421 for $2.5 \bullet 10^6$ s in the hexagonal mode if the source is in its quiescent state. We choose this mode, because we are also interested in the data of JEM-X and OMC. Both telescopes will detect Mrk 421 in $2.5 \bullet 10^6$ s with a high significance.

We propose to perform these observations in the hexagonal dithering pattern mode, as this mode will enhance the sensitivity of SPI. But using one single hexagonal dithering pattern, with the point source on axis, the equations which have to be solved for SPI image reconstruction are underdetermined. Very strong side lobes will appear in the image at distances of 10^O to 20^O from the centre. Therefore we propose a composed observation with four different pointings of the hexagonal dithering pattern with an offset of one degree in $l = l \pm 1^O$ and $b = b \pm 1^O$ from the source location (l, b). The idea of this composed mode is to increase the number of equations for the image reconstruction [A. Strong, private communicat.]. This mode of observation will not lead to reduction in the sensitivity and will improve the imaging capability of SPI. Furthermore it will ensure that the source will stay in the FoVs of IBIS, JEM-X and the OMC.

Because the study of AGNs addresses a key issue of INTEGRAL´s scientific research area it is our intention to continue this work with a similar request for observing time during AO-2.

9. Instrument Descriptions

9.1 The Radiotelescopes

The Torun Centre for Astronomy (TcfA, K. Katarzynski) will participate in the proposed observations with its 32 m radiotelescope. With its cooled receivers it will measure radiofluxes at 6 cm (5 GHz) down to 300 mJy with a precision of 40 mJy and better for stronger sources.

The results of the TCfA monitoring program for Mrk 421 show that one can expect variability with amplitudes from 600-900 mJy and a measurement precision between 20-40 mJy. Actually Mrk 421 is observed three times per week looking for variability time scales of days or weeks. However, after information about high-energy activity, it will be tried to increase the frequency of observations up to one per day. The same observational conditions apply for this proposal as well, however an increase of the observation frequency (up to five observations per week) during INTEGRAL campaigns is envisaged.

At the radio telescope in Nancay (H. Sol) complete spectra from 1.27 GHz (23.6 cm) to 3.4 GHz (8.8 cm) will be measured. This telescope is also able to measure the four Stokes parameters which describe the polarization. Such polarization data appear important in view of the polarization variations detected on BLBI scales (see Figure 5).

The Metsahovi radio telescope is a 13.7 meter dish located in Kirkkonummi, Finland (M. Tornikoski). It monitors AGNs at 22 or 37 GHz. It is planned to perform supporting radio observations with it during the INTEGRAL mission for many of the near-equatorial to northern INTEGRAL sources including Mrk 421. An advantage of this telescope is that its time allocation is relatively flexible allowing observations of Mrk 421 before and during INTEGRAL observations as well as conducting follow-up observations.

9.2 Very Long Baseline Interferometry (VLBI)

The VLBI technique provides the highest angular resolution achievable in astronomy (0.001") and permits imaging of the very inner regions of AGNs. Total-intensity and polarized VLBI maps of Mrk 421 are shown in Figure 5. Coordinated VLBI and CAT observations of this source were carried out in 1998 by two of the authors. These revealed very obvious and rapid changes in the core region of Mrk 421 at a time when it also showed strong TeV activity providing hints for a link between the behaviour of Mrk 421 on VLBI scales and the level of TeV activity (Charlot et al 1998). Similar observations are suggested here. The VLBI observing time is granted either by the European VLBI Program Committee (for the European VLBI Network) and/or by the American Program Committee (for the Very Long Baseline Array) based on scientific proposals. It is the plan to submit such a proposal on Mrk 421 once a decision about our present INTEGRAL proposal has been made.

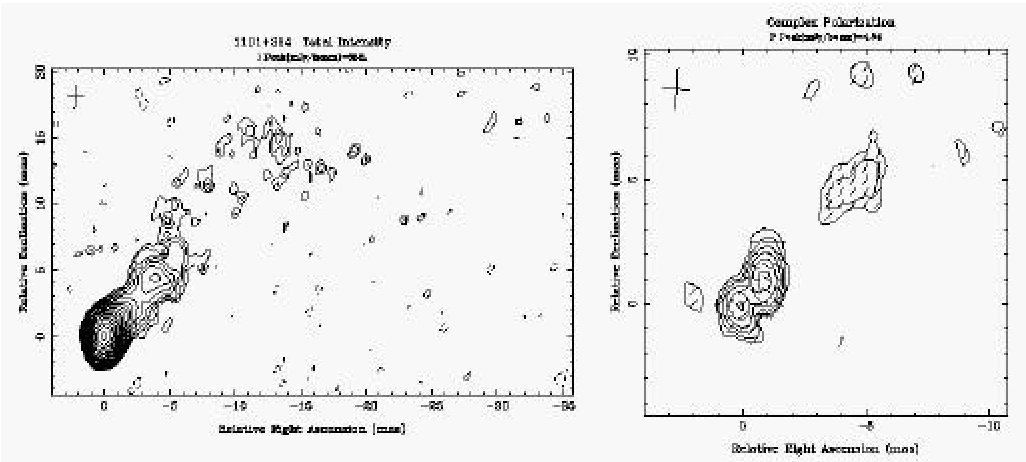

Figure 5: Total intensity (left) and polarized (right) VLBI images of Mrk 421 at 3.6 cm
(from Charlot et al. 1998)

9.3 The IR telescopes

In the IR we propose to use the facilities of the service mode offered on large telescopes as UKIRT on the Mauna Kea. Coordinated with the INTEGRAL observations we shall apply for such observation times which can be sent at almost any time allowing also for observations under alarm.

9.4 The optical telescopes

TAROT (Tèlèscope à action rapide pour les Objets Transitoires; A. Marcowith) is an automatic observatory dedicated to real-time follow-up observations of optical transient counterparts of cosmic γ-ray bursts. However, it is also used for a systematic survey of active galactic nuclei. Reaching a limit magnitude in the V-band of 16-17 it can detect relative magnitude variations to better than 10%. Data in 6 filters are available (C, B+V, R, I, V). Its latitude location (at Calern plateau close by Nice) is the same as the one of the CAT and Celeste Cerenkov telescopes. TAROT is then the perfect optical counterpart for the high-energy ground-based telescopes.

The Bordeaux Observatory CCD Meridian Telescope (P. Charlot) measures in the V-band down to a limiting magnitude of 16 with an accuracy of 0.05 magnitude. Therefore it can easily detect Mrk 421 (~13 magnitude). Since 1998 this telescope observed regularly about 50 AGNs including Mrk 421. In 1999 and 2000 this source was observed at specific periods, generally following alerts initiated by CAT. Figure 6 shows the light curve obtained in early 2000 after such an alert. Since 2001 Mrk 421 is observed as much as possible, i. e. every night during its visibility period, it will also be observed during the times when INTEGRAL is observing Mrk 421.

Optical observations will also be performed with two telescopes from Tuorla (a 70 cm and a 1 m telescope) and with the 60 cm KVA telescope on the La Palma observatory (A. Sillanpaa, L. Takalo).

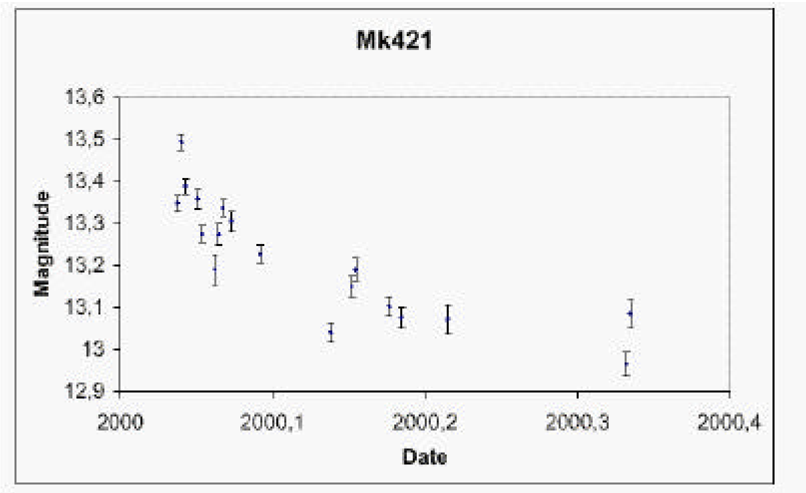

Figure 6: Optical light curve of Mrk 421 obtained in early 2000 with the Bordeaux Observatory CCD meridian telescope.

9.5 Cherenkov telescopes

A decisive contribution to our planned observations comes from the Cherenkov telescopes. They measure γ-rays in the TeV energy range by measuring the Cherenkov light from air showers. These telescopes will act as trigger telescopes for our ToO observations as outlined in section 8. People from the CAT in France (A. Djannati-Atai, B. Degrange, F. Piron, M. Punch), MAGIC on La Palma (K. Mannheim and A. Saggione) and VERITAS from the United States (J. Finley, D. Kieda and T. Weekes) are involved in this proposal. All these telescopes will monitor the source regularly and alert us if a significant increase of the flux from this source is observed.

Instrument	**Measurement range**	**Limiting sensitivity**	**Trigger instrument**
Torun radiotelescope: 32 m dish	6 cm (5 GHz)	300 mJy	No
Metsahovi radiotelescope: 13. 7 m	22 & 37 GHz	100 mJy	yes
TAROT	visible	16 magnitude	yes
Bordeaux Obs. CCD meridian Tel.	visible	16 magnitude	yes
Tuorla telescope: 70 cm	V-band filter	18 magnitude	Yes
Tuorla telescope: 1 m	V-band filter	18 magnitude	yes

60-cm-KVA telescope on La Palma	BVR filters	19 magnitude	yes
XMM	0.1 - 15 keV	$3 \bullet 10^{-16}$ erg/(cm^{-2} s^{-1}) (for 100 ks)	no
CAT	300 GeV - 15 TeV	10^{-12} cm^{-2} s^{-1} (> 250 GeV)	Yes
CELESTE	50 GeV - 300 GeV		yes
MAGIC (La Palma)	30 GeV - 30 TeV	10^{-11} cm^{-2} s^{-1} (at 50 GeV) 10^{-13} cm^{-2} s^{-1} (at 1 TeV)	Yes
VERITAS (Whipple)	300 GeV - 10 TeV	~10^{-12} cm^{-2} s^{-1} (> 100 GeV)	Yes

Table 3: The characteristic properties of the telescopes/observatories/instruments involved in this multi-wavelength study (without the INTEGRAL instruments).

10. Interpretation of the data

This analysis will be performed as a collaborative effort and will be co-ordinated by the PI. The team has a great experience in analysing observational data and to interpret them theoretically. The results of the observations proposed here will be made available as quick as possible to the scientific community via the usual tools (talks on conferences and publications in refereed journals).

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