DEADLINES: 1st of Feb., June, Oct.
EMAIL TO: tventuri@ira.inaf.it (EVN PC Chairman)

rcvd:

(1) Date Prepared: April 20, 2009

(2) Title of Proposal: PMN J0948+0022: a newly discovered peculiar γ-ray blazar under the lens of a global array

(3) AUTHORS (Add * for new location)	INSTITUTION	E-mail	G/U	Students Only: For Thesis?	Students Only: Ph.D. Year
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see attached list					

(4) Related previous or current VLBI proposal(s): RSG02 ◯ Resubmission

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(7) Scientific Category: ◯ astrometry & geodesy ◯ galactic ⊗ extragalactic ◯ other:
Rapid Response Science: ◯ Known Transient ◯ Exploratory ⊗ Target of Opportunity

(8) Wavelength(s) requested (those not available on the global network are indicated with a small circle):
◯ 90cm ◯ 50cm ∘ 30cm ◯ 21cm ◯ 18cm ◯ 13cm ◯ 6cm ∘ 5cm ◯ 3.6cm ◯ 3.6/13cm
∘ 2cm ⊗ 1.3cm ◯ 7mm ◯ 3mm
⊗ Global Network standard bands ◯ Special frequencies:________

(9) Recording format: ◯ Default continuum setup (VLBA only), ◯ VLBA/MkIV, ◯ MkIII: Mode____
Bandwidth per BaseBand channel: ____
Aggregate bit rate: 512 (8 BB channels at 32 MSamples/sec of ◯ 1 bit, ⊗ 2 bit)

(10) ⊗ Multi-epoch observation: 3 epochs of 8 hours each, separated by 4 weeks

(11) Network	Requested antennas	Total time requested
EVN & MERLIN	Cm, Ef, Jb, Mc, Mh, On60, Sh, Ys	3×8
VLBA		
other NRAO		
ATNF, other	Mo, Ho, Ka (Pk, ATCA)	3×8 (2×8)
Non-VLBI Intruments		

(12) ABSTRACT (Do not write outside this space. Please type)
A gamma-ray source positionally consistent with the flat spectrum radio quasar PMN J0948+0022 has been detected by the Large Area Telescope onboard the *Fermi Gamma-ray Space Telescope*. On the basis of its optical spectrum, the source is classified as a narrow line Seyfert 1 (NLS1), a class of AGN that are typically not radio loud and not previously known as γ-ray sources. Owing to the combination of the optical spectra, the gamma-ray emission, and the radio loudness of this source, the discovery has been viewed as an exceptional one and it has triggered the launch of an intensive coordinated multi-wavelength campaign. Multi-band campaigns are a key to understand the nature of these peculiar sources and simultaneous VLBI observations are needed to constrain the elements of the picture, e.g. by constraining the Doppler factor with brightness temperature measurements. Although the source is apparently quite compact, a jet structure is visible at several frequencies and it can be resolved with global VLBI with long N-S baselines.

Scheduler use only
(8/03)

(14) Proposal is ◯ Suitable ⊗ Unsuitable for dynamic scheduling.

(15) Polarization: ◯ Single Polarization ⊗ Dual Circular Polarization
Global network standard for single polarization is LCP for all λs except 13cm (RCP) and 3.6cm (RCP).

(16) Tape usage (Show <recording time>/<total time>): ______

(17) Assistance required:
Observation Setup: ◯ Consultation, ◯ Extensive help, ⊗ Observe file preparation
Postprocessing: ⊗ Consultation, ◯ Extensive help, ◯ Calibration service

(18) Processor: ◯ Socorro, ⊗ JIVE, ◯ Haystack, ◯ Bonn, ◯ Washington, ◯ Other__________
Special processing: ⊗ XPol, ◯ Pulsar gate, ◯ Multiple Fields: ______
Averaging time: ______ Spectral channels per baseband channel: ______
⊗ Other special processing: e-VLBI real time correlation

(19) Postprocessing Location: INAF/IRA, JIVE

(20) Source list: ⊗ J2000 ◯ B1950
If more than 4 sources, please attach list. If more than 30, give only selection criteria and GST range(s)

	Source 1	Source 2	Source 3	Source 4
Name(s)	PMN J0948+0022			
RA (hh mm)	09h 48m 57.3201s			
Dec (dd.d)	+00d 22' 24.558"			
GST range (Europe)	03:30-11:30			
GST range (US)				
GST range (Other)	21-05/06 (Aus/Ka)			
Band(s)	22 GHz			
Flux density (Total, Jy)	0.4			
Flux density (correlated, mJy)	400			
RMS needed (mJy/beam)	0.1			
Peak/RMS needed	$\sim$ 1000			

(21) Preferred VLBI session or range of dates for scheduling, and why:

(22) Dates which are NOT acceptable, and why:

(23) Attach a self-contained scientific justification, not in excess of 1000 words.
Preprints or reprints will not be forwarded to the referees.

Information about the capabilities of the VLBA may be found on the World Wide Web by starting at the NRAO home page, http://www.nrao.edu, and selecting the VLBA from "Sites and Telescopes."

A brief summary of the capabilities of the EVN antennas is given in the EVN STATUS TABLE in the EVN USER GUIDE, which may be found at http://www.evlbi.org/user_guide/user_guide.html.

Please include the full postal addresses for first-time users or for those that have moved (if not contact author).

Introduction and Scientific Goals

In recent times, the case of radio-loud narrow line Seyfert 1 (NLS1) active nuclei has been receiving increasing attention. NLS1 are characterized by an optical spectrum with narrow permitted lines FWHM(Hβ) < 2000 km/s, the ratio between [OIII]λ5007 and Hβ smaller than 3 and a bump due to FeII (see, e.g., Pogge 2000 for a review). They exhibit also prominent soft X-ray excesses. These properties point to very high (near Eddington) accretion rates and relatively low masses ($10^6 - 10^8 M_\odot$). Only a small percentage ($\sim 7\%$) of NLS1 are radio-loud ($S_{\nu=4.85GHz}/S_{\lambda=440nm} > 10$). In these cases, their flat radio spectra and VLBI variability suggest that several of them could host relativistic jets (Komossa et al. 2006, Doi et al. 2006).

However, the presence of relativistic jets has remained elusive so far, owing to the almost complete lack of knowledge of their properties at high energy. After three months of operations, the LAT (the Large Area Telescope onboard *Fermi*) has revealed 132 bright sources at $|b| > 10^\circ$ (Abdo et al. 2009a), including 58 flat spectrum radio quasars (FSRQ). Among these FSRQs, there is the remarkable detection of γ-rays from one radio-loud NLS1, the quasar PMN J0948+0022 ($z = 0.5846$), with an average flux in the energy band $E > 100\,\mathrm{MeV}$ of $F = (12.1 \pm 2.2) \times 10^{-8}\,\mathrm{ph\,s^{-1}\,cm^{-2}}$ (Abdo et al. 2009a) . This has made it possible to build the first whole Spectral Energy Distribution (SED) from radio to γ-rays of a radio-loud NLS1, to constrain the inverse-Compton emission, and to evaluate the role of this new type of source in the framework of the blazar sequence and evolution (Abdo et al. 2009b).

Since *Fermi* operates in an all-sky scanning mode, the LAT is able to provide regular monitoring of the γ-ray sky and this constitutes a catalyst for the setup of coordinated multi-wavelength campaigns. Indeed, the Fermi/LAT Collaboration organized an ongoing multi-wavelength campaign on PMN J0948+0022, which started on 26 March 2009 and will end after 3 months[1]. The main goal of the campaign is to monitor the multiwavelength evolution of this peculiar source in order to better understand its nature. In addition to the continuous monitoring from the *Fermi*-LAT, observations are already granted in X-rays, optical/UV, and in the radio through single dish monitoring.

Simultaneous global VLBI observations, with a good north-south resolution, would be an extremely valuable addition to the campaign, and they could help in solving the questions relative to the complex nature of the accretion/ejection coupling in NLS1. In particular, PMN J0948+0022 is an unique opportunity that should not be missed, for the following reasons:

1. NLS1 are in general not well studied on parsec scales. Owing to the combination of the optical spectra, the gamma-ray emission, and the radio loudness of this source, PMN J0948+0022 is an exceptional laboratory in which it is possible to study both the parsec scale structure and the multi-λ SED. A monitoring of the brightness temperature would be valuable in the interpretation of the multi-frequency data. Doppler factor and magnetic field intensity can be independently estimated and compared by the study of the SED and of the VLBI data. In combination with the inverse Compton emission parameters constrained by the *Fermi* observations, it will be possible to investigate the energy density ratio U_e/U_B for the first time, which is a fundamental quantity in jet physics.

2. No recent VLBI observations of PMN J0948+0022 are available. MOJAVE[2] will follow-up on this source in the coming months but at lower resolution and sensitivity. Only the proposed Global e-VLBI experiment can add the highest resolution images for the multi-frequency campaign. Moreover, the well known variability in the γ-ray emission of FSRQs suggests that the source may not be as active as now in a few months time. Earlier VLBI measurements (Doi et al. 2006) have also revealed a reduction of the radio flux density of this source as high as 70% over 46 days, so it is essential that the observations are taken during the campaign and not later on.

3. Although this source is apparently quite compact, Doi et al. (2006) have also reported the presence of two components that could be resolved within its jet (see Fig. 1). Global baselines and high observing frequency ($\nu \geq 15$ GHz) can provide the high angular resolution that is necessary to constrain the jet geometry. Moreover, we request to observe the source three times during the campaign, in order to reveal possible component motion (at least compared to the previous VLBI measurement) and to pinpoint the site of variability within the jet.

[1] the campaign web page is at `http://confluence.slac.stanford.edu/display/GLAMCOG/MW_Campaign_PMNJ0948p0022`

[2] `http://www.physics.purdue.edu/astro/MOJAVE/MOJAVEIItable.html`

Requested resources

Since the campaign was set up and announced only in late March, an EVN proposal could not be submitted through the regular deadlines. However, the observing window and the multi-wavelength coverage are unprecedented at this time, providing an unique opportunity to study this exceptional source with global VLBI. Therefore, we request a ToO observation of PMN J0948+0022, taking advantage of real time correlation of connected telescopes for three epochs between April and June.

We request 22 GHz observations, in order to maximize the angular resolution. Moreover, the source has a strongly inverted radio spectrum and its brightness is also maximum at this frequency (Doi et al. 2006). We estimate that its correlated flux density is $S_{22} \geq 300$ mJy, which permits fringe fitting with high signal-to-noise ratio within the coherence time. For example, the 1σ sensitivity between Ef and Sh in 1 minute is 18.0 mJy, for 8 MHz subbands, 2-bit sampling. For this reason, phase referencing will not be necessary. Accurate coordinates are also available, as follows: RA= $09^h\,48^m\,57^s.3201$, Dec= $+00^d\,22^m\,25^s.558$ (Beasley et al. 2002).

The recent e-VLBI demo of IAY2009 successfully showed the capability of doing real time VLBI at 512 Mbps with an array including telescopes in Australia and Japan. While the common coverage of Australia and western-EVN baselines is quite short and at low elevation, the baselines from Australia to Shanghai and Kashima would provide the necessary N-S resolution the EVN alone would miss. Moreover, we would like to point out that in our proposed configuration the telescopes providing the longest baselines would contribute with short spacings as well, making good amplitude calibration of the longest baselines possible. This is essential for the measurement of the brightness temperature. The advantage of the e-VLBI technique over disk recording would be not only logistical but also in terms of reliability. Any problems during the run would be immediately visible, which would help us conducting a successful experiment with this unique and not frequently exercised global array. Therefore, our telescope request is as follows (see the resulting proposed (u, v)-coverage is shown in Fig. 2.):

– EVN: we request all EVN telescopes with 22 GHz receiver. We particularly stress the relevance of **Effelsberg** to obtain high signal-to-noise fringes, and of **Shanghai** that is a key element for the coverage as it would contribute to the good resolution in both the E-W and N-S direction, acting as a bridge between the European and the Australian telescopes. A **minimum of 5 telescopes from the EVN** is requested in order to make the observations worthwhile.

– Non-EVN stations: the Kashima 34m radio telescope would be a useful addition to the array. It is equipped with a K-band receiver, and it successfully took part in earlier e-VLBI demos. At the time of writing, the schedule of the telescope[3] shows the possibility to allocate time for the project. The inclusion of Kashima would benefit the experiment with additional north-south baselines to Australia, resulting in an improved resolution and the possibility of self-calibration of visibilities on large (u, v)-spacings. The minimum requirement is to have at least **4 telescopes combined from Australia and Asia** (including Sh), for phase and amplitude self-calibration. In particular, we propose a two-stage strategy for the Australian telescopes. The first observation would be done with just Mopra and Hobart, which would be easier with the current receivers/links. The following runs would be attempted with more extensive resources: from end of May the ATCA will be potentially available and Parkes will have the 22 GHz receiver on from about June 10.

Finally, if the results warrant it, an additional full EVN+LBA+Ka run could be scheduled during the LBA run 2-6 July, maybe recorded to include Ceduna and Tidbinbilla. This would also complement with denser sampling and better resolution the future MOJAVE data. However, the present request is for e-VLBI only, at a rate of 512 Mbps, or possibly at 256 Mps for the Australian and Kashima telescopes.

For fringe-finder we suggest 0234+285, or any other suitable source available. Since phase-referencing is not necessary, the target will be observed continuously, except for the regular gaps every 10-15 minutes for Tsys measurements. A five minutes scan on a nearby ~ 1 Jy fringe-finder every hour could help better monitoring of the data quality from the telescopes. We have no special requirement w.r.t correlation parameters, 16/32 spectral channels and 1/2s correlator integration time would be sufficient. Cross-hand correlation is not absolute important but it would be practical for the observations.

[3] `http://www2.nict.go.jp/w/w114/stsi/34m/plan/plan34m.html`

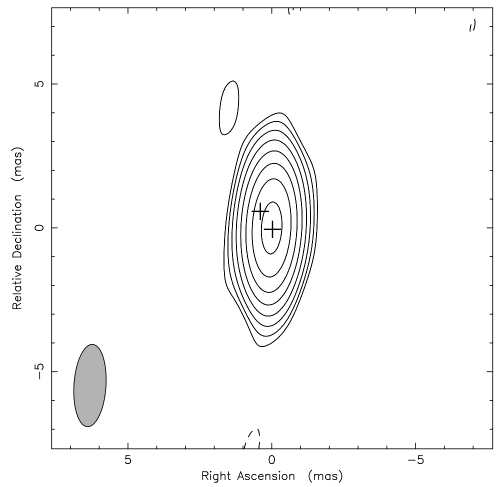

Figure 1: VLBA contour maps of PMN J0948+0022 at 5 GHz, adapted from Doi et al. (2006). The contour levels are $(-1, 1, 2, 4, 8, 16, 32, 64, 128) \times 0.56$ mJy beam$^{-1}(3\sigma)$. The cross symbols represent the positions of visibility-based model fitting components.

References

Abdo A.A., Ackermann M., Ajello M., et al. 2009a, ApJ submitted (arXiv:0902.1559v1)
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Beasley, A. J., Gordon, D., Peck, A. B., et al. 2002, ApJS, 141, 13
Doi, A., Nagai, H., Asada, K., Kameno, S., Wajima, K., & Inoue, M. 2006, PASJ, 58, 829
Komossa, S., Voges, W., Xu, et al. 2006, AJ, 132, 531
Pogge, R. W., Maoz, D., Ho, L. C., & Eracleous, M. 2000, ApJ, 532, 323

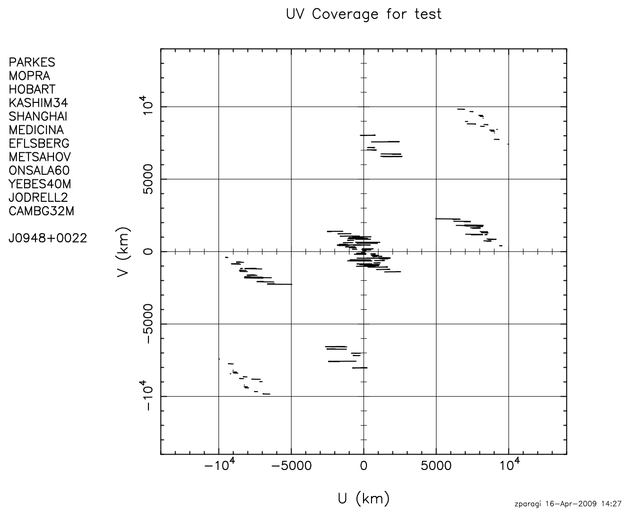

Figure 2: Proposed (u, v)-coverage for the Global e-VLBI experiment. Australian and Asian telescopes contribute with long spacings but also in the inner part of the plane, so that amplitude self-calibration can be successful.

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