DEADLINE : 8 May, 1998
SEND TO : VSOG, ISAS, 3-1-1 Yoshinodai, Sagamihara, Kanagawa 229-8510, JAPAN

Please read Appendix C of Announcement of Opportunity for details on how to fill in this Cover Sheet.

(1) Date prepared : 1998, May 1

(2) Proposal title : Monitoring PKS 1413+135 For Superluminal Motion

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(5) Proposal Abstract :

We propose multi-epoch observations of PKS 1413+135 to determine if superluminal motion is present in this source. These observations will determine whether this object is a young or "frustrated" AGN with a two sided jet. If the jet is confined it must be decelerating. Radio monitoring data indicate that PKS 1413+135 is highly variable, a common feature of sources exhibiting superluminal motion. Ground based observations suggest, but do not conclusively prove, that superluminal motion may be present in PKS 1413+135, but they do prove conclusively that evolution is occuring on *both* sides of the core. Very few AGN show evolution on both sides of the core. Observations with HALCA provide enough resolution to detect even modestly superluminal motion. A finding of superluminal motion, particularly on both sides of the core, would be difficult to reconcile with "unified" schemes for AGN.

(6) Proposal Category (indicate all that apply):

Object type:
☑ AGN, ☐ Maser, ☐ Stellar, ☐ Pulsar, ☐ Other :

Observation type:
☑ Continuum, ☐ Spectral Line, ☐ Polarization, ☑ Time-critical, ☐ Other :

(7) Number of proposed experiments

An 'experiment' is one or more observations of one source at a fixed HALCA set-up. A request to observe the same source at 1.6 GHz and separately at 5 GHz requires two columns to be filled in in item (8) below. A request to observe the same source with HALCA simultaneously observing at 1.6 GHz and 5 GHz requires one column to be filled in. Multi-epoch observations of the same source at the same frequency – a 'monitoring experiment' – requires only one column to be filled in. Suggested observing dates, especially for for time-critical and monitoring experiments, should be specified in item (10).

The number of experiments in this proposal is: 2

(8) Details of proposed experiments

	Experiment 1	Experiment 2	Experiment 3	Experiment 4
Source name (J*hhmm±ddmm*)	J1416+1320	J1416+1320		
Alternative name	PKS 1413+135	PKS 1413+135		
RA(J2000) (hh mm ss.ssss)	14 15 58.8180	14 15 58.8180		
Dec(J2000) (dd mm ss.ssss)	+13 20 23.718	+13 20 23.718		
Observing frequency band (GHz)	1.6	5		
Continuum observations:				
Standard VSOP freq. channels?	☑	☑	☐	☐
Channel A range (MHz)				
Channel B range (MHz)				
Spectral line observations:				
Ch.A spectral line rest freq. (MHz)				
Ch.A LSR velocity (km/s)				
Ch.B spectral line rest freq. (MHz)				
Ch.B LSR velocity (km/s)				
FWHM of field of view required (mas)				
Min. spectral channels per IF channel				
Correlator averaging time (sec)				
No. of correlating passes (if >1)				
Total flux density (Jy)	0.5	1.1		
Correlated flux (mJy)	0.4	1.0		
Ground Radio Telescopes:				
Suggested array given at Item (10)?	☑	☑	☐	☐
GRT observing mode:				
128Mbps LCP (standard)	☑	☑	☐	☐
128Mbps LCP/RCP	☐	☐	☐	☐
256Mbps LCP/RCP	☐	☐	☐	☐
Preferred correlator:				
No preference	☐	☐	☐	☐
Mitaka	☐	☐	☐	☐
Penticton	☐	☐	☐	☐
Socorro	☑	☑	☐	☐
Monitoring programs:				
Number of observations	4	4		
Mean interval (days)	180	180		
Related AO1 proposal code(s)	V083	V083		

(9) VSOP spacecraft observing mode (see Section 3 and Table 5 of the VSOP Proposer's Guide):

☑ 2 channel x 16 MHz, 2-bit (Standard mode),

☐ Other:

Phase calibration tones:

☑ On (Standard continuum mode),

☐ Off (Standard spectral line mode)

(Include justification of any non-standard choice at (10) below)

(10) Additional notes to the scheduler :

We request observations with HALCA and the VLBA at 1.6 and 5 GHz. We request that the observations last for at least two (2) orbits of HALCA. This will allow for the best possible UV coverage for both ground-ground and space-ground baselines.
The jets in PKS 1413+135 are oriented at position angle of 60 degrees East of North. Suitable UV coverage is obtained in March-April 1999, July 1999, January 2000, March-April 2000, and July 2000.

(11) Attach a scientific and technical justification, not in excess of 2 pages of text and 2 pages of figures. Up to one page of (u,v) plots per source may optionally be included.
(Refer to the VSOP Announcement of Opportunity for detailed instructions.)
Preprints and reprints will not be forwarded to the Scientific Review Committee.

Send two paper copies of the complete proposal to:

VSOP Observing Proposals
VSOP Science Operations Group
Institute of Space and Astronautical Science
3-1-1 Yoshinodai, Sagamihara
Kanagawa 229-8510 JAPAN

In addition, e-mail the completed LaTeX file to submit@vsop.isas.ac.jp

Information from the Cover Sheets of scheduled proposals will be made available from the VSOP WWW site.

Proposals must be received at ISAS by 8 May 1998

Scientific Justification

An increasing body of evidence suggests that "red BL Lacs" and "red Quasars" may have a significance which transcends merely being obscured AGN. Deep optical observations have revealed gas-rich, dusty spiral hosts, unlike all other radio-loud AGN. In addition, high-resolution radio observations have revealed extremely compact ($\sim$ few hundred parsecs) radio lobes, similar to those seen in Compact Symmetric objects (CSOs) and GigaHertz Peaked Sources (GPSs). In some cases, the radio jets appear to be interacting with dense gas within the nucleus. These observations fit well with a scenario proposed by Wilson & Colbert 1995, whereby radio-loud AGN form as by-products of galactic mergers. In such a merger, nascent activity might well be combined with explosive star formation, particularly in the nuclear regions. The combination of star formation, radiation pressure from the AGN and ram pressure from the jets would clear out a previously dusty nuclear ISM on timescales similar to the coalescence timescale of the merging galaxies.

The goal of this investigation is a deeper understanding of one of the brightest red BL Lacs, PKS 1413+135 ($z = 0.247$), which may be one of the youngest AGN known ($\sim$ few thousand years; Perlman et al. 1996). PKS 1413+135 was originally classified as a BL Lac object due to its highly polarized near-IR continuum and extreme radio variability (Bregman et al. 1981, Beichmann et al. 1981, Stocke et al. 1992). It is unique among BL Lacs in having a spiral host (McHardy et al. 1991, 1994; Stocke et al. 1992). By comparison, "unified" theories for AGN associate BL Lacs with beamed FR 1 radio sources, found in giant elliptical galaxies (Urry & Padovani 1995). Observations with the VLA in A array at 20 cm reveal that PKS 1413+135 has no kpc-scale structure to a dynamic range of 9600:1 (Perlman & Stocke 1994). Under standard unified schemes this would indicate a highly beamed source, yet at milli-arcsecond scales the source is clearly two-sided, indicating that the source is seen close to the plane of the sky! (Figure 1) Thus this source presents a severe challenge to unified schemes.

The broadband spectrum of PKS 1413+135 shows a steep cutoff in the near-IR first noted by Beichmann et al. (1981). Consistent with the near-IR cutoff due to $A_v > 30$ mag of extinction, the X-ray spectrum is heavily absorbed, yielding $N(H) > 2 \times 10^{22}\mathrm{cm}^{-2}$. Redshifted 21 cm observations (Carilli et al. 1992) detected an absorbing HI column of $N(\mathrm{HI}) = 1.3 \times 10^{19}(T_s/f)\mathrm{cm}^{-2}$. Molecular CO (j=1-0), HCO+ (j=2-1, 3-2), and HCN (j=1-2,2-3) absorption has been detected by Wiklind & Combes (1994) suggesting that the AGN is behind a GMC in the optical galaxy. More recent observations have shown that the molecular absorption features are highly variable in time (Wilkind & Combes 1997). Interestingly, there is no evidence that the extincted AGN heats the absorbing gas, e.g. bright emission lines from a NLR or a mid-IR thermal continuum. To explain this dilemma, Perlman et al. (1994) and Stocke et al. (1992) proposed that the AGN is background to the observed galaxy and perhaps gravitationally lensed.

VLBA observations of PKS 1413+135 (Perlman et al. 1994, 1996; see Figure 1) show a complex, two-sided structure. The bend of the jet on the East side is direct evidence for interactions of the jet with a dense medium. Figure 1 shows images of PKS 1413+135 obtained with the VLBA at 8 GHz at three epochs. All three images have the same spatial and intensity scales and clearly show evolution on both sides of the core. In figure 2 we present observations of PKS 1413+135 obtained in July 1997 at 5 GHz using the VLBA and HALCA. The top image is from the VLBA data only while the lower image is from using the full data set. This image clearly shows that HALCA can resolve the structure in the jets of PKS 1413+135 into individual components. It is interesting to note that 90 with the HALCA images.

Since the images show no evidence of a second image or arc, they rule out macrolensing, but not microlensing by a GMC in the optical galaxy (see, e.g., Narayan & Schneider 1990). In both the microlensing and the macrolensing senerios, the "host" galaxy must be in the foreground of the AGN. The images also are very similar to those of some GPSs and CSOs, such as 0710+439 and 2352+495 (Conway et al. 1992, Readhead et al. 1994), as first noted by Perlman et al. (1994). As pointed out by Stanghellini et al. (1993), many GPS sources are significantly reddened, with little evidence of nonstellar optical continua; furthermore, several are found in disk galaxies (Stanghellini et al. 1993), deepening the similarity.

There are two possible explanations for the observed properties of PKS 1413+135. One is that it is a very young source (see, e.g., Readhead et al. 1996 and O'Dea & Baum 1997). Alternatively, it may be an older source frustrated by interactions with a dense confining medium. Readhead et al. (1994) have

dismissed the latter possibility for 2352+495, since a frustrated source would require free-free absorption, which would quench the radio source below a few GHz, and excessive mass requirements within the inner 100 pc ($\sim 2 \times 10^{11} M_{\odot}$). The situation for PKS 1413+135 is similar. But interestingly, the core's spectrum is inverted (with $\alpha < -1.5$) at $\nu < 8.4$GHz, leaving open both the standard explanation of synchrotron self-absorption or the alternative possibility of free-free absorption. The possibility of free-free absorption is suggested by the large absorbing column already known for this source, as well as the evidence shown in the maps for interactions with a dense medium.

Figure 1 shows clear evolution on both sides of the core, something which is corroborated by lower-frequency VLBA data. These evolutionary effects cannot be convincingly linked with motions of components on either side of the core with the ground based observations. We have found that VLBA-only images do not provide enough resolution to sufficiently resolve individual components within the jets of PKS 1413+135 in order to detect superluminal motion. The VLBA-only observations, however, suggest motions of approximately 0.1 milli-arcsecond per year ($\sim 1.5c$) in PKS 1413+135, but have insufficient resolution to provide a conclusive case for superluminal motion. The components of the jets have a very steep spectrum (Perlman et al. 1996). This prevents VLBA-only observations at higher frequencies from detecting the components more than a few milliarcseconds of the core due to dynamic range limitations. This is the region where the newest and fastest moving components are expected. Figure 2 demonstrates that HALCA can provide the necessary resolution to resolve individual components in PKS 1413+135. Since PKS 1413+135 is either a young source or is frustrated and in either case interacting with a dense medium, we expect that the jet components should be decelerated as they propagate outward. By obtaining many epochs of observations of PKS 1413+135 we can also look for any deceleration of the jet components. Furthermore, monitoring observations of PKS 1413+135 have been carried out with the Green Bank Interferometer (GBI) and the University of Michigan Radio Observatory for the past two decades (see Figure 3). PKS 1413+135 has been observed to undergo many flare-like events which suggests that PKS 1413+135 should exhibit superluminal motion. The 8 GHz GBI monitoring of PKS 1413+135 requires component sizes of a light-month or less. This corresponds to angular sizes of tens of microarcseconds, and brightness temperatures well in excess of the inverse-Compton limit of $T_B \sim 10^{12} K$, unless beaming is present. This is one more reason why high resolution images, such as those provided by HALCA, are needed to understand this source.

We propose observations with HALCA and the VLBA of PKS 1413+135 at 1.6 and 5 GHz in order to determine if superluminal motion is present in this source. An observation of superluminal motion would be very difficult to reconcile with the two-sided jet we observe under unified schemes. One epoch of observations at 5 GHZ with HALCA have been made (July 1997) and a second epoch is scheduled (July 1998). It is essential to this proposal that the proposed 5 GHz observations be obtained. Observations at 1.6 GHz are essential to probing evolution in the outer parts of the radio structure in PKS 1413+135, which are extremely steep-spectrum ($\alpha \sim -2$, Perlman et al. 1996) and low-surface brightness at 5 GHz and above. The combination of two frequencies of VLBA+HALCA observations, plus VLBA-only observations at higher frequencies (begun in 1995 and to be proposed again in a companion proposal) will allow us to monitor the spectral index of jet components as they move outward.

References

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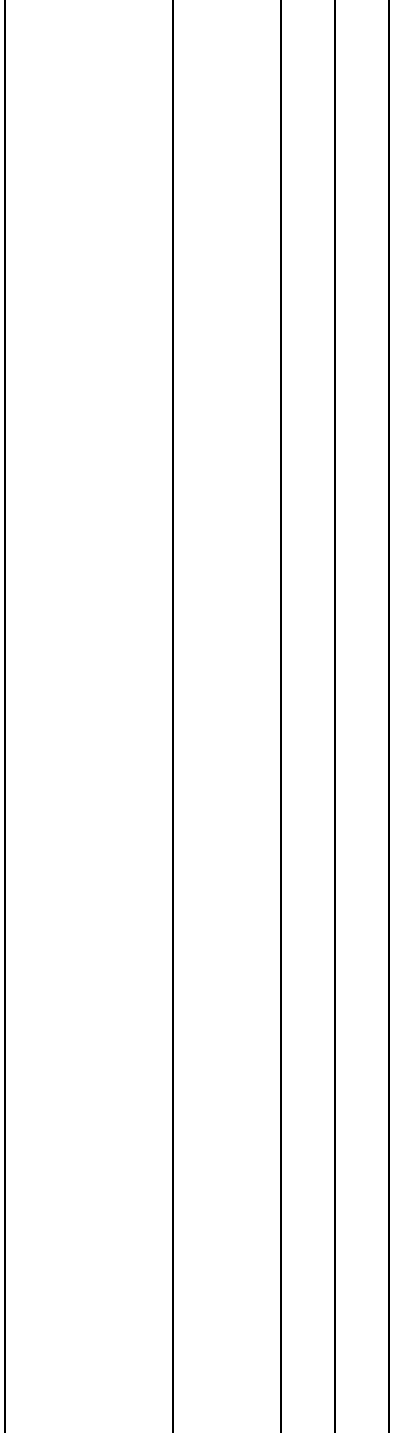

Figure 1. 8 GHz images of 1413+135 taken in 1992 (top), 1994 and 1995 (bottom) with the VLBA. All three images have same intensity and physical scales. The images are spaced vertically to represent the time between observation epochs. No motion of components is detected on scales greater than one milli-arcsecond. Vertical lines are drawn for reference.

Figure 2. 5 GHz images of 1413+135 from the July 1997 epoch of HALCA observations. The top panel is an image using only ground radio telescopes (VLBA) and the bottom panel includes HALCA. The images are made from the same data set and have the same intensity and physical scales. Approximately 90 provides the needed resolution to identify separate components in the jets of 1413+135.