JVN＋広帯域による AGN 研究の展開

大学連携VLBIワークショップ 2014/12/05

土居明広 (宇宙科学研究所)

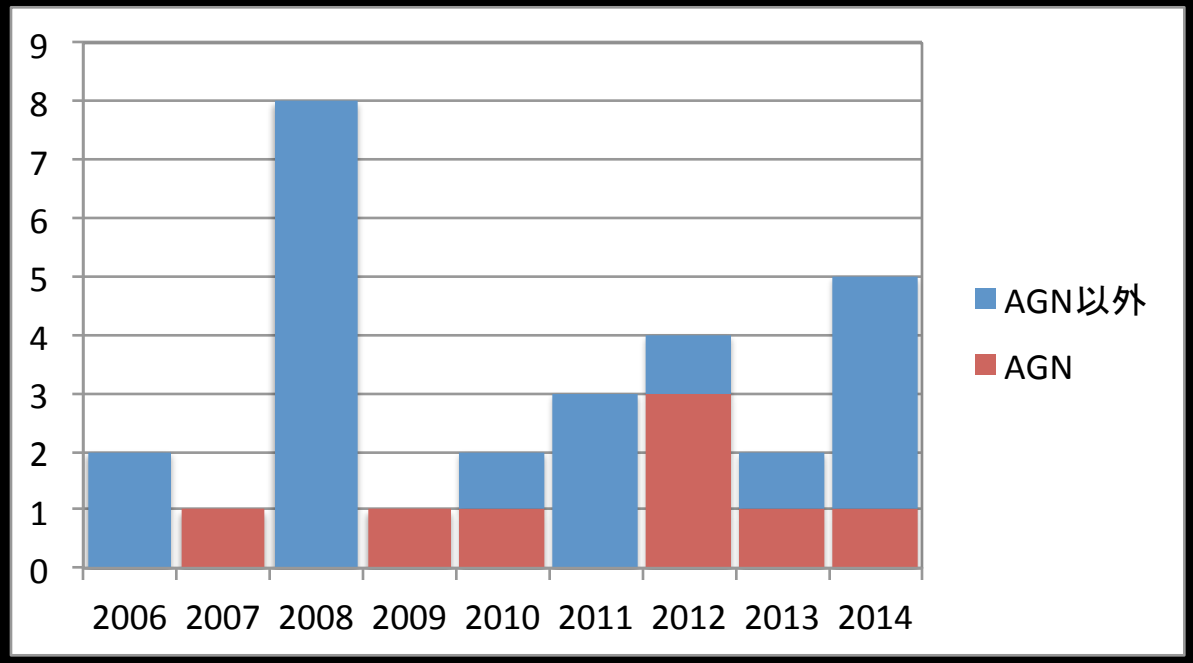
これまでの JVN + AGN

Publications in refereed Journals from JVN (28)

ID	PI	Title
2014PASJ..tmp..110F	Fujisawa, Kenta	Observations of the bursting activity of the 6.7 GHz methanol maser in G33.641−0.228
2014PASJ...66...78F	Fujisawa, Kenta	Periodic flare of the 6.7-GHz methanol maser in IRAS 22198+6336
2014PASJ...66...31F	Fujisawa, Kenta	Observations of 6.7 GHz methanol masers with East-Asian VLBI Network. I. VLBI images of the first epoch of observations
2014ApJ...781...75W	Wajima, Kiyoaki	Short-term Radio Variability and Parsec-scale Structure in a Gamma-Ray Narrow-line Seyfert 1 Galaxy 1H 0323+342
2014A&A...562A..82S	Sugiyama, K.	Rotating and infalling motion around the high-mass young stellar object Cepheus A-HW2 observed with the methanol mase
2013PASJ...65...79S	Sawada-Satoh, Satoko	Internal Motion of 6.7-GHz Methanol Masers in H II Region S269
2013PASJ...65...57D	Doi, Akihiro;	Multifrequency VLBI Observations of the Broad Absorption Line Quasar J1020+4320: Recently Restarted Jet Activity?
2012PASJ...64...58S	Sasada, Mahito	Multi-Wavelength Photometric and Polarimetric Observations of the Outburst of 3C 454.3 in 2009 December
2012ApJ...759...84N	Niinuma, K.	Possible Detection of Apparent Superluminal Inward Motion in Markarian 421 after the Giant X-Ray Flare in 2010 February
2012PASJ...64..109K	Kadota, Akiko	An Intrinsic Short-Term Radio Variability Observed in PKS 1510-089
2012PASJ...64...17F	Fujisawa, Kenta	Bursting Activity in a High-Mass Star-Forming Region G33.64-0.21 Observed with the 6.7GHz Methanol Maser
2011PASJ...63.1345M	Matsumoto, Naoko	Astrometry of 6.7GHz Methanol Maser toward W 3(OH) with Japanese VLBI Network
2011PASJ...63...53S	Sugiyama, Koichiro	Internal Proper Motions of Methanol Masers at 6.7GHz in Massive Star-Forming Region Onsala 1
2011PASJ...63.1293I	Imai, Hiroshi	Multiple Outflows Traced by H2O Masers around the Ultra-Compact H II Region G 34.26+0.15
2010PASJ...62L..11N	Nagai, Hiroshi	VLBI Monitoring of 3C 84 (NGC 1275) in Early Phase of the 2005 Outburst
2010PASJ...62..431I	Imai, Hiroshi;	Japanese VLBI Network Mapping of SiO v = 3 J = 1−0 Maser Emission in W Hydrae
2009PASJ...61.1389D	Doi, Akihiro	VLBI Detections of Parsec-Scale Nonthermal Jets in Radio-Loud Broad Absorption Line Quasars
2008PASJ...60.1069N	Nagayama, Takumi	H2O Maser Outflow from the Red Supergiant Star NML Cygni Observed with Japanese VLBI Network
2008PASJ...60.1051U	Ueda, Kosuke	Japanese VLBI Network Observations of SiO Masers in the M-Type Giant IRC −10414
2008PASJ...60.1001S	Sugiyama, Koichiro	A Synchronized Variation of the 6.7GHz Methanol Maser in Cepheus A
2008MNRAS.390..523M	Motogi, K.	Microstructure and kinematics of H2O masers in the massive star-forming region IRAS 06061+2151
2008PASJ...60..465T	Tsuboi, Masato	The 2006 Radio Outbursts of a Microquasar Cygnus X-3: Observations and Data
2008PASJ...60..183N	Nagayama, Takumi	VLBI Observations of Water Masers in Onsala1: Massive Binary Star-Forming Site?
2008PASJ...60...55I	Imai, Hiroshi	JVN Observations of H2O Masers around the Evolved Star IRAS 22480+6002
2008PASJ...60...23S	Sugiyama, Koichiro	Mapping Observations of 6.7 GHz Methanol Masers with the Japanese VLBI Network
2007PASJ...59..703D	Doi, Akihiro	Japanese VLBI Network Observations of Radio-Loud Narrow-Line Seyfert 1 Galaxies
2006PASJ...58..883I	Imai, Hiroshi	A Collimated Jet and an Infalling-Rotating Disk in G192.16-3.84 Traced by H2O Maser Emission
2006PASJ...58..777D	Doi, Akihiro	Bigradient Phase Referencing

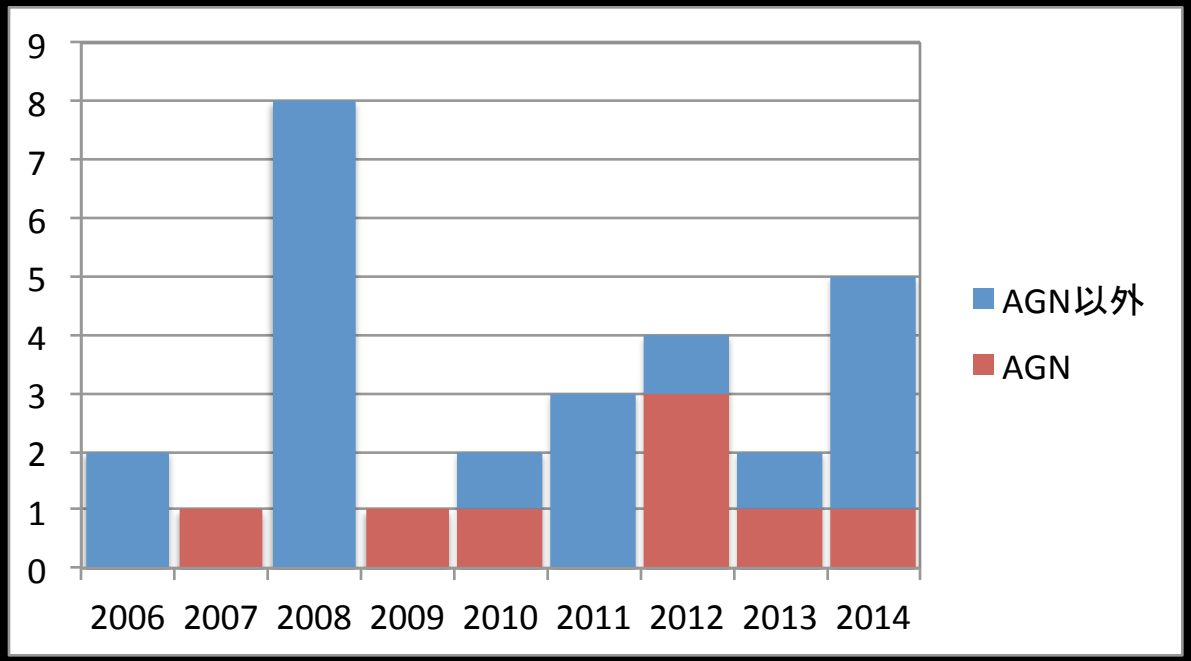
ADSにて “Japanese VLBI” 等で検索、VERA, SELENE 関係等を除いたもの

Publications in refereed Journals from JVN



- 増加中
  → 継続すべき明らかな根拠

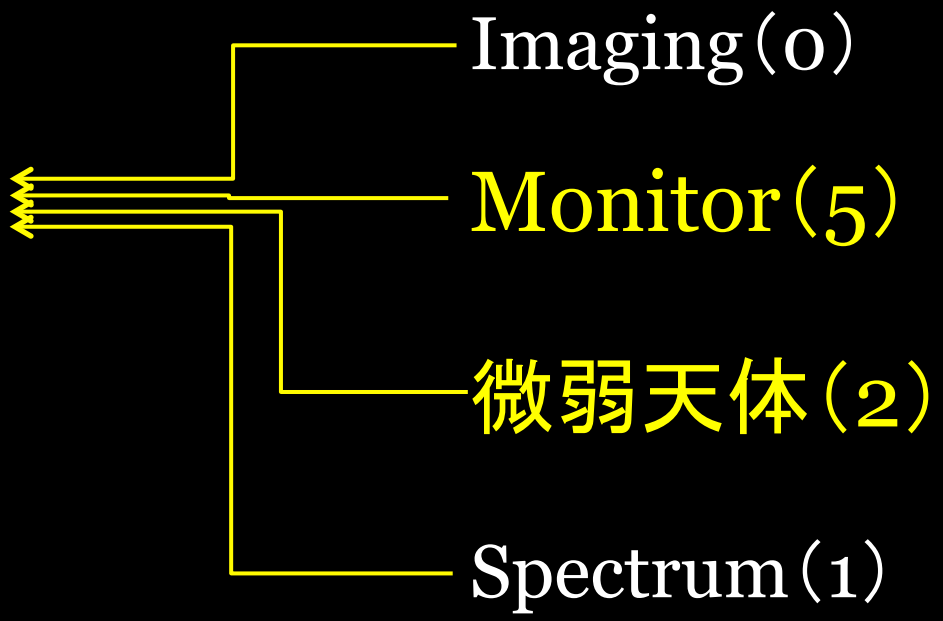
Publications in refereed Journals from JVN



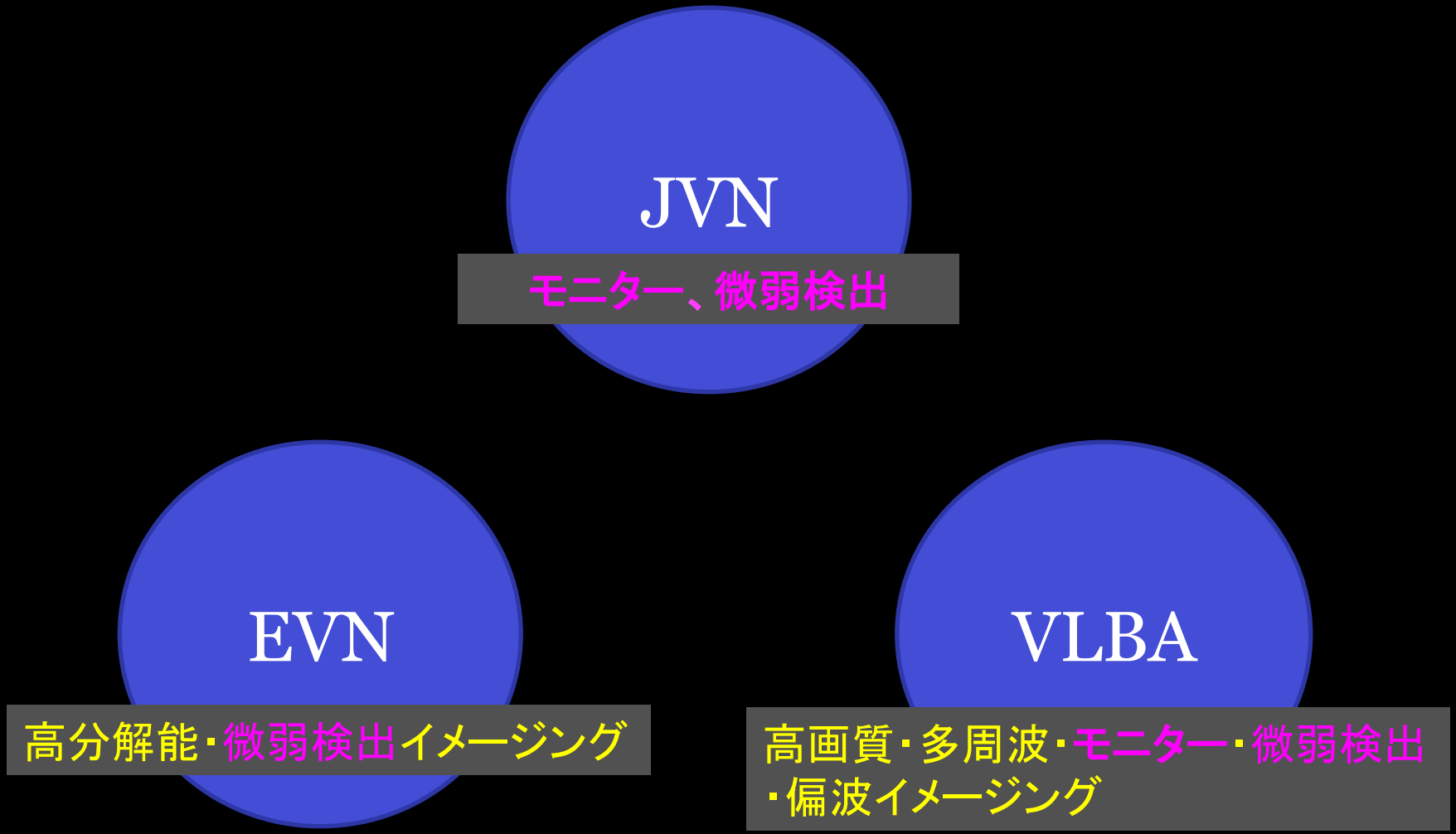
- 2008年: 4/8 は H2O
  - VERA astrometry 以外のテーマ取り込み？
- 2012年: 3/4 は AGN
  - Fermi 効果？
- 2014年: 4/5 はメタノール
  - 実を結び刈り取りに？

Publications in refereed Journals from JVN

分野	論文数
AGN	8
メタノール	9
H2O	7
その他	4
（合計）	28



棲み分けの構図？


JVN
モニター、微弱検出
EVN
高分解能・微弱検出イメージング
VLBA
高画質・多周波・モニター・微弱検出
・偏波イメージング

JVN + AGN モニター観測

Wajima et al. (2014)

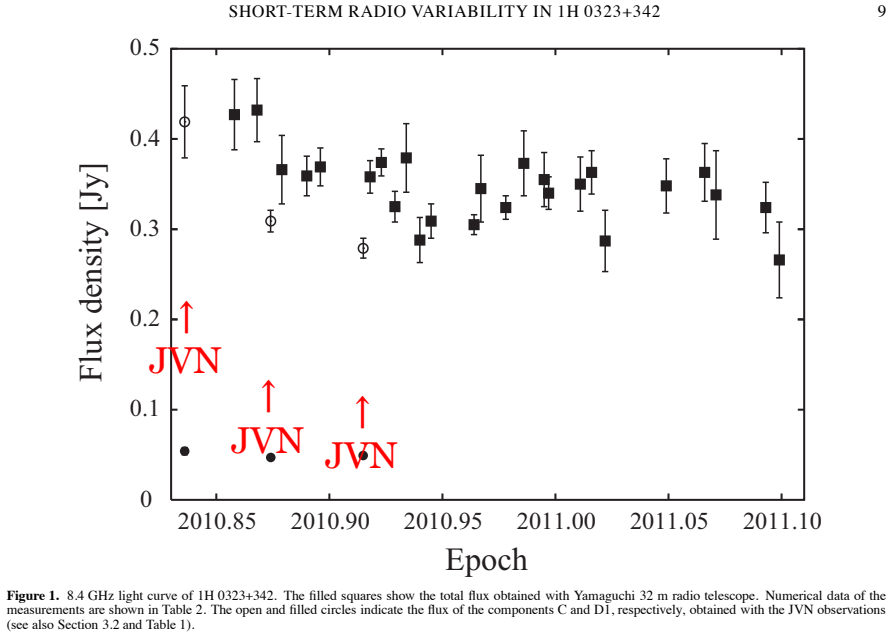


Figure 1. 8.4 GHz light curve of 1H 0323+342. The filled squares show the total flux obtained with Yamaguchi 32 m radio telescope. Numerical data of the measurements are shown in Table 2. The open and filled circles indicate the flux of the components C and D1, respectively, obtained with the JVN observations (see also Section 3.2 and Table 1).

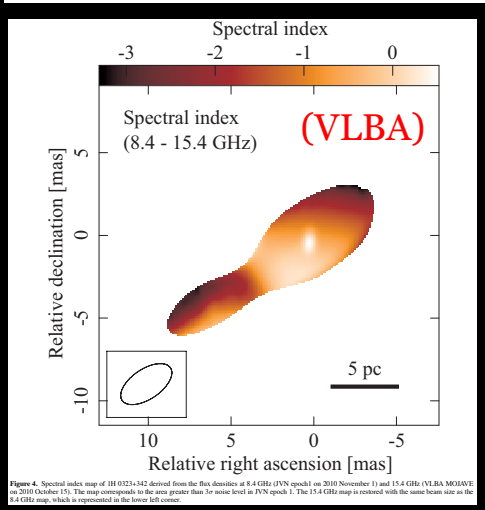


Figure 4. Spectral index map of 1H 0323+342 derived from the flux densities at 8.4 GHz (JVN epoch1 on 2010 November 1) and 15.4 GHz (VLBA MOJAVE on 2010 October 15). The map corresponds to the area greater than 3σ noise level in JVN epoch 1. The 15.4 GHz map is restored with the same beam size as the 8.4 GHz map, which is represented in the lower left corner.

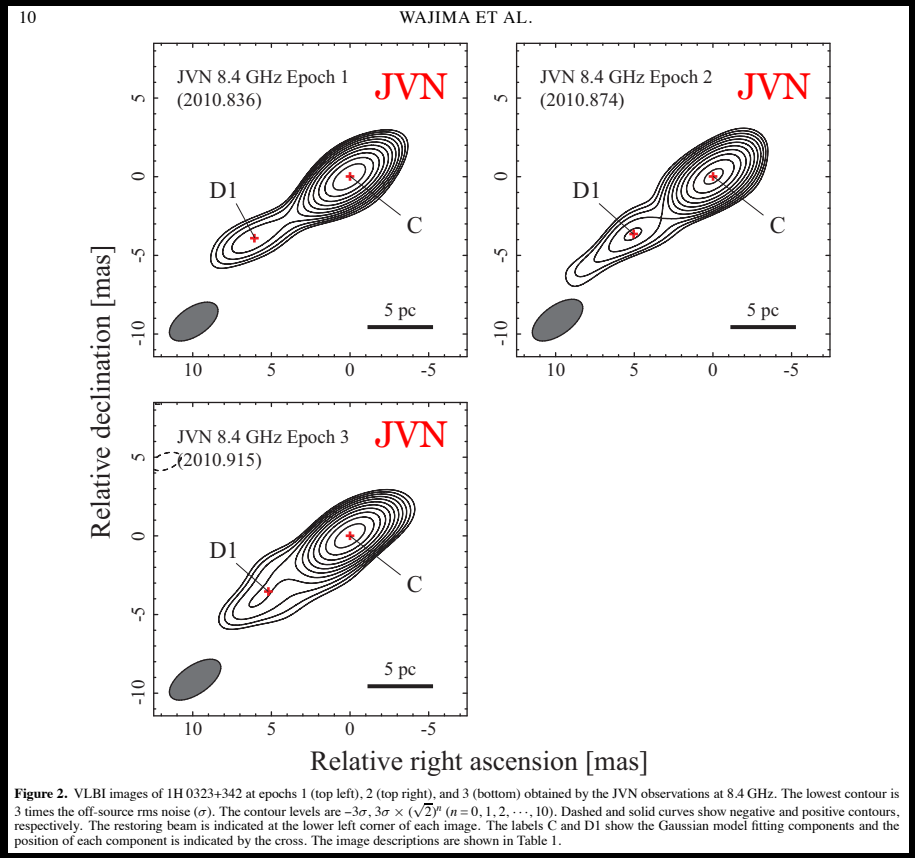


Figure 2. VLBI images of 1H 0323+342 at epochs 1 (top left), 2 (top right), and 3 (bottom) obtained by the JVN observations at 8.4 GHz. The lowest contour is 3 times the off-source rms noise (σ). The contour levels are -3σ, $3\sigma \times (\sqrt{2})^n$ ($n = 0, 1, 2, \cdots, 10$). Dashed and solid curves show negative and positive contours, respectively. The restoring beam is indicated at the lower left corner of each image. The labels C and D1 show the Gaussian model fitting components and the position of each component is indicated by the cross. The image descriptions are shown in Table 1.

- 密なシングルディッシュモニターが JVN モニターをサポート
- （Proper motion は not conclusive）
- （イメージ分析は VLBA）

JVN + AGN モニター観測

Niinuma et al. (2012)

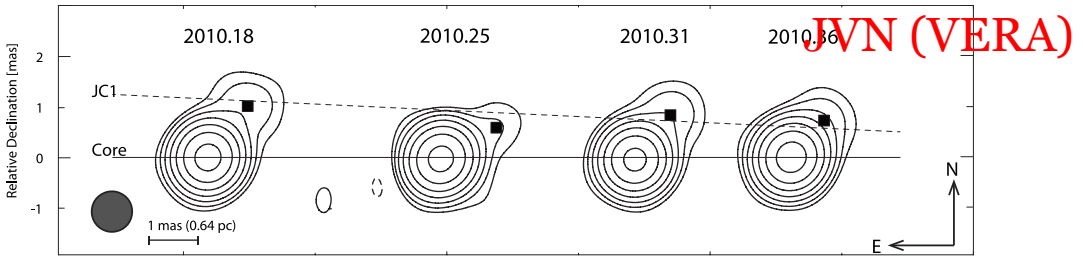


Figure 3. VLBI images of Mrk 421 produced by restoring model-fit components. The epoch and the scale of 1 mas for our images are indicated on the top of each image as year "YYYY.YY" and in the bottom of the panel of the first epoch, respectively. The interval of each image is proportional to the date when each observation was made. The filled squares represent the position of JC1 relative to the core, and the solid and the dashed lines show the trajectory of the core and of JC1, respectively. The decrease in the separation between the core and JC1 is shown by these two lines. The beam size of this figure is the same as Figure 1 and is shown in the bottom-left corner of the panel of the first epoch. Contours begin at 3 mJy beam^{-1} and increase in -1 and 2^n steps.

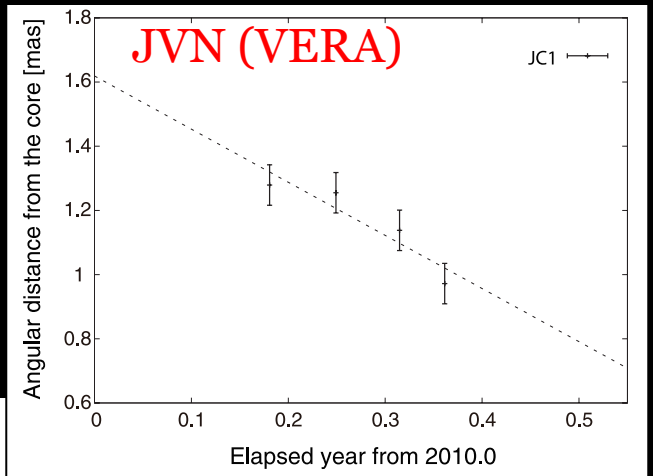


Figure 2. JC1 positions and weighted linear fit to JC1 positions (dashed line). The position uncertainties of each data point are uniformly rescaled so that the reduced χ^2 is unity. As a result of the least-squares fit, we obtained the proper motion of -1.66 ± 0.46 mas yr^{-1}.

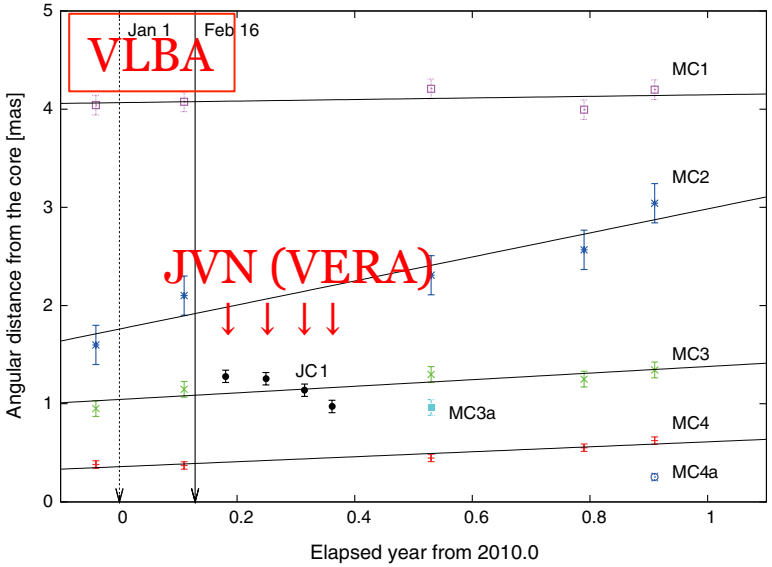


Figure 5. Angular distances of each component detected with our observations and MOJAVE, relative to the core. The dashed and the solid arrows indicate the date when the large X-ray flares occurred. Also, each solid line shows the results of the linear fit to each component without JC1.

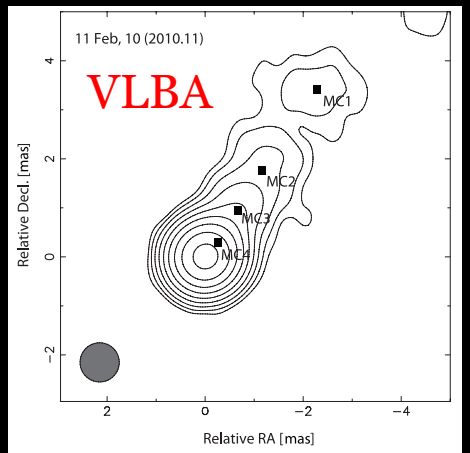


Figure 4. VLBA image of Mrk 421 with natural weighting at 15 GHz (MOJAVE program). The epoch is indicated on the top of each panel as "DD MMM, YY (YYYY.YY)," and the filled squares represent the position of each component relative to the core. The beam size of this figure is the same as Figure 1 and is shown in the bottom-left corner of the panel of the first epoch. Contours begin at 0.9 mJy beam^{-1} and increase in 2^n steps.

- スパースな VLBA モニターを、密な JVN モニターでサポート

JVN + AGN モニター観測

Kadota et al. (2012)

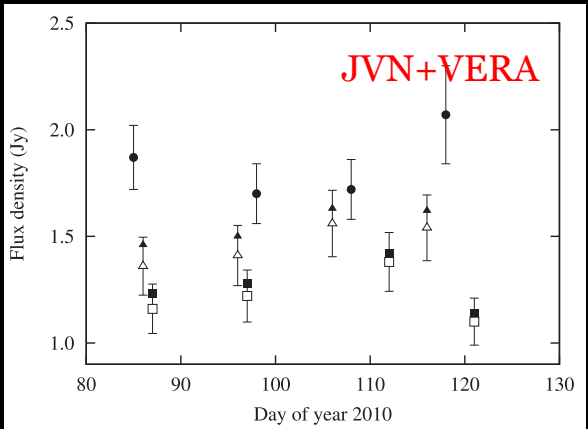
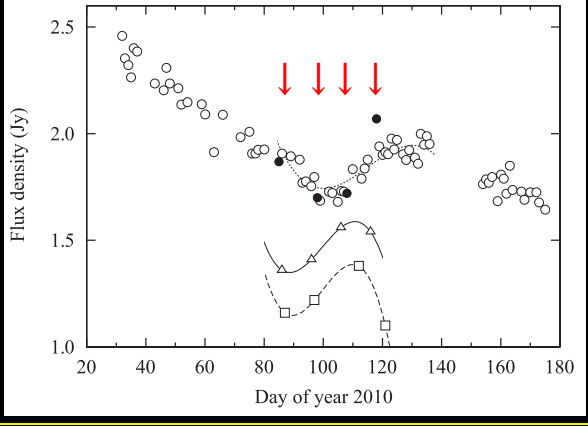


Fig. 3. Flux density variations of VLBI components. The symbols for 8.4, 22, and 43 GHz are circle, triangle, square, respectively. Filled symbols represent the sum of the core and jet components. Open symbols represent the core components.



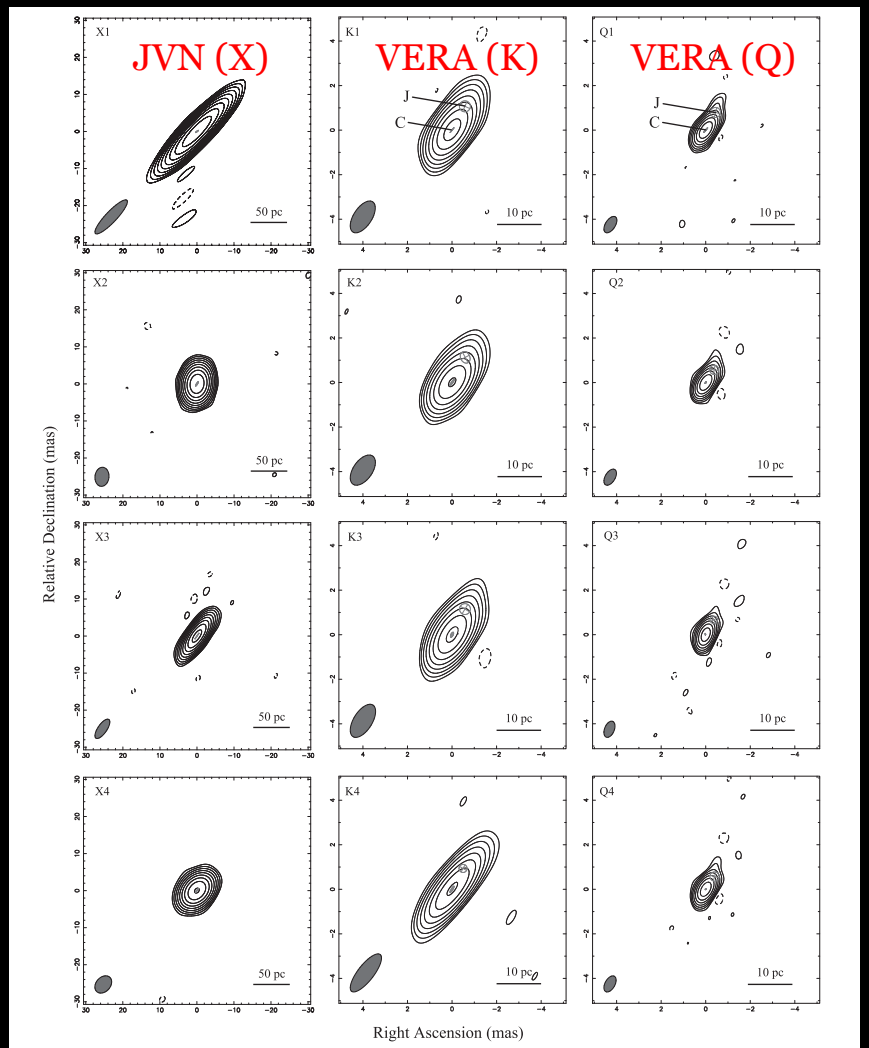


Fig. 2. VLBI images. The left panels show 8.4 GHz images, the center panels for 22 GHz, and the right panels for 43 GHz images, respectively. Images of the 1st, 2nd, 3rd, and 4th observations are shown from the top to bottom rows. Contours indicate $-3\sigma, 3\sigma \times 2^n$ ($n = 0, 1, 2, \cdots$) of the intensity of each image. Synthesized beams are shown at the left bottom of each image. Elliptical and circular Gaussian models are overlaid as gray symbols. Due to the lack of Ogasawara of VERA, the beam was elongated in X1.

- JVN+VERA で多バンドモニター（4 epochs)
- 密なシングルディッシュモニターがサポート
- コンポーネントのフラックス比変動を調査

JVN + AGN モニター観測

Nagai et al. (2010)

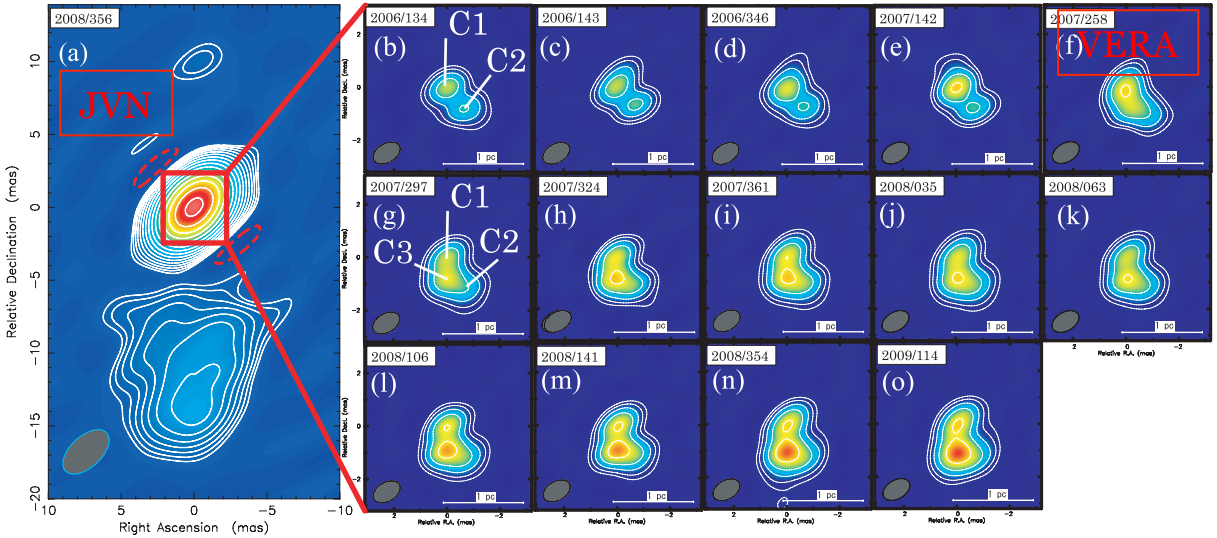


Fig. 1. (a) JVN image of 3C 84 at 8 GHz. The contours are plotted at the level of 86.2 mJy × $\left(\sqrt{2}\right)^n$ ($n = -1, 0, 1, 2, 4, \ldots, 128$). The lowest contour corresponds to three-times image noise r.m.s.. The beam size is 3.85 × 2.14 mas at a position angle of −47°, which is shown in the lower left corner of the image. (b)–(o) VERA images of 3C 84 at 22 GHz. All images are shifted in reference to the northern component (component C1). The contours are plotted at levels of 4.18, 8.36, 16.72, 33.44, and 66.88% of the peak intensity (4.989 Jy beam) on 2009 April 24. The restoring beam (1.1 × 0.7 mas, position angle of −60°) was set to make images uniform.

- モニターは VERA が担当

(JVN) + AGN モニター観測

Sasada et al. (2012)

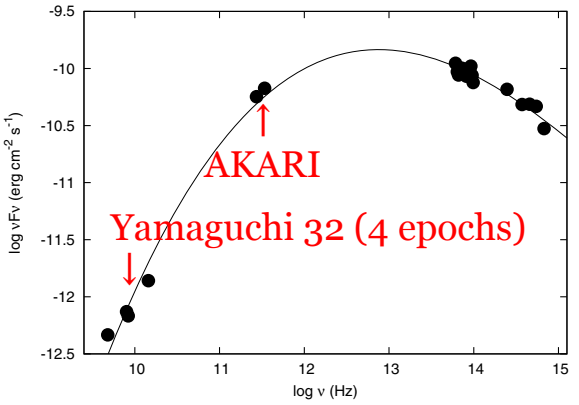


Fig. 5. Spectral energy distribution from the radio to optical bands during the outburst state. The solid line represents the best-fitted third-order log-polynomial function.

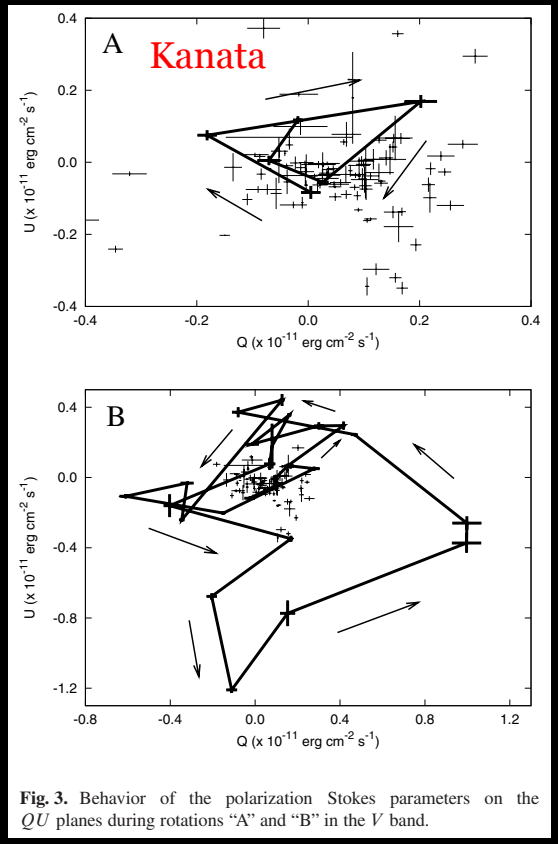


Fig. 3. Behavior of the polarization Stokes parameters on the QU planes during rotations "A" and "B" in the V band.

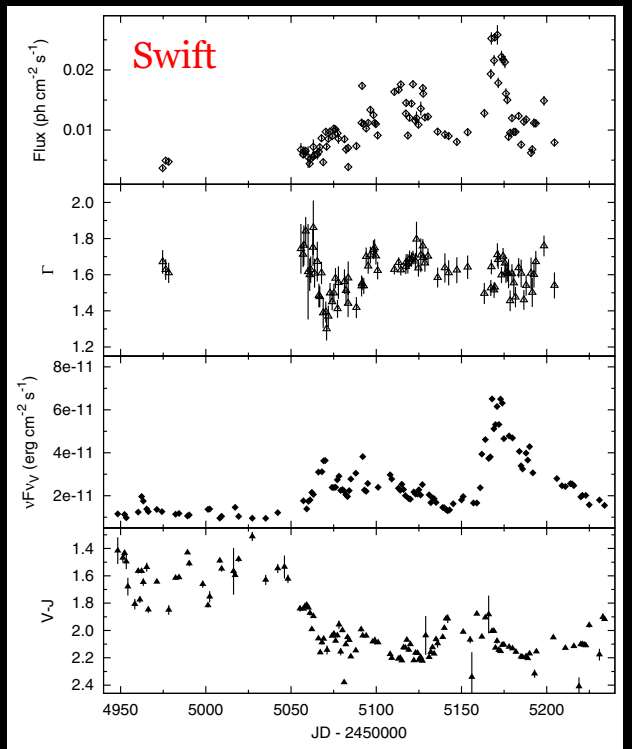


Fig. 1. Light curves, temporal variation of photon index, and color variation of 3C 454.3. From top to bottom, the panels show the light curve and the temporal variation of the photon index, Γ, in the X-ray band at 1 keV, the light curve in the V band, and $V - J$ color variation.

- 多波長モニターに 山口 32 m シングルディッシュモニターが参加

JVN + 微弱検出

■ 萌芽的な観測

(1) NLS1 で初めての VLBI 検出調査 (Doi et al. 2007, PASJ)

(2) BALQSO で初めての VLBI 検出サーベイ (Doi et al. 2009, PASJ)

(3) 楕円銀河サーベイ (Takemura, Sudou et al. in prep.)

(4) Fermi un-ID 天体の大規模サーベイ (Niinuma in prep.)

(5) HBL blazars のVLBI検出サーベイ (Akiyama in prep.)

※ 水色は広帯域観測

傾向 の 特徴

- JVN+AGN モニターの要求は非常に多い
  - “JVN モニター” というには epoch 数をもう少し増やしたい
- JVN+微弱検出の観測が増えてきた
  - 広帯域モードで実験的におこなわれている
  - イメージングを求めていない

⇒ 課題の抽出 と 対策へ

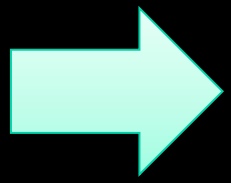
これからの JVN + AGN

求められている JVN 像？

(A) AGN モニターがしっかりやれる

(B) 微弱天体をサーベイできる

– 且つ、VLBA / EVN とは棲み分ける特化性能



(1) 高頻度
(2) 大量
(3) 高感度

→ 運用の改善が必要
- 自動化（システム、人員）
- 先鋭化（参加局）

→ 感度の向上が必要
- 広帯域化

12 Gbps での試験的観測
(NLS1 サンプル:　Doi, Oyama, Yamauchi+)

- VERA 2-beam
  - 周波数: 22 GHz
  - モード:
    - A-beam: 2 Gbps (512 MHz)
    - B-beam: 2 Gbps (512 MHz)
    - B-beam: 8 Gbps (2048 MHz)
  - 総観測時間 = 7 hour
    - 10 min/source
    - 1 min/slew
    - 21+20 source
    - + 8 calibrators

（ブロック図）

NLS1 サンプル（2--200 mJy @ 22 GHz）

ターゲット											キャリブレータ				
Ra (h m s)			Dec (d m s)			想定 mJy/b@22 GHz	想定 mJy@22GHz	citation	integ time (sec)	calibrator	コメント	S image peak mJy	X image peak mJy	Spindex	S_22GHz (予想) mJy
3	47	40.195	1	5	14.25	9.8	10.1	Veron-Cetty+2001	627	J0352+0238	JVAS 詳細不明				
7	13	40.291	38	20	40.08	2.6	2.7	Whalen+2008	900	J0709+3737	微妙	161	140	−0.1	126
7	44	2.242	51	49	17.48	3.0	3.0	Whalen+2008	900	J0733+5022	very good	602	540	−0.1	498
7	58	0.047	39	20	29.09	2.7	2.9	Whalen+2008	900	J0752+3730	微妙	143	137	0.0	133
8	14	32.135	56	9	56.55	17.5	20.2	Yuan+2008	198	J0824+5552	good	681	406	−0.4	276
8	49	57.99	51	8	28.83	86.8	88.4	Yuan+2008	120	J0903+5151	難しい。これ自身VLBA calib.	361	143	−0.7	72
8	50	1.171	46	26	0.41	5.3	5.4	Yuan+2008	900	J0847+4609	very good	252	287	0.1	316
9	2	27.152	4	43	9.4	38.5	39.5	Yuan+2008	120	J0901+0448	very good	184	304	0.4	442
9	48	57.295	0	22	25.6	27.1	28.1	Yuan+2008	900	Mrk1239 を。	これ自身VLBA calib.				
9	52	19.099	−1	36	43.63	14.8	15.1	Veron-Cetty+2001	275	J0945−0153	難しい	199	100	−0.5	60
9	53	17.106	28	36	1.63	11.2	12.1	Yuan+2008	476	J0945−0153	まあまあ	252	215	−0.1	191
10	31	23.728	42	34	39.4	4.2	4.3	Yuan+2008	900	J1038+4244	good, inverted!	84	227	0.8	475
10	34	38.599	39	38	28.17	6.0	6.5	Veron-Cetty+2001	900	J1033+4116	very good, inverted!	305	988	0.9	2367
10	37	27.454	0	36	35.76	6.9	7.0	Yuan+2008	900	ペトロフで未検出 (J1048+0055 離角 2.69 deg)		207	181	−0.1	164
10	47	32.654	47	25	32.24	185.2	193.6	Yuan+2008	120	J1051+4644	ダメ	171	66	−0.7	33
11	10	5.034	36	53	36.12	4.7	5.3	Yuan+2008	900	J1104+3812	まあまあ	206	182	−0.1	166
11	19	34.026	53	35	18.45	3.9	4.4	Zhou+2006	900	J1120+5404	Sp不明。難しい		60		
11	38	24.545	36	53	26.99	3.2	3.2	Yuan+2008	900	J1130+3815	very good	980	1077	0.1	1155
11	40	47.897	46	22	4.82	19.9	20.6	Whalen+2008	152	J1138+4745	まあまあ	139	133	0.0	129
11	46	54.298	32	36	52.24	3.7	3.9	Yuan+2008	900	J1138+4745	難しそう	196	123	−0.4	87
11	51	17.757	38	22	21.75	2.8	2.7	Whalen+2008	900	J1146+3958	very good	665	801	0.1	920
12	2	26.806	−1	29	15.54	2.9	3.1	Zhou+2006	900	J1207−0106	very good	163	279	0.4	416
12	3	9.594	44	31	52.52	3.1	4.9	Veron-Cetty+2001	900	J1203+4510	Sp不明。90mJy@C				
12	18	26.516	29	48	46.52	9.6	10.2	Veron-Cetty+2001	650	J1217+3007	flat, very good	248	246	0.0	245
12	38	52.147	39	42	27.59	2.6	2.8	Yuan+2008	900	J1242+3751	まあまあ	582	473	−0.2	405
12	46	34.683	2	38	9.02	9.3	9.6	Yuan+2008	689	J1250+0216	まあまあ	589	256	−0.6	138
13	2	58.925	16	24	27.49	4.7	7.2	Veron-Cetty+2001	900	J1300+141B	Sp不明だが		100		
13	5	22.746	51	16	39.55	21.2	21.9	Yuan+2008	135	J1259+5140	inverted	98	388	1.1	1079
14	21	14.075	28	24	52.23	11.8	12.3	Whalen+2008	432	J1419+2706	very good	386	397	0.0	405
14	35	9.523	31	31	48.3	9.9	11.3	Yuan+2008	614	J1435+3012	まあまあ	136	115	−0.1	102
14	43	18.578	47	25	56.53	41.6	43.2	Yuan+2008	120	なし (J1452+4522 離角2.59deg)		73	183	0.7	362
15	5	6.467	3	26	30.83	92.2	96.0	Yuan+2008	120	J1458+0416	very good。これ自身VLBA calib.	455	516	0.1	567
15	22	28.758	−6	44	41.83	3.0	3.6	Veron-Cetty+2001	900	なし (J1510−0543 離角 3.06 deg)		295	296	0.0	297
15	48	17.924	35	11	28.37	35.6	35.7	Yuan+2008	120	なし (J1602+3326 離角 3.34 deg)		976	424	−0.6	228
15	48	56.806	−4	59	34.26	2.7	2.9	Veron-Cetty+2001	900	J1550−0538	難しい	176	96	−0.5	61
16	29	1.315	40	7	59.62	3.0	3.0	Whalen+2008	900	J1623+3909	very good	180	228	0.2	272
16	33	23.585	47	18	58.96	15.8	16.4	Yuan+2008	241	J1637+4717	very good	648	650	0.0	651
16	44	42.536	26	19	13.19	22.1	22.9	Yuan+2008	123	J1642+2523	まあまあ	521	239	−0.6	134
17	3	30.379	45	40	47.09	29.1	29.9	Veron-Cetty+2001	120	J1658+4737	まあまあ	1077	542	−0.5	325
17	13	4.476	35	23	33.43	2.8	2.8	Whalen+2008	900	J1708+3346	まあまあ	127	117	−0.1	110
17	22	6.081	56	54	52	9.3	10.0	Yuan+2008	695	J1722+5856	flat , まあまあ	127	129	0.0	131