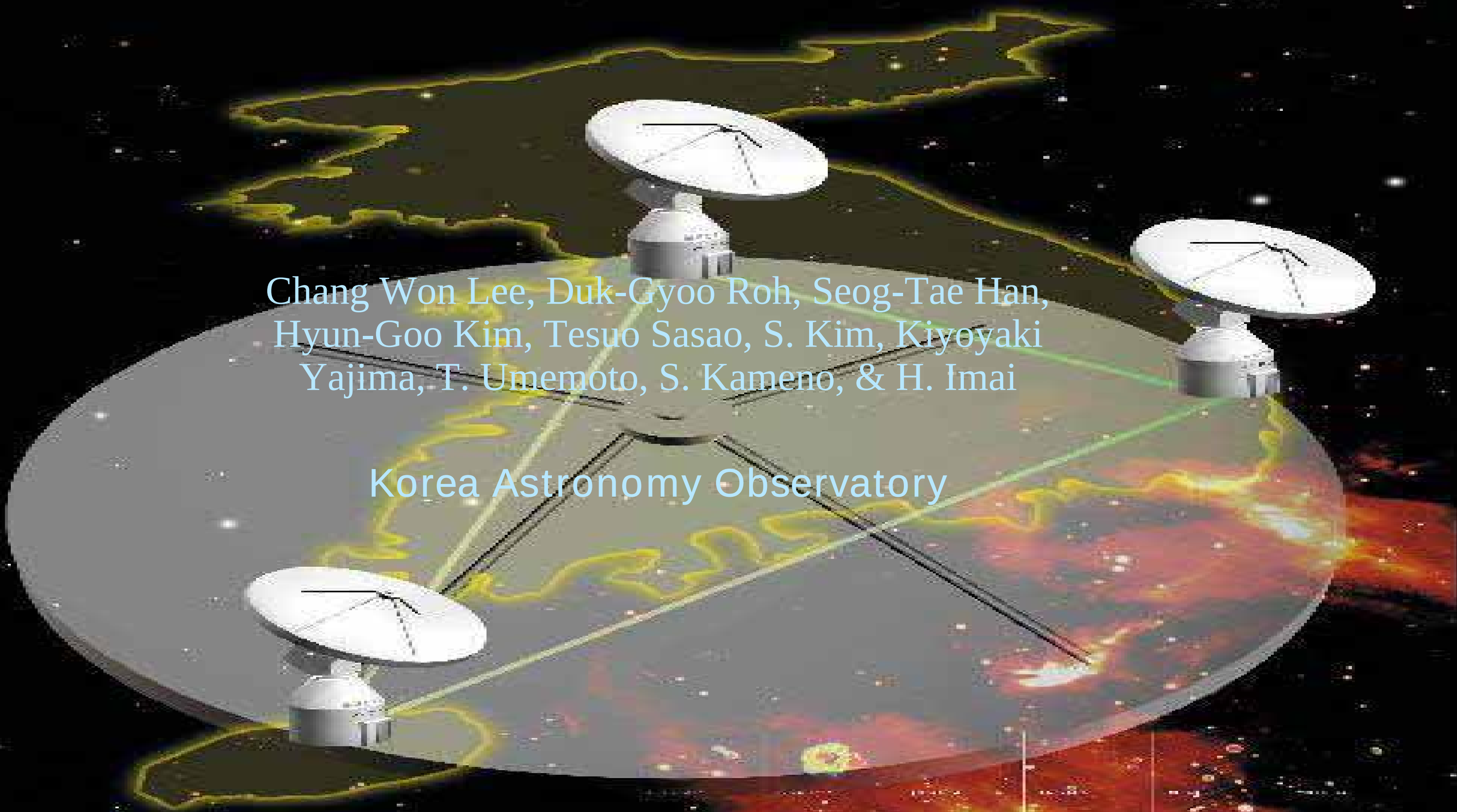
KVN and Its Science



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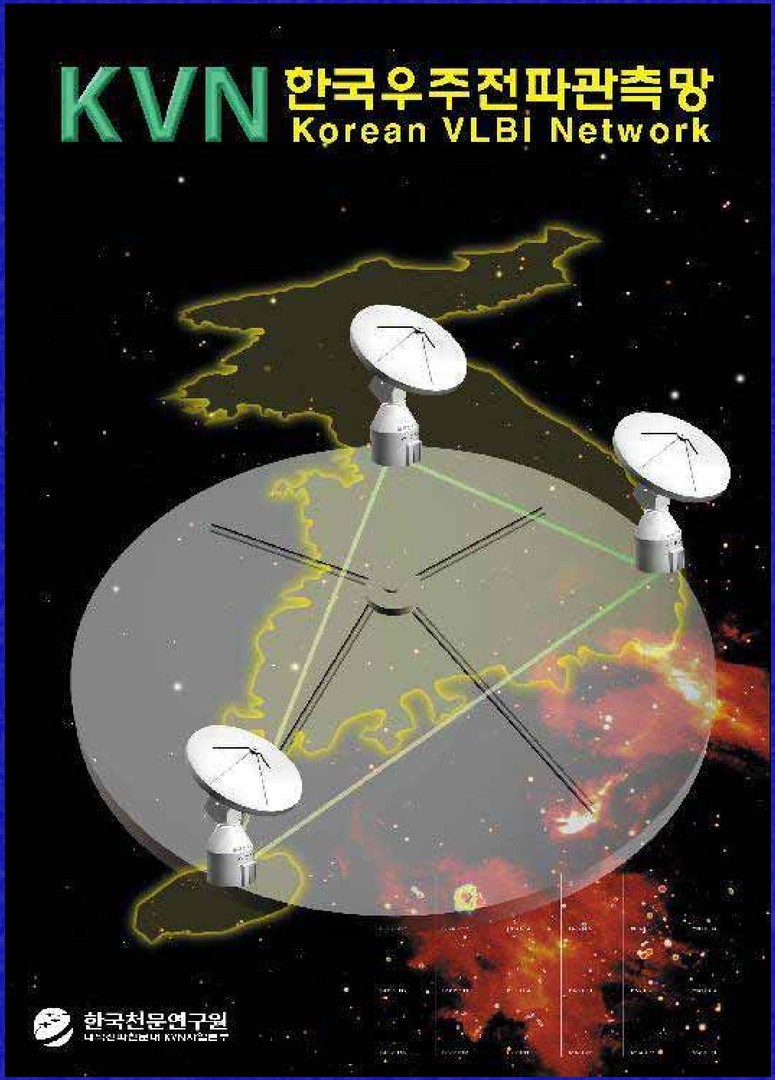
VLBI Next Generation Correlator Workshop

August 9 – 10, 2004, NICT, Kashima

Outline of KVN Project

- Construction of three 21-m radio telescopes over South Korea for the VLBI study
- Three stations with the longest baseline of ~ 478 km
- Receiving Frequencies:
  2/8 GHz (for Geodesy)
  22, 43, 86, 129 GHz (for Astronomy)
- Project Period:
  2001. 1. - 2007. 12. (7 years)

"The first dedicated VLBI with a capability of simultaneous observations in multi-frequencies from 22 to 129 GHz"

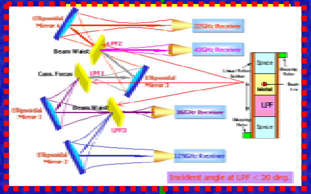


KVN Systems

High surface accuracy (~150 μm) for mm VLBI

η_A=0.6 at 100 GHz

Fast switching capability (within 2.5^o)



Multi-channel receivers at 22, 43, 86, & 129 GHz

KVNDAS

H-Maser Clock

Recorder

Recorder

KVN Correlator

Hard Disk-based Recorder (1 Gbps data rate)-Mark5B

KVN Receiver – Main features

- Four Channel Receivers (22, 43, 86, & 129 GHz) with Each Band having 2GHz coverage
- Simultaneous Observation Capability at Four Frequency Bands Including mm Wavelength Regime
- Phase Referencing using Multi-Channel Receivers
- Dual Polarization (RCP & LCP) Observation Capability
- Two Channel Receivers (22, 43 GHz) at Early KVN Stage

KVN DAS – Main features

- Maximum Bandwidth of 256 MHz (limited by Maximum Recording Speed 1,024 Mbps)

- Various Observing modes

  - 256MHz (Mode 1)
  - 128MHz x 2Ch (Mode 2)
  - 64MHz x 4Ch (Mode 3)
  - 32MHz x 8Ch (Mode 4)
  - 64+64+128MHz (Mode 7)
  - 32+32+64+128MHz (Mode 8)
  - 32+32+32+32+128MHz (Mode 9)
  - 16+16+32+32+32+128MHz (Mode 10)
  - 16MHz x 16Ch (Mode 5) - 8MHz x 16Ch (Mode 6) (Geodetic)
  - Dual Polarization Observation → Mode 2, 3, 4, 5

KVN Correlator

- At least 10 baselines for 5 stations, hopefully 21 baselines for 7 stations
- Spectral resolution of 62.5 KHz (0.22 km/s at 86 GHz) → 1024 lags for each 64 MHz bandwidths as a basic correlation unit
- To improve the spectral resolution
  - Serial operation of CB or
  - Extension of the number of lags as a basic correlation unit

KVN Spatial Resolution and Sensitivity

- KVN Spatial Resolution: ~ 1 – 6 mas at 22 - 129 GHz

- KVN Sensitivity

$$\Delta S = (1/\eta_s)(SEFD_i\ SEFD_j)^{(1/2)} / [N(N-1)\ \Delta\nu\ t_{int}]^{(1/2)},$$

where η_s =system efficiency factor,

$$SEFD = 2kT_{sys}/A_e$$

Continuum (at 22 GHz)

- Fringe detection sensitivity : ~ 7 ΔS ~ 73mJy

(when D=21m, Tsys=100K, BW= 64 MHz, η_A=0.6, η_s =0.8, tint= 200sec, N=2)

- Map sensitivity : ~2.0mJy

(when D=21m, Tsys=100K, BW=64 MHz, η_A=0.6, η_s =0.8, tint= 1800sec, N = 3)

KVN Sensitivity for Maser

Maser

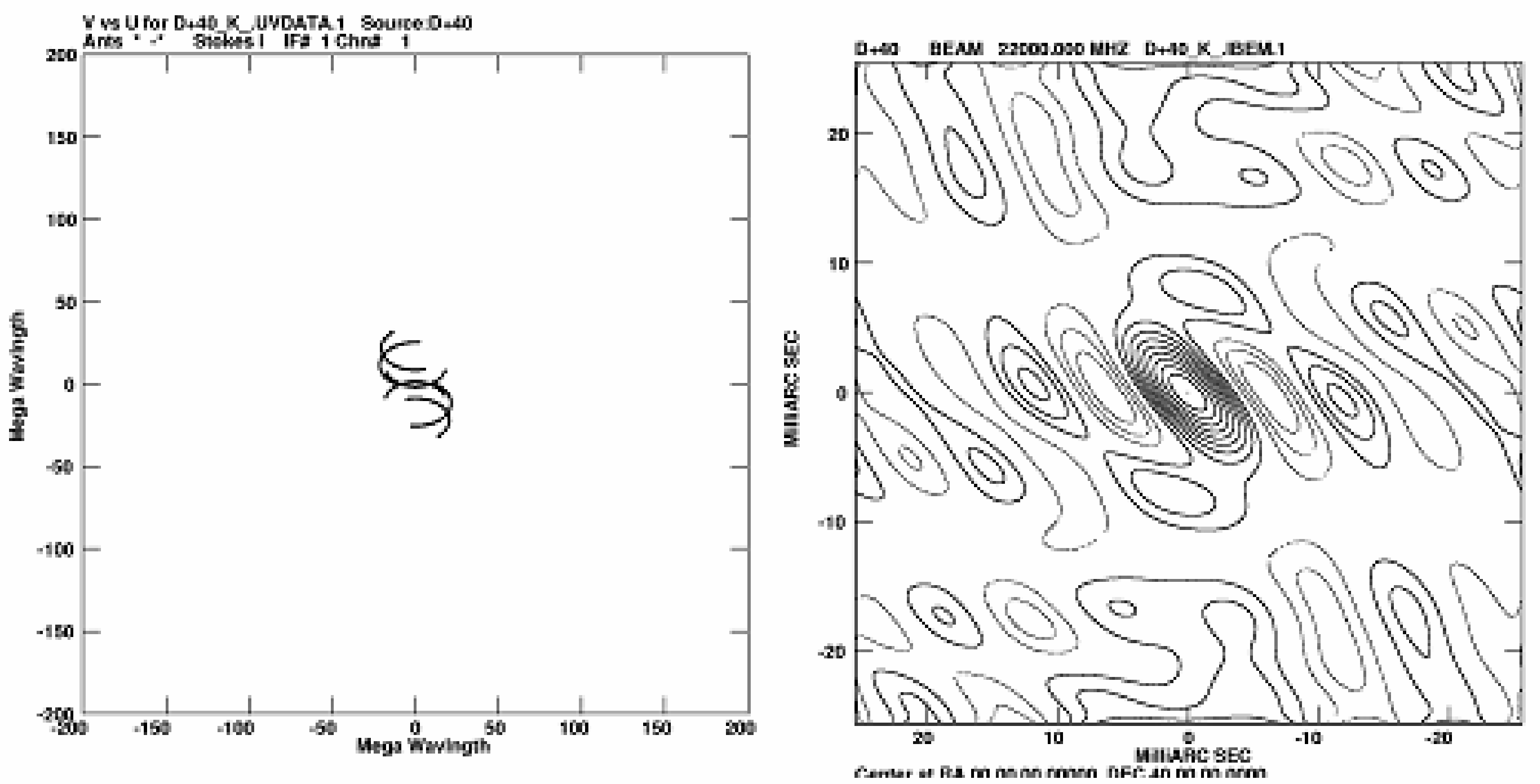
- Fringe detection sensitivity : ~ 7 ΔS ~ 2.2Jy

(when D=21m, Tsys=100K, BW=50 KHz, η_A=0.6, η_s=0.8, tint= 200sec, N=2)

- Map sensitivity : ~61mJy

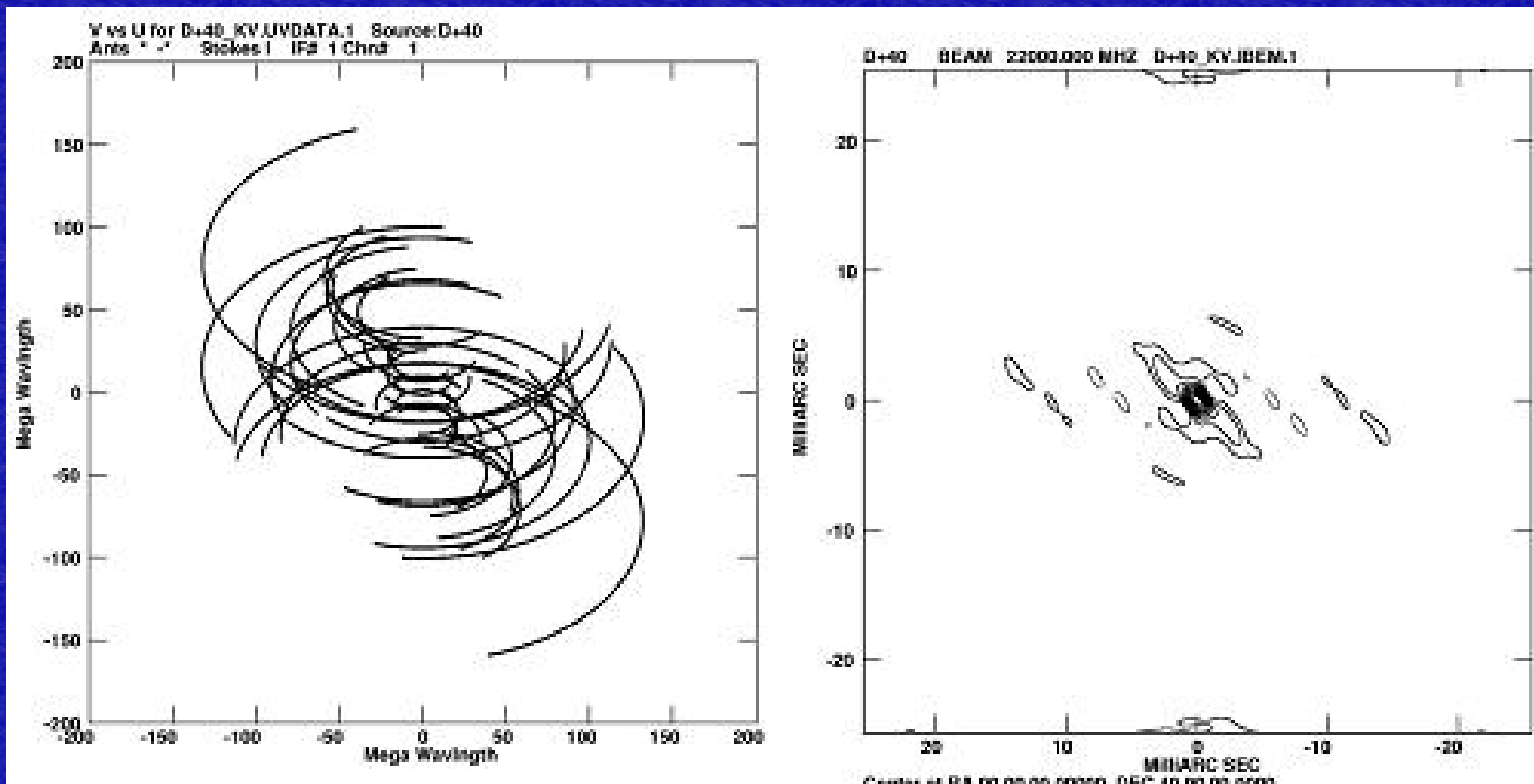
(when D=21m, Tsys=100K, BW= 50 KHz, η_A=0.6, η_s=0.8, tint= 1800sec, N = 3)

UV Coverage and Synthesized Beam for KVN



δ=40° source at 22 GHz (from D.G. Rho 2003)

UV Coverage and Synthesized Beam for KVN+VERA



δ=40º source at 22 GHz (from D.G. Rho 2003)

Advantages of KVN

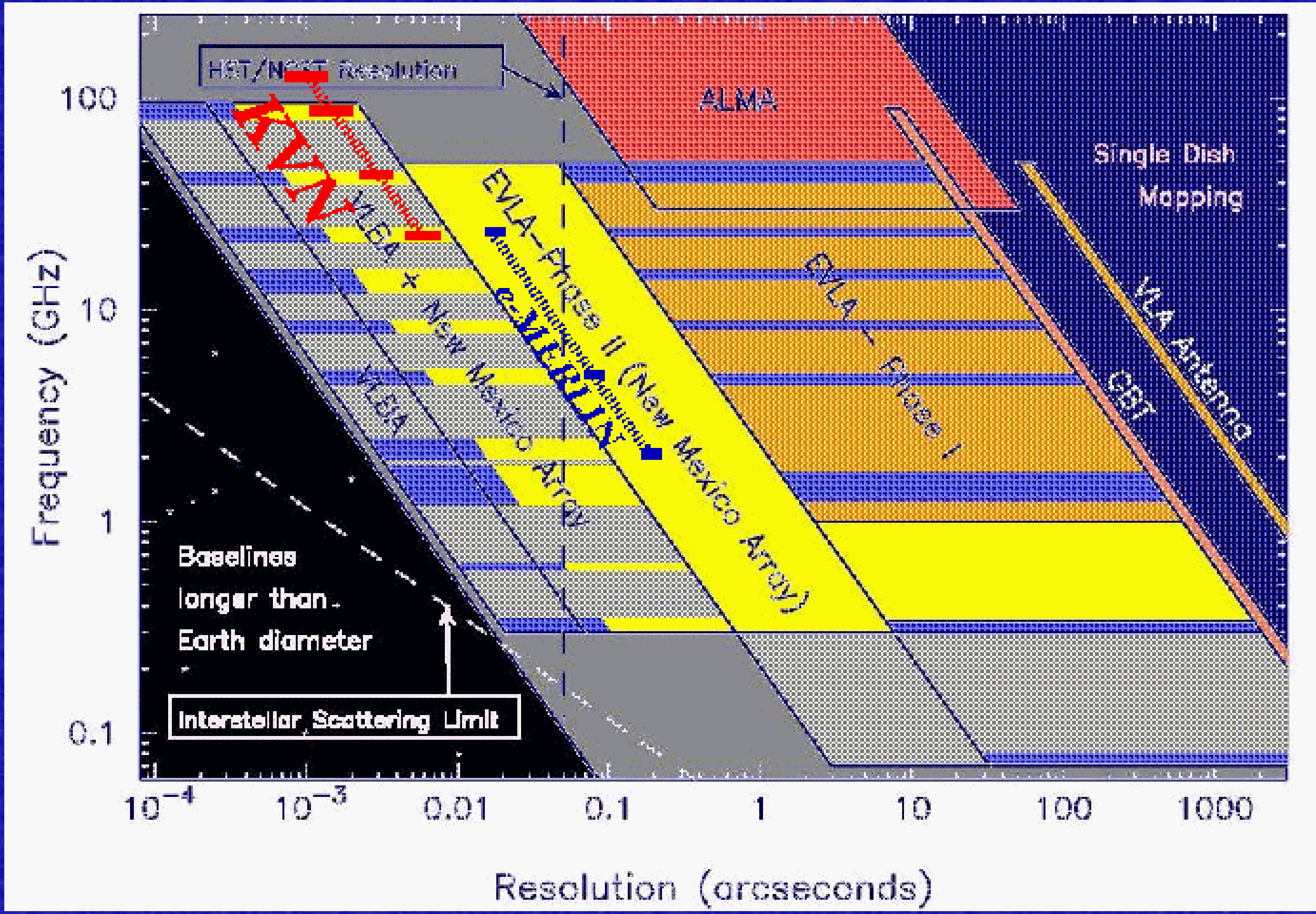
- *Simultaneous multi-frequency VLBI observations from 22 to 129 GHz*

- Phase-compensated mm VLBI

- <u>VLBI system with "Good" size baselines useful for studying several mas scale objects</u>

- Collaboration with VERA (+VSOP2) to improve spatial resolution and imaging capability

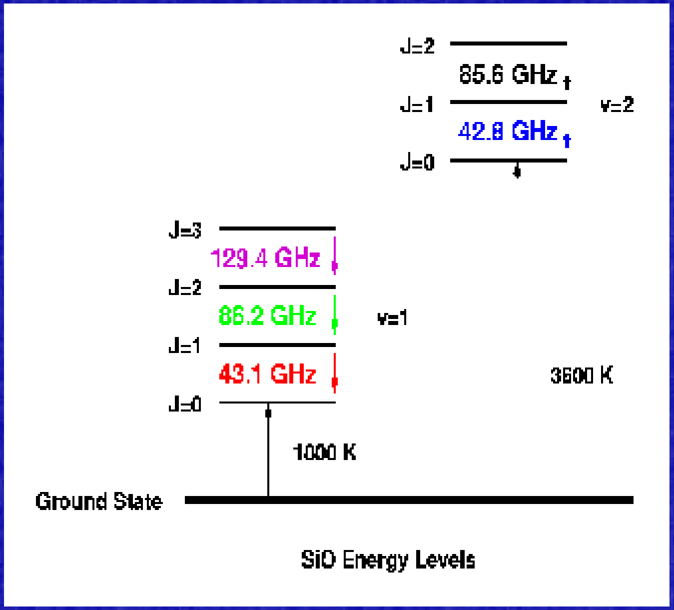
Advantages of KVN

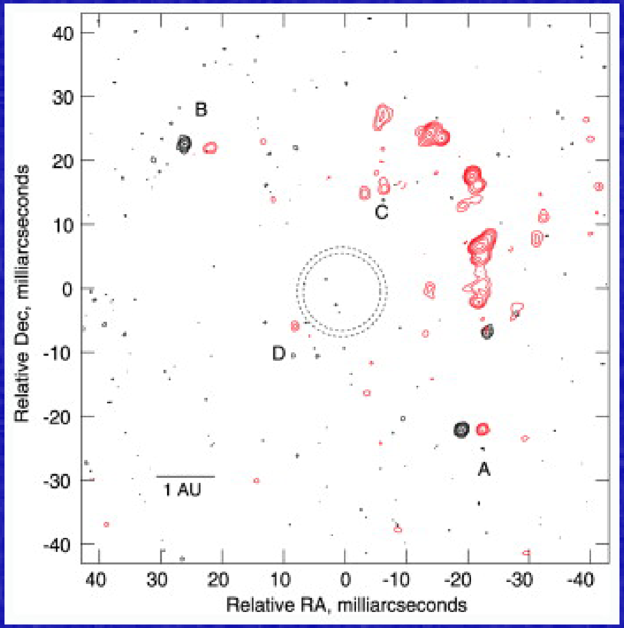


KVN Science targets

- H_2O and SiO masers from Evolved stars and Star forming regions.
- Continuum emissions from YSO, Micro-quasar, and AGN
- More …

Simultaneous Multi-frequency Observations for H_2O and SiO Masers of Late Type Stars

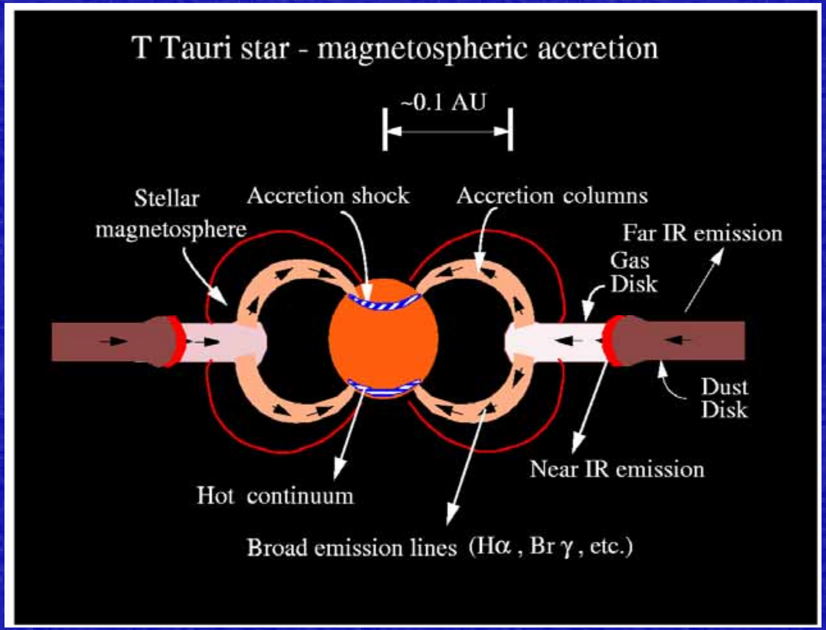




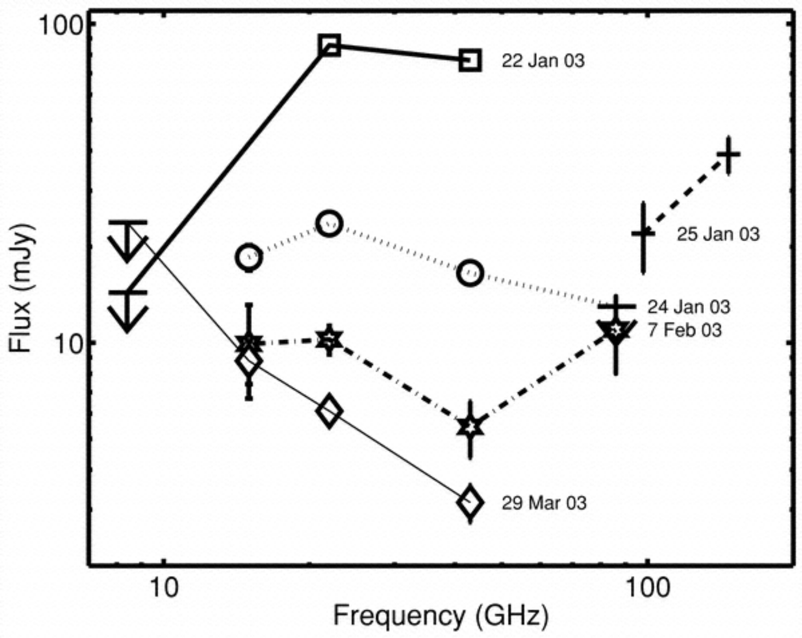
The 43 GHz masers (red) and the 86 GHz masers (black) with VLBA in R-Cas by Phillips et al. 2003

1. *To study physical relations between maser formation and pulsation driven shocks* → Time monitoring is needed
[Different phase lags between H_2O (large) and SiO masers (rather small) are believed due to pulsation driven shocks from the activity of the central star (Reid & Menten 1998, Imai et al. 2003)].
2. *To study SiO pumping mechanisms* with simultaneously obtained SiO masers in three transitions

Simultaneous Multi-frequency Continuum Observations of YSOs



Courtesy of L. Hartmann



Spectra of GMR-A (WTTS) (Bower 2003) from VLA, VLBA, BIMA, & NMA obs.

1. Time monitoring of the "flare" in multi-frequency in protostars and WTTS

1) Flare origin -- from magnetic reconnection (e.g., Tsuboi et al. 2000)

2) Rather bright, and variable (rising up ~160mJy within a few hours) especially in higher frequency

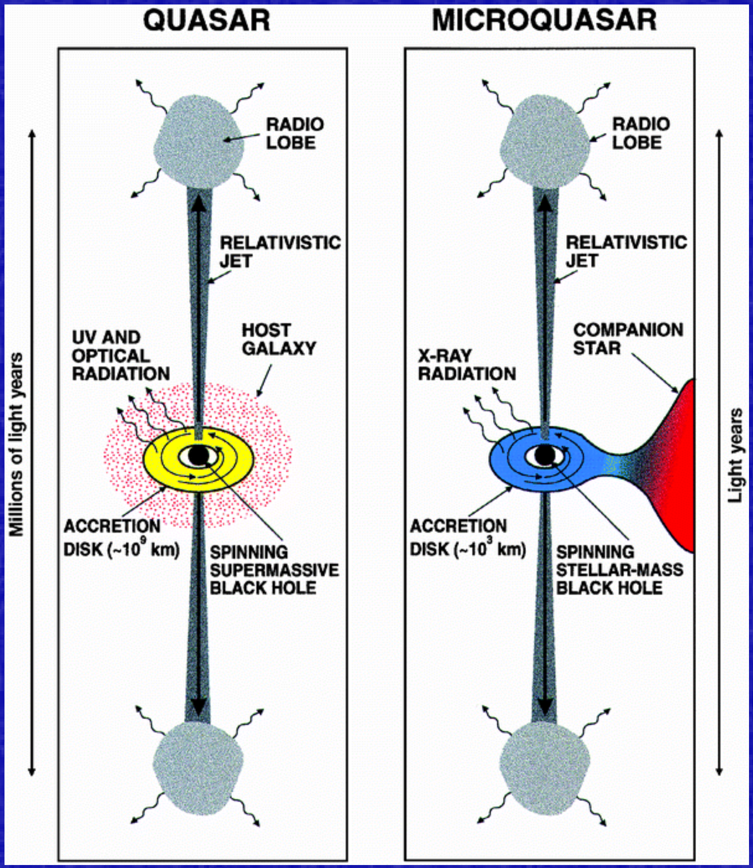
→ To measure time scale change of the SED of YSOs which will give a clue of understanding of flaring, cooling, and information of magnetic fields of YSOs

Simultaneous Multi-frequency Observations of Continuum from YSOs

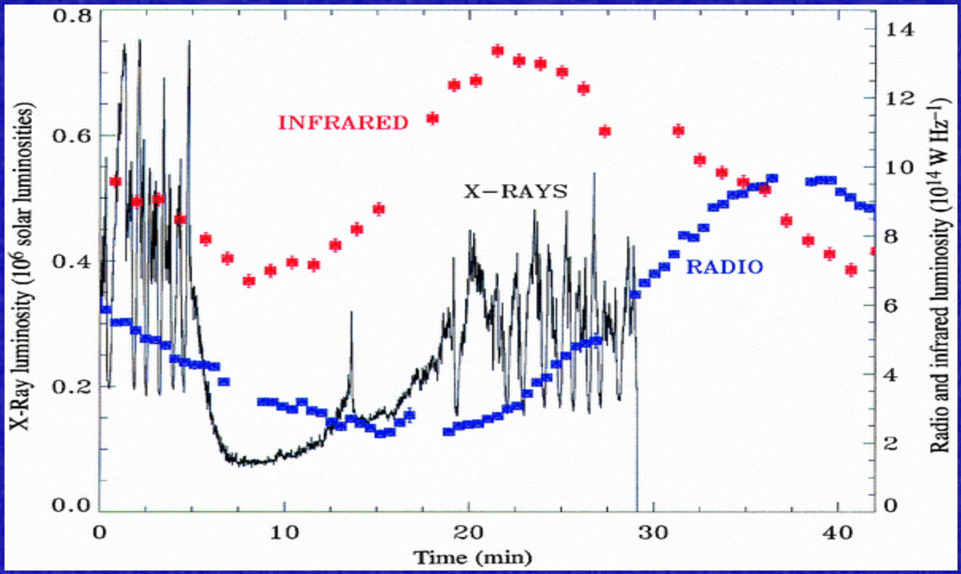
2. To make direct imaging of flaring magnetosphere of YSO with 1.2 R_o scale with KVN+VERA+VSOP2

3. Good quality (high frequency) continuum map in YSO with H_2O maser, and Astrometry of the continuum

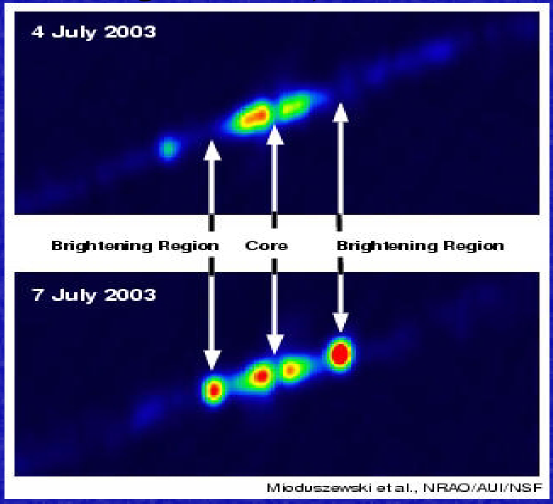
Multi-frequency Continuum Observations of Microquasar



Micro-quasar :A spinning BH or NS + a companion normal star + accretion disk + relativistic jets emitting radio continuum (Mirabel & Rodriguez 1998)

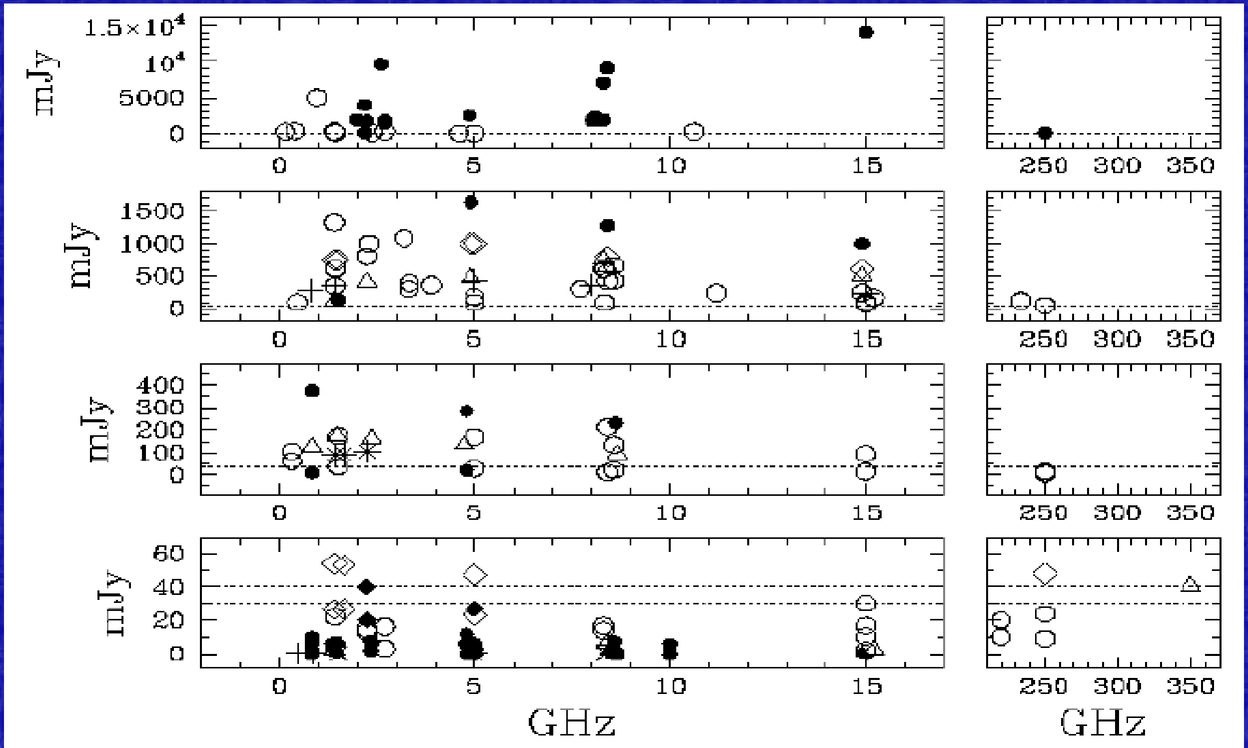


Intensity Variability (Mirabel & Rodriguez 1998)



SS443- Daily Variation

Multi-frequency Continuum Observations of Microquasar

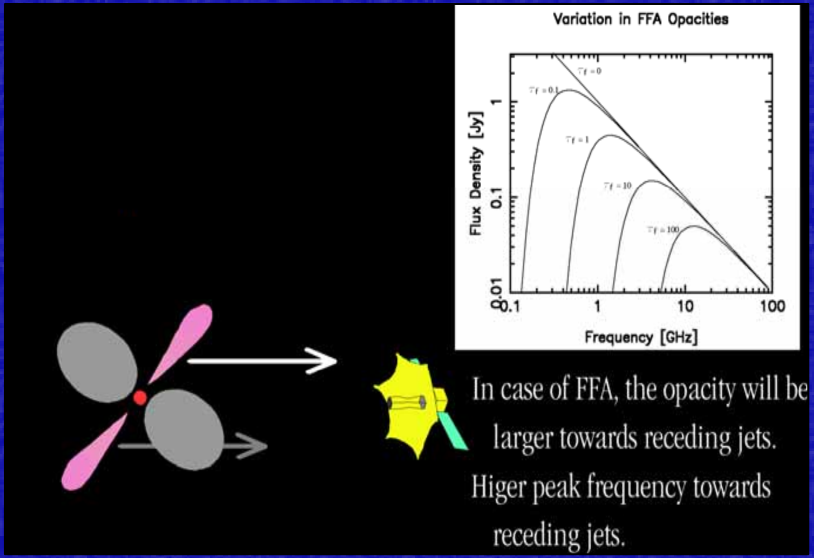


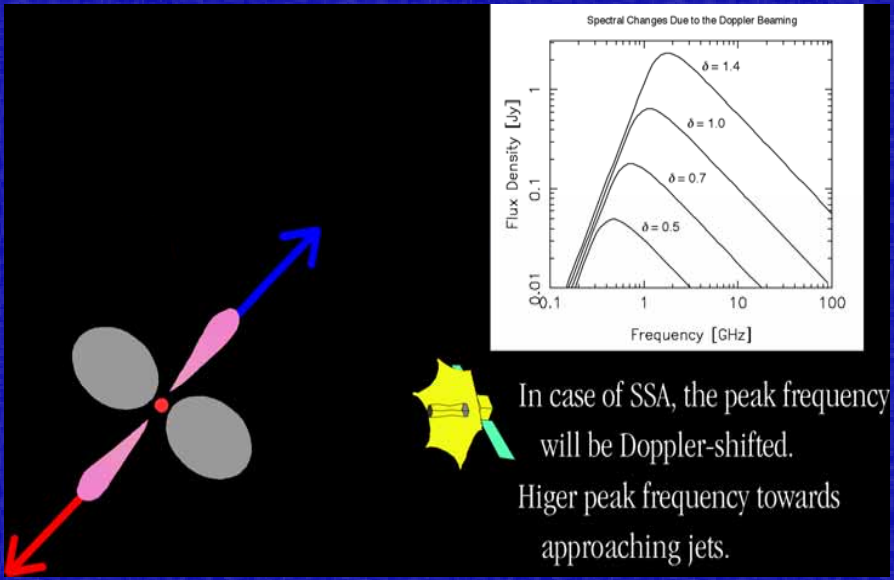
Flux is rather flat across a wide frequency range and a gap of observation between 20 – 200 GHz (Kim et al. 2002)

- *Multi-frequency observations are needed in the 'gap' region.*
- *High time resolution observations of microquasars in flare stage* because of its fast variability (even with a few minutes interval) in some case.
- *Time for the target of opportunity is needed.*

Multi-frequency Continuum Observations of AGN : SED of AGN

1. *To discriminate Free-Free Absorption (FFA) from Synchrotron Self Absorption (SSA) in the jets of AGN*



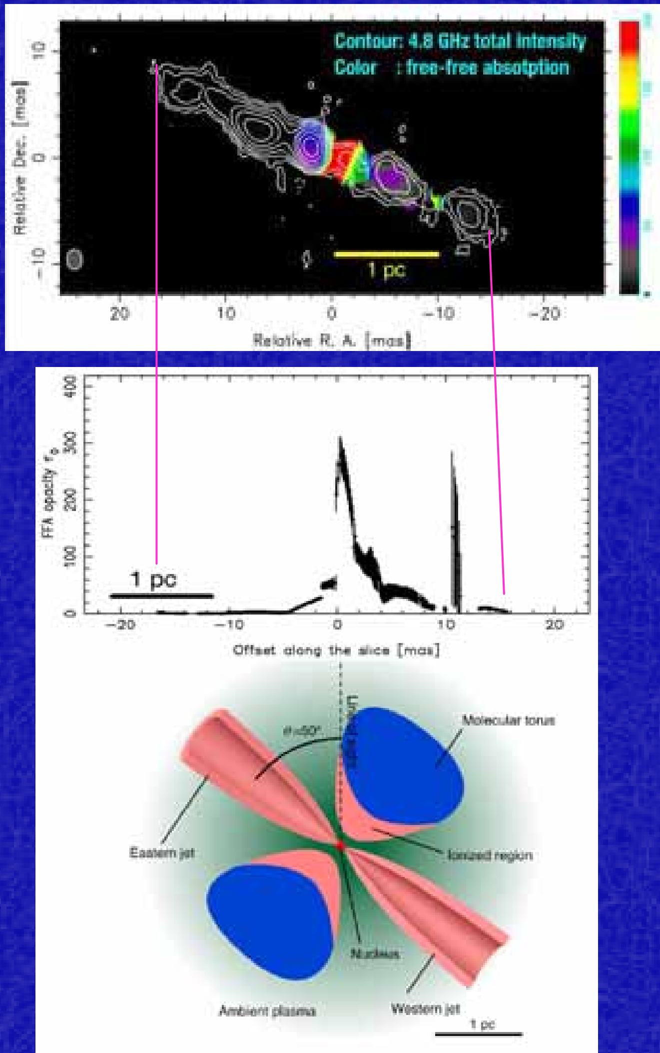


Courtesy of S. Kameno

Multi-frequency Continuum Observations of AGN : SED of AGN

2. *The FFA observation is useful to trace the dense plasma in the accreting disk of the AGN*

The Identification of FFA will inform us which frequency regime is less affected by the FFA and so the distribution of dense plasma can be better drawn in that frequency band (usually higher frequency band) where the opacity becomes lower (Kameno et al. 2003)



Multi-frequency Simultaneous Observations of H_2O maser and Continuum of AGN

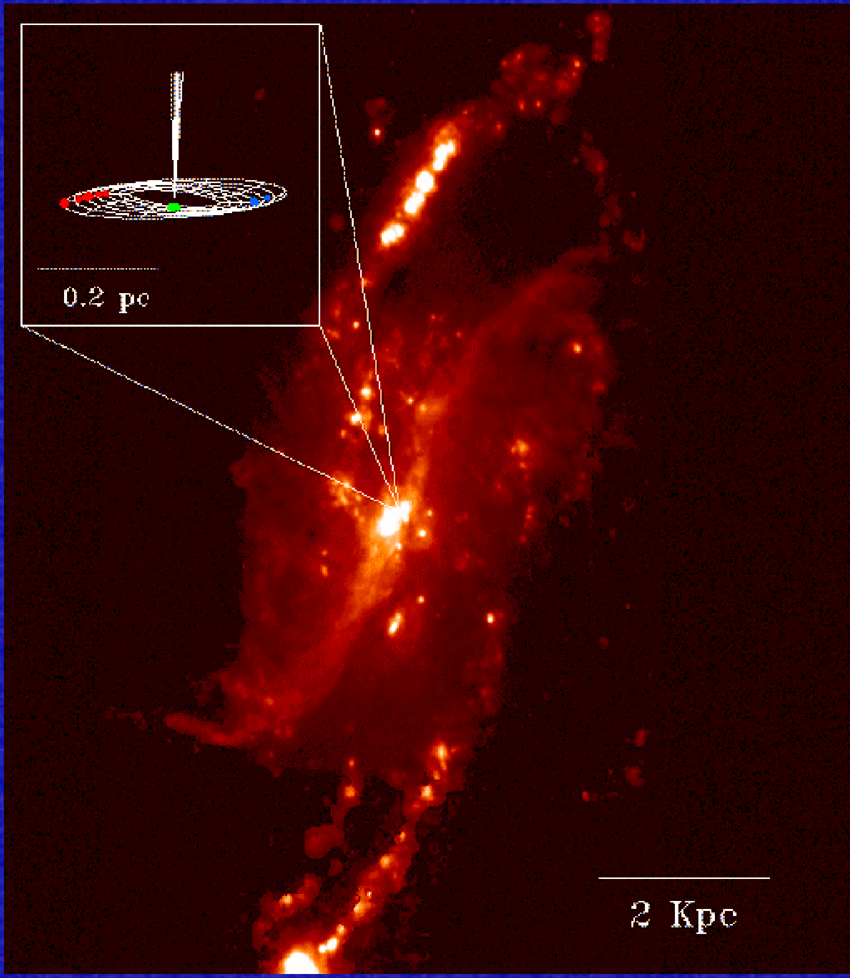
- *H_2O masers to trace pc-scale accreting warm gas in AGN*

→*Maser spot will be precisely determined with respect to continuum.*

→

1. *Distance of the galaxy*
2. *Measurement of the offset between the radio emission and the black hole*

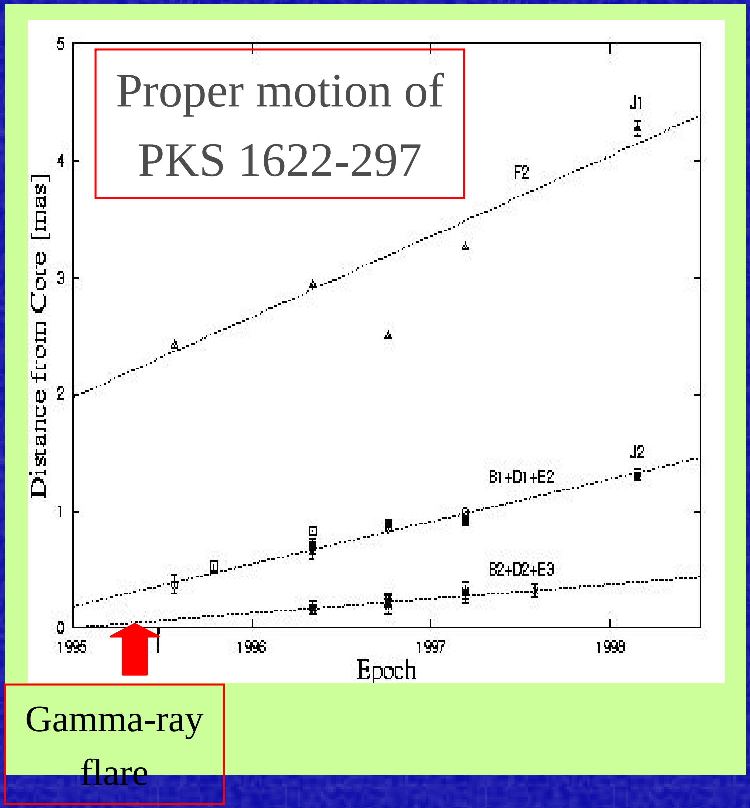
→ Need combination with VERA for ~1 mas spatial resolution



Greenhill et al. 2001

Multi-frequency Continuum Observations of Gamma-ray flared AGN

- *To study some connection between Gamma-ray flare & jet formation* by obtaining detailed structure of new jet component in optically thin frequency regime (high frequency)
- *To study Acceleration phenomena in the beginning of the jet formation* from *high resolution time monitoring observations*
- Collaboration with VERA (+VSOP2) needed



(Jorstad et al. 2001, Wajima et al. in prep.)

KVN will give

a unique opportunity of the study of various VLBI targets from the Simultaneous Multi-frequency Observations with phase compensated mm-VLBI.

For more and better science,

collaborations with VERA+VSOP2 are required.