

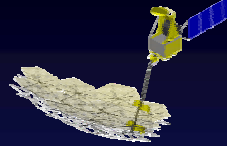


# VSOP-2 Correlator Design Requirement

Y. Murata

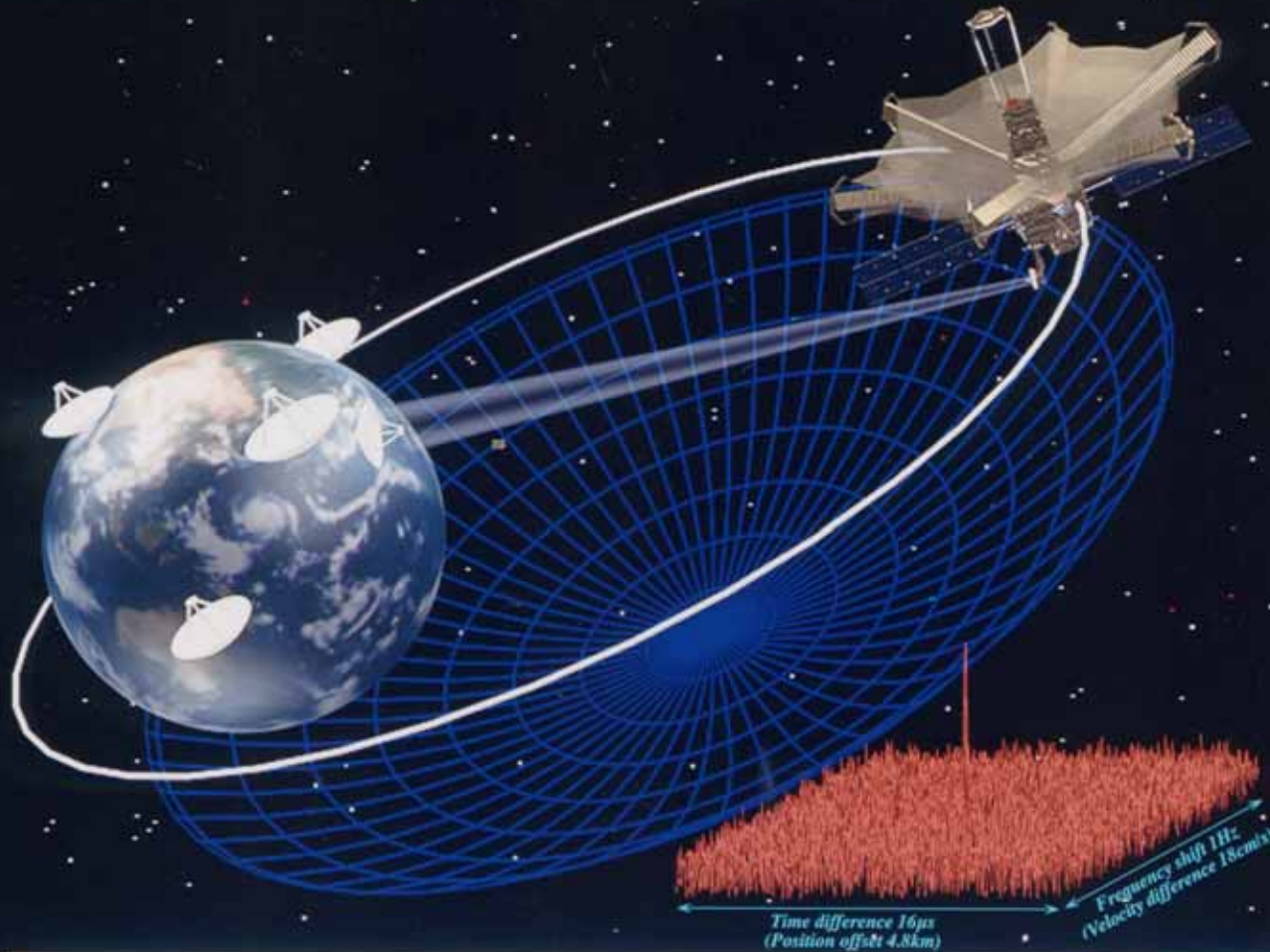
ISAS/JAXA

# HALCA and VSOP



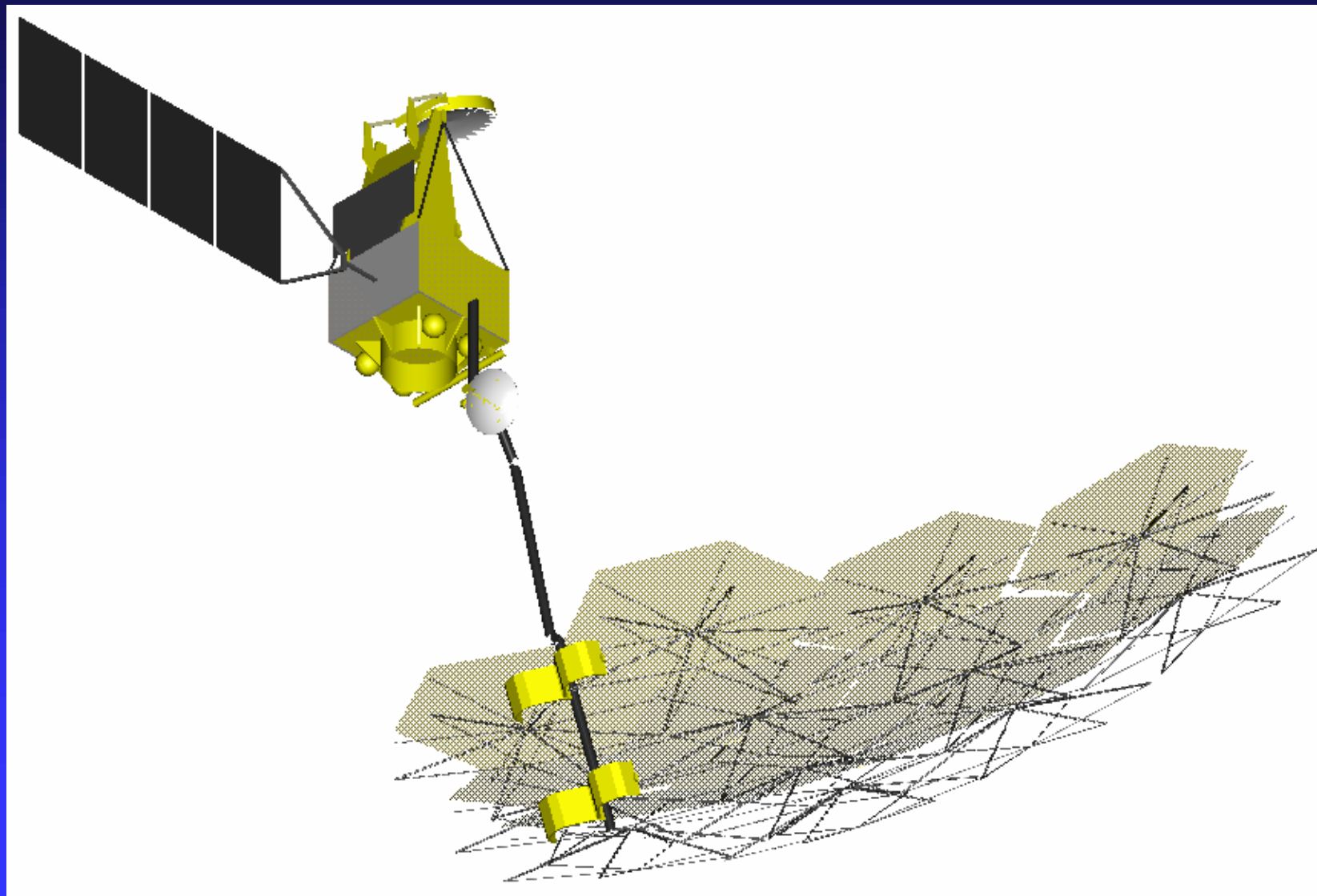
VLBI Space Observatory Programme

Highly Advanced Laboratory for Communications and Astronomy

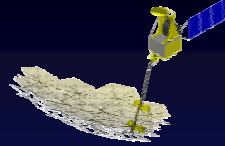


The ISAS satellite HALCA and the Usuda 64m antenna conducted their first successful interferometric test on 7th May 1997 during observations of the quasar PKS1519-273 at a wavelength of 18cm. The spike shows the first 'fringes' — the coherent combination of the signals from the two elements — at the VSOP correlator in Mitaka, NAO. This is a major step towards the synthesis of a radio telescope bigger than the Earth.

# VSOP-2衛星外觀

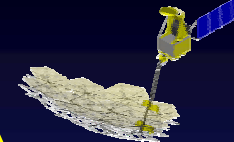


# VSOP-2



- VSOP-2 is a mission for the highest resolution imaging of AGN and young stellar objects.
- Improvements over VSOP by factors of  $\sim 10$ 
  - Higher frequency
    - Highest observing frequency 43GHz
  - Higher resolution
    - 38 micro arcsecond @43GHz
  - Higher sensitivity
- The angular resolution is approaching the dimensions of
  - accretion disk and black hole in nearby AGN
  - jet launching site
  - Structure of magnetospheres of protostar

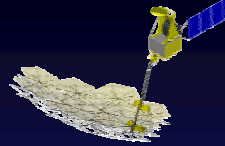
# Comparison of VSOP-2 and VSOP, VLBA



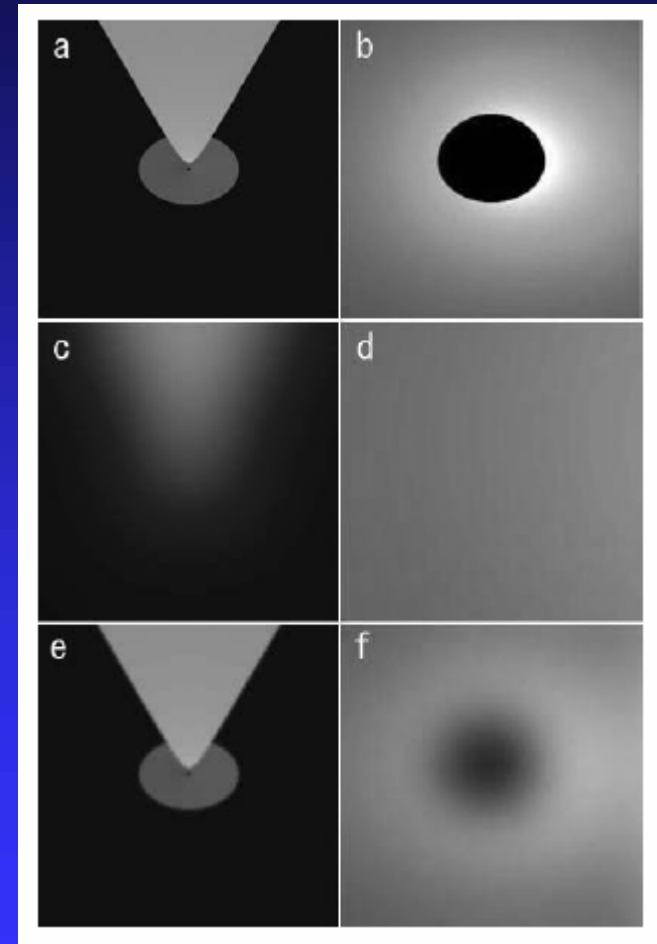
	VSOP-2	VSOP	VLBA
Antenna diameter	9m	8m	25 m
Apogee height	25,000km	21,500 km	0 km
Orbit period	7.5 hour	6.3 hour	1day
Polarization	LCP/RCP	LCP	LCP/RCP
Data downlink	1 Gbps	128 Mbps	512 Mbps*
Observing frequency (GHz)	8, 22, 43	1.6, 5, (22)	5,8,22,43,86
Highest resolution	38 $\mu$ as	360 $\mu$ as	96 $\mu$ as
sensitivity (5/8 GHz)	22 mJy	158 mJy	7.9 mJy
(22 GHz)	39 mJy	N.G.	23 mJy
(22 GHz with phase-ref.) ( 1.5hour integration)	9.1 mJy	--	5.3mJy
Launch	2010FY(target)	Feb.1997	

- Baseline sensitivities are calibrated assuming the VLBA antenna as the ground antenna.

# Accretion Disk of AGN



- Imaging of the accretion disk around the blackhole
  - Higher frequency observation to avoid the influence of the plasma gas around the core.
  - $T_B > 10^9\text{-}10^{10} \text{ K}$  @ ADAF disk (Standard model disk  $10^5 \text{ K}$ )
  - 10  $R_g$  resolution @ M87 ?



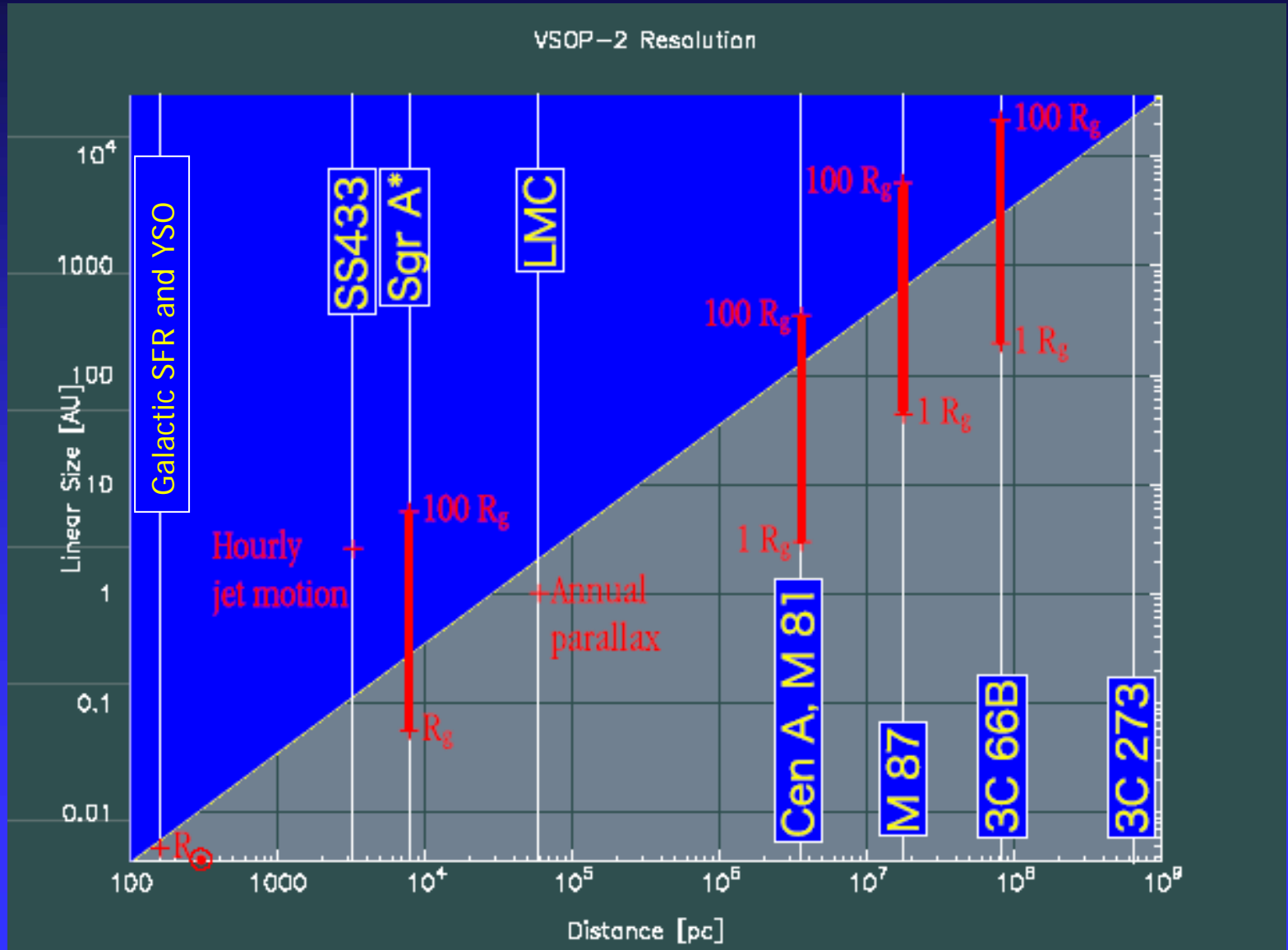
· model  
·  $R_g \sim 3 \mu\text{asec}$

· VSOP  
· resolution  
·  $\sim 100 R_g$

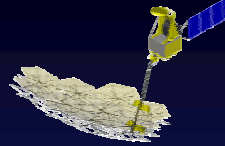
· VSOP2  
· resolution  
·  $\sim 12 R_g$

Takahashi et al. 2003

# VSOP-2 Resolution

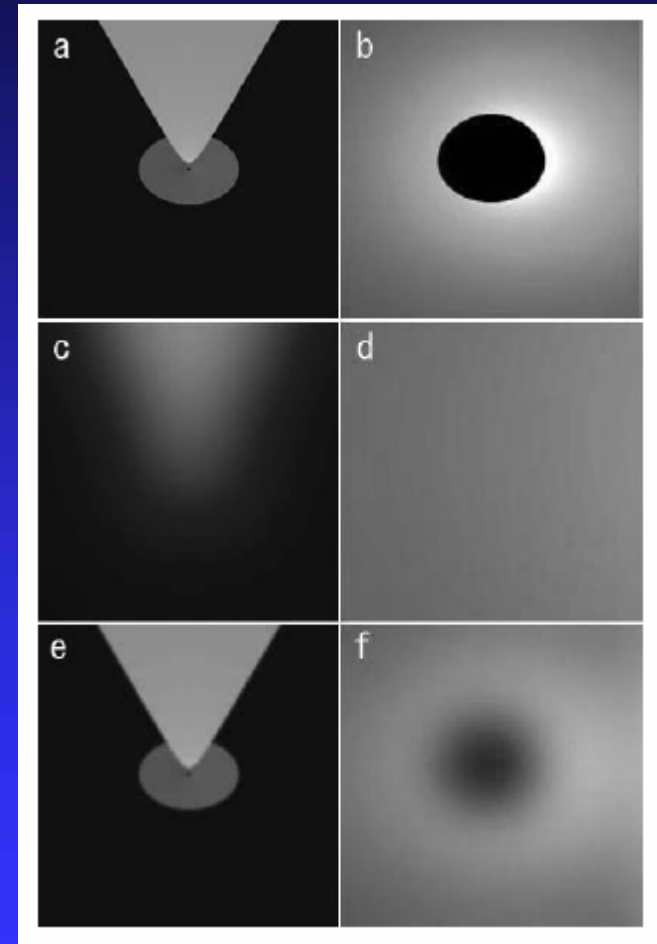


# Accretion Disk of AGN



- Imaging of the accretion disk around the blackhole
  - Higher frequency observation to avoid the influence of the plasma gas around the core.
  - $T_B > 10^9\text{-}10^{10}$  K @ ADAF disk (Standard model disk  $10^5$  K )
  - 10  $R_g$  resolution @ M87 ?

- High Frequency
- Resolution



• model  
 $R_g \sim 3 \mu\text{asec}$

• VSOP  
resolution  
 $\sim 100 R_g$

• VSOP2  
resolution  
 $\sim 12 R_g$

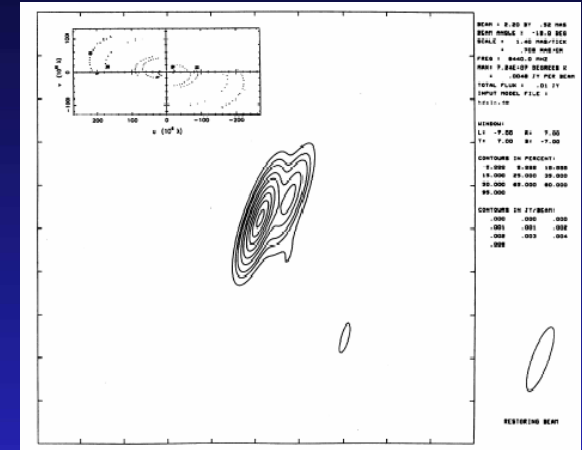
Takahashi et al. 2003



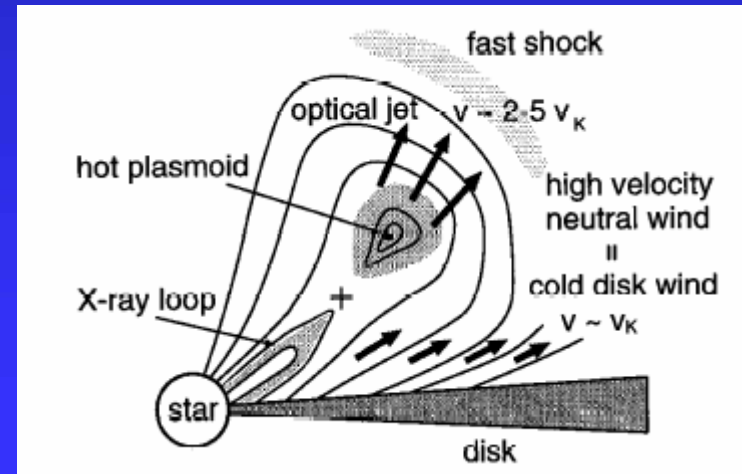
# Magnetic structure of the protostars



- Nonthermal emission from the protostars
  - Strong correlation between X and Radio
  - Emission region  $\sim 5\text{-}25 R$
  - $T_B > 10^{7-9}\text{K}$
  - Resolution of VSOP-2  $\sim 1R$  @ 150pc
  - Circular polarization from the Gyro-synchrotron radiation
  - Imaging of the flare region
- Polarization
- Resolution



Phillip et al. 1996

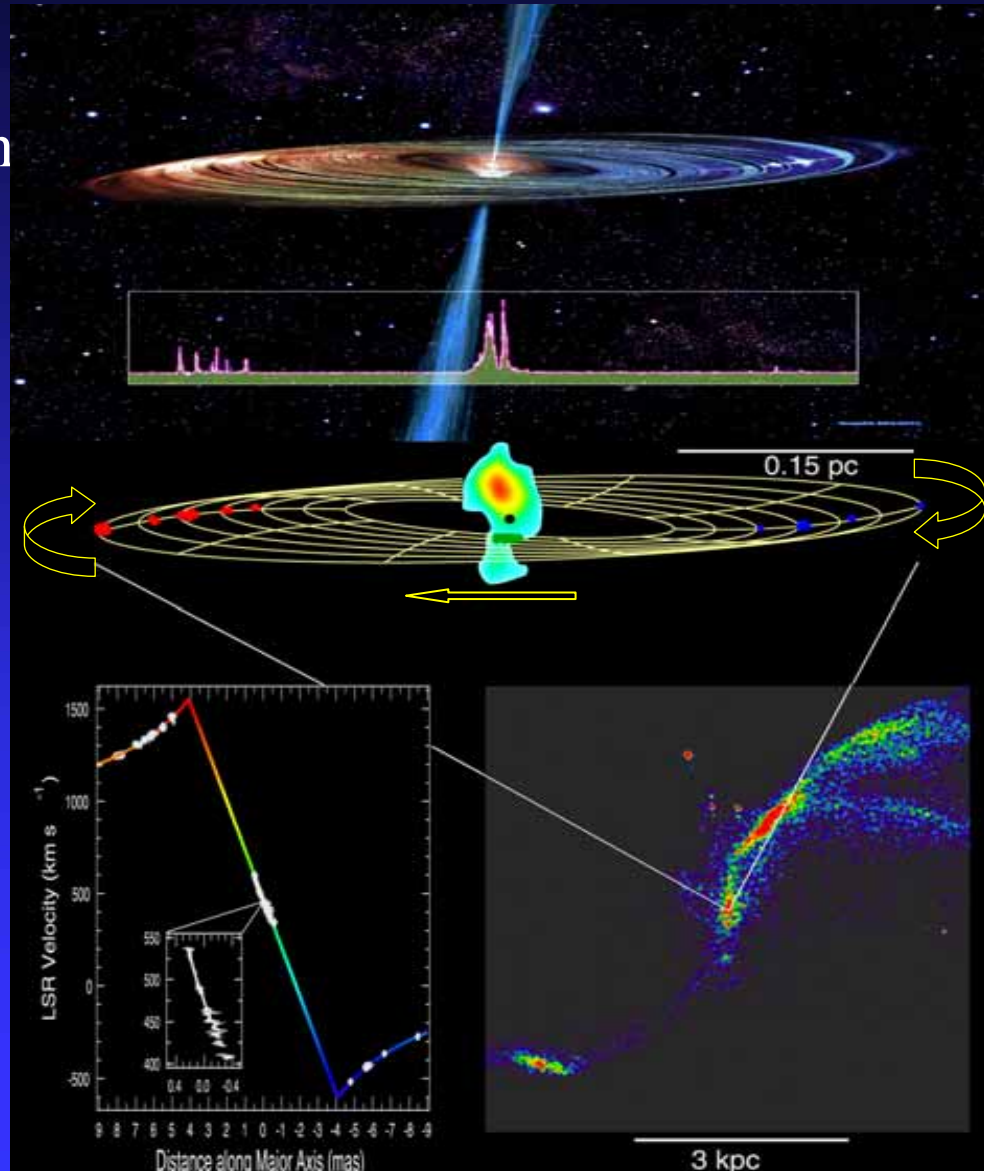


Hayashi et al. 1996

# Dynamical structure of galaxies and YSO's using maser observation.



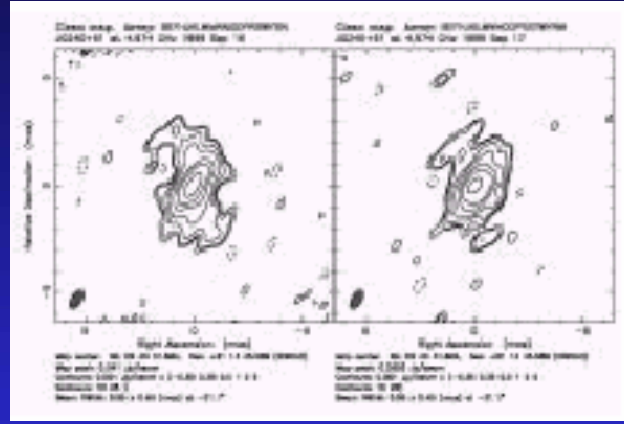
- NGC 4258 type galaxy
  - Detect the H<sub>2</sub>O maser motion in shorter period.
  - 3-dimensional motion of the maser spots
  - More accurate measurement of the distance of the objects
  - Estimate of the mass of the central region
- Motion of YSO disk
- YSO jets, Late-type stars
  - Phase referencing
  - Resolution





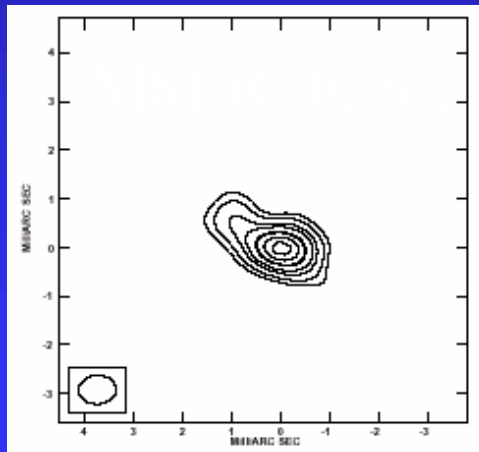
# Too weak sources by VSOP

- XRBs
  - Possible to observe in anytime  $\sim 7$
  - Only it is in active  $\sim 10$
  - Jet motions



Xray Binary  
LSI+61 ° 303  
C band  
  
(Taylor et al, 2000)

- Galaxies
  - Radio Quiet Quasars
  - Seyfert Galaxies
  - Near normal galaxies



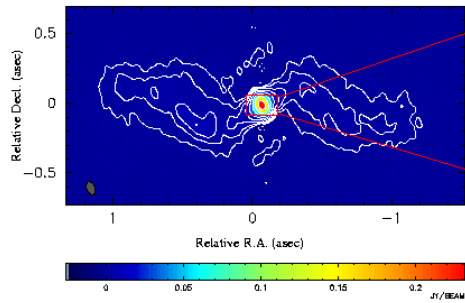
Seyfert Galaxy  
M81

- Sensitivity
- Resolution

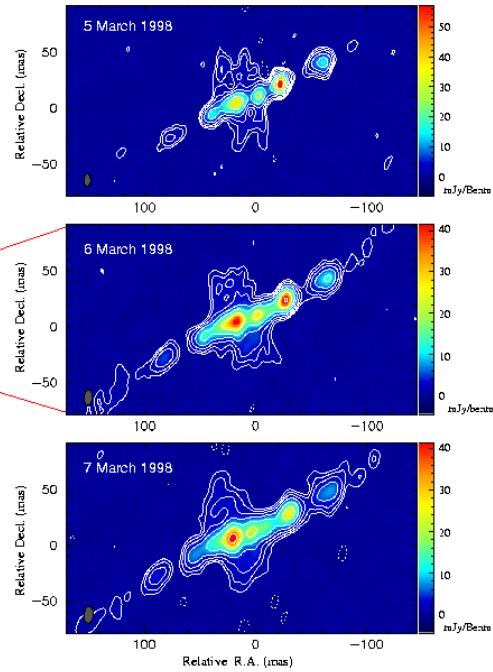
Bartel and Bietenholz (2000)

# XRB observations by radio interferometer

MERLIN+VLA Image of SS433



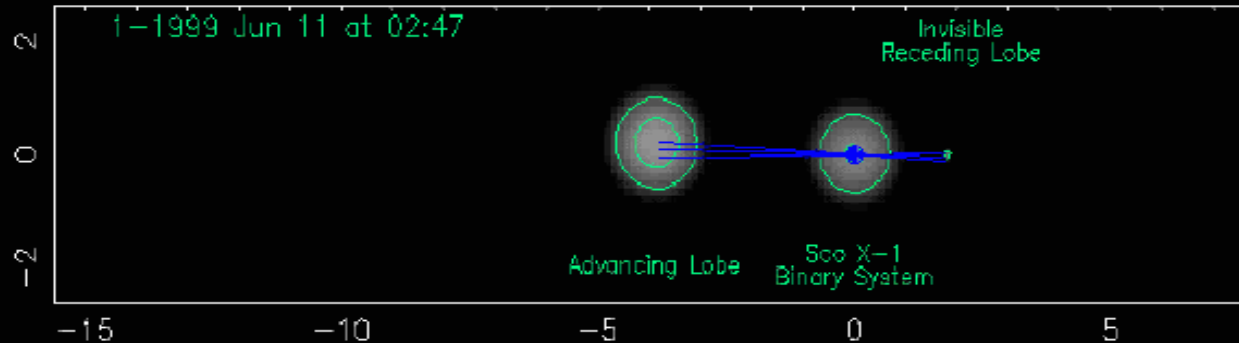
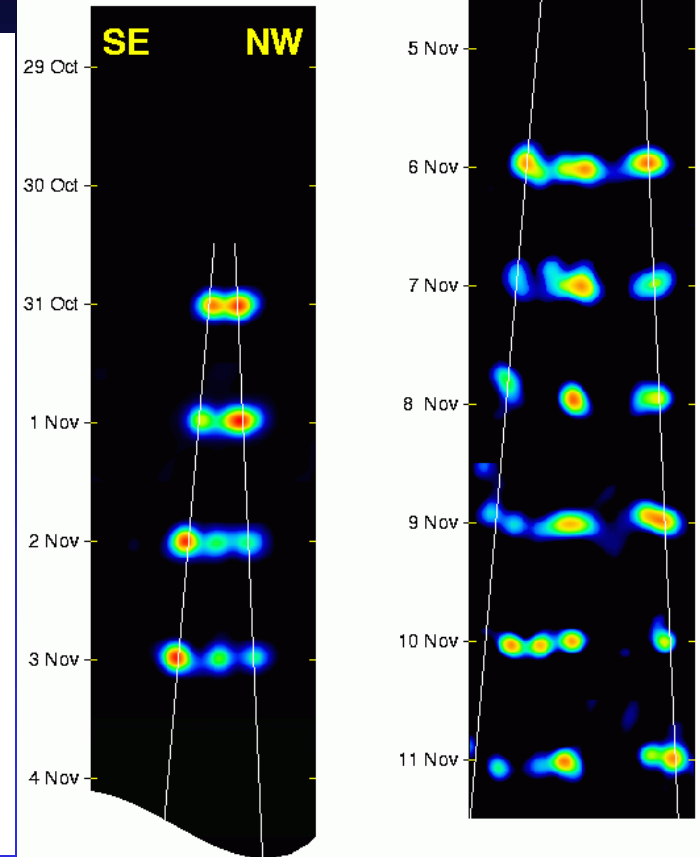
VLBA Images of SS433



Courtesy of Amy J. Mioduszewski (U. of Sydney)

**MERLIN**

GRS1915+105

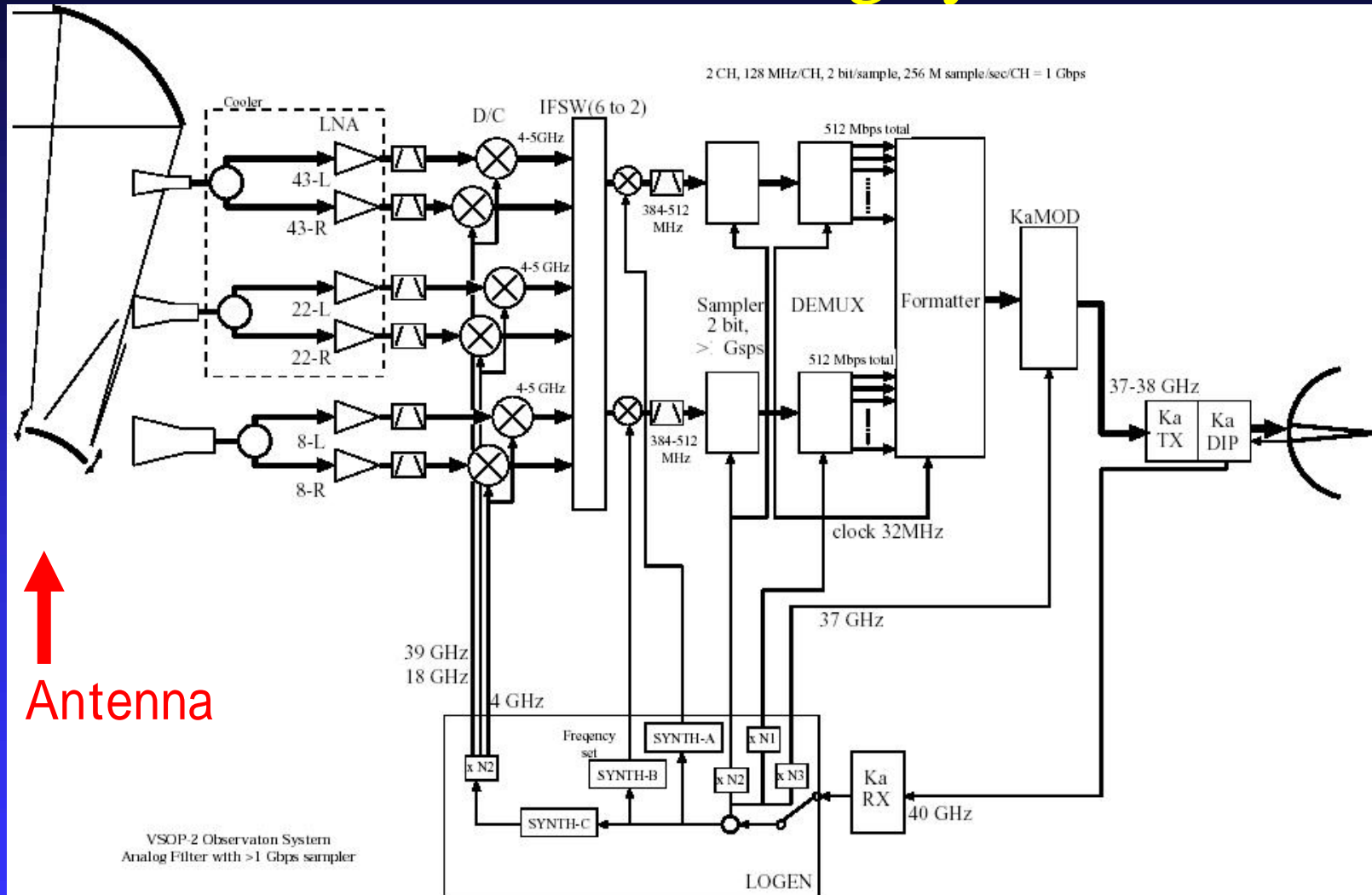
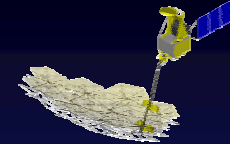


# Requirements for VSOP-2

- High Frequency
  - 1.6, 5, (22) 8, 22, 43 GHz
- High Resolution
  - 0.36 0.038 mas
- High Sensitivity ( $> \times 10$  )
  - Cooled receivers
  - Wideband observation (1 Gbps transmission)
- Phase-referencing observations
  - Higher sensitivity
  - Astrometry observation
- Polarization observation (L/R receivers)

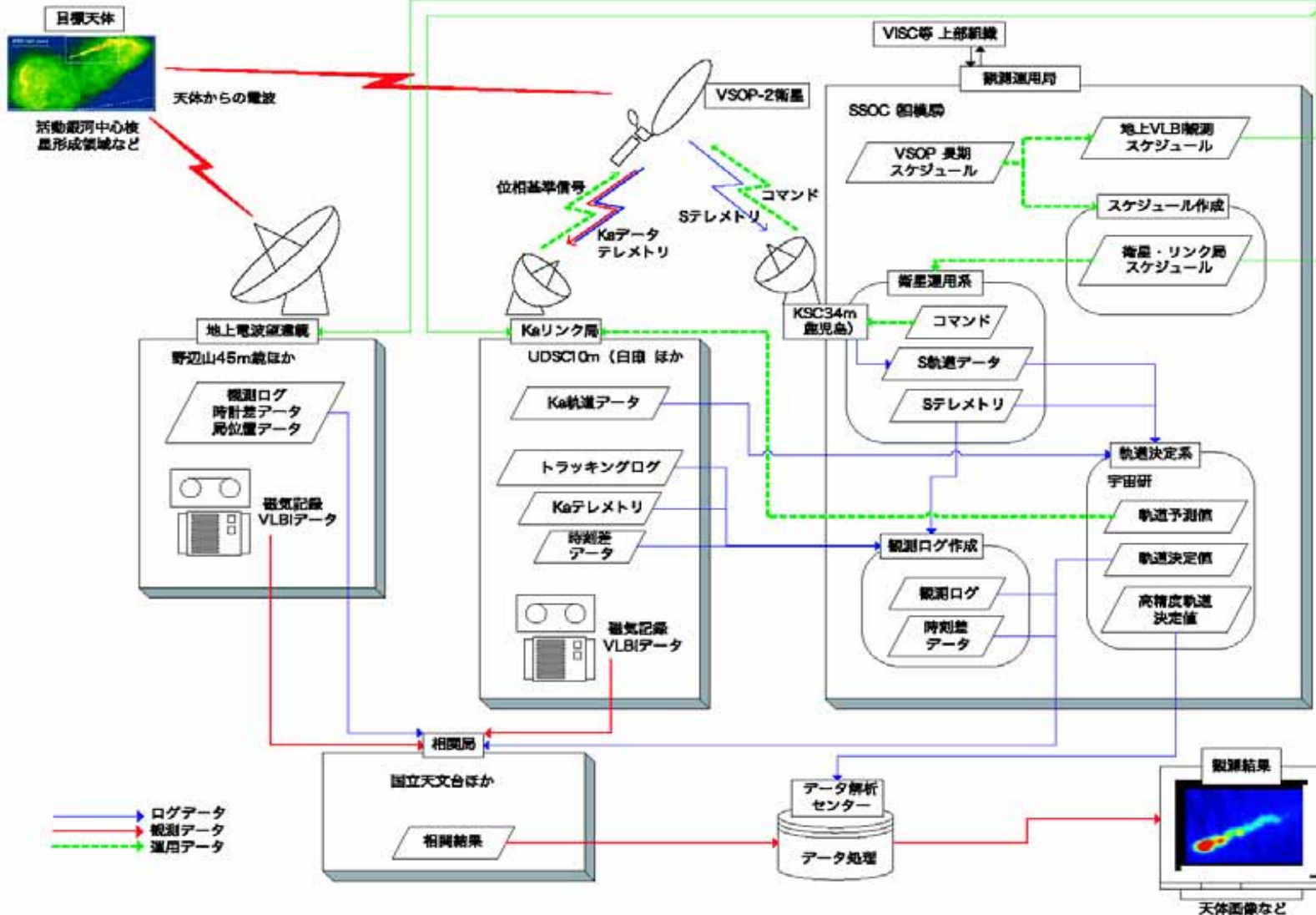
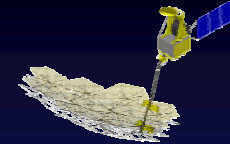


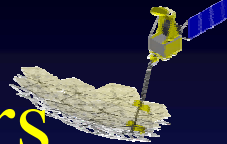
# VSOP-2 observing system



- 8,22,43 GHz dual polarization, Cooled LNA 30K (for 22,43GHz)
- High speed sampling device >1GHz
- 1Gbps downlink at 37-38GHz

# Operation and Data flow



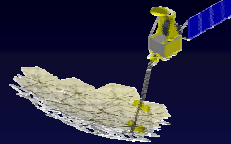


# VSOP-2 spec's important for correlators

- Dual polarization
- 1 Gbps downlink
  - 128 MHz x 2ch (2 bit) or 256 MHz x 2 ch 1 bit
- Phase reference by switching
- Space VLBI requirements
  - Orbit determination data/time correction file inputs
  - Space VLBI type data output
    - IDI FITS ??
  - International Data compatibility
    - Mark 5, K5/VSI
    - VSI specs.

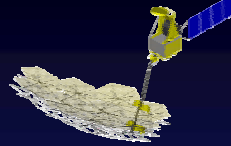


# Correlators for the VSOP mission



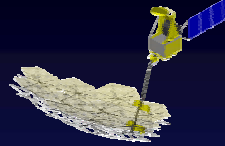
Correlator	Stations	Data rate (Mbps)	# channel	Dump rate (sec)	Tape type	Notes (VSOP Observation)
VLBA (Socorro)	20 (24)	512	1024	0.125	VLBA, MkIV	VLBA, EVN obs
VSOP (Mitaka)	10	512 (1024/5st)	16384 (1024 out)	0.025	VSOP (S2, VLBA)	Non VLBA EVN Line
S2 (Penticton)	6	128 (2048/16st)	8192*	0.001	S2	Survey, Pulsar, Line
JIVE (Dwingeloo)	16	1024	2048	0.25 (0.125)	VLBA, MkIV Mark5	Not for VSOP

# Correlators for VSOP (2)



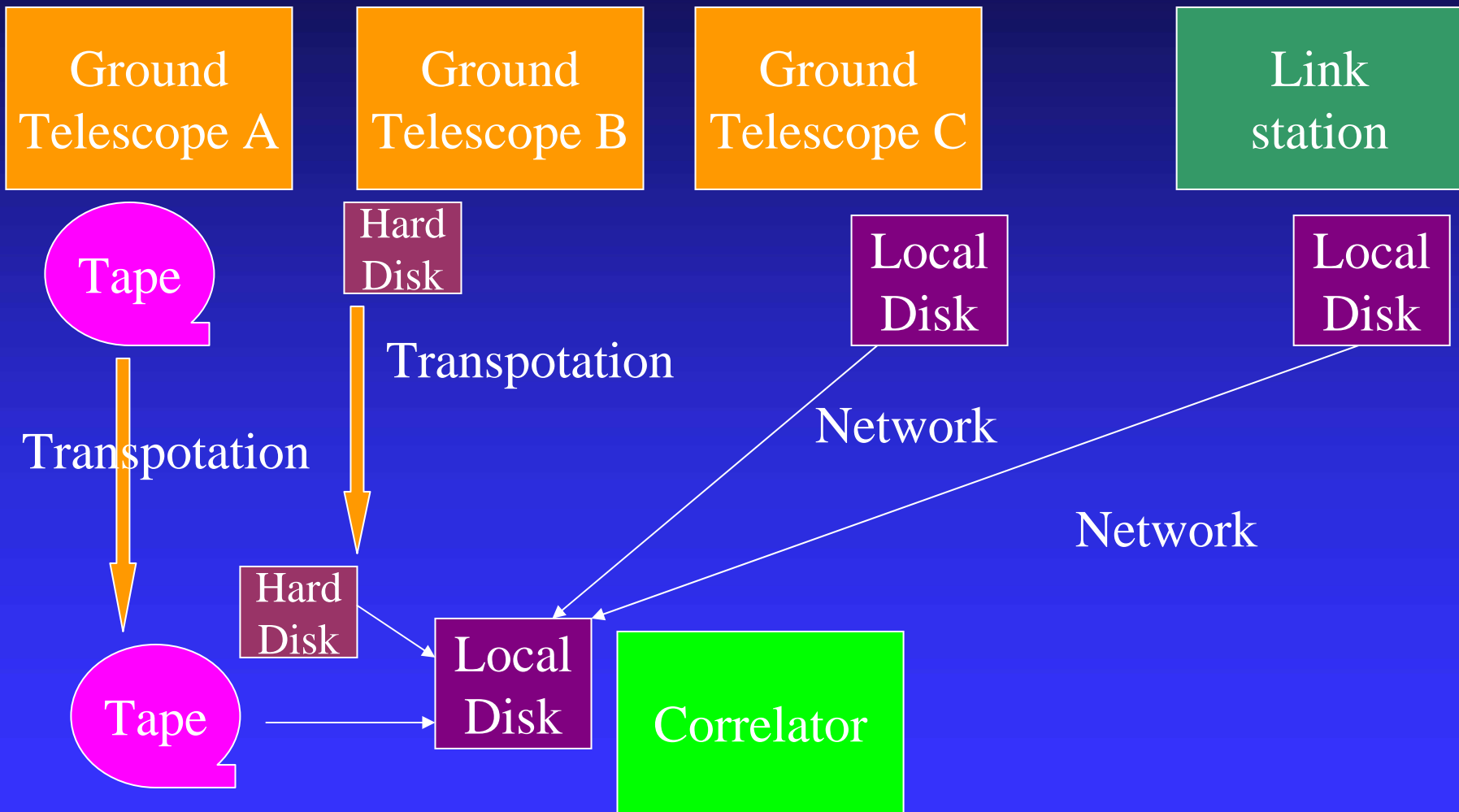
- # of stations
  - Max of VSOP observation 17 stations in GOT
  - Typical VLBA observation (11-14, VLBA + Large Telescopes)
  - EVN + HALCA (8-9) , SHEVE (AT+Hart+Asia, 5-7)
  - Minimum 2 - 4 (Survey mode)
- Max rate of recording
  - 128 Mbps (normal mode)
  - 128 Mbps (space), 256 Mbps (L/R, 128Mbps each pol.)
- Spectral line & Pulsar
  - Total 800 observations. Line ( ~ 10, Pulsar 1-2)
- Tape compatibility
  - VSOPT, S2, VLBA, MkIV
  - Copier: VSOPT S2, VSOPT VLBA (not for MkIV)
  - AT & VLBA : AT Mitaka Copier (S2 VSOPT VLBA)  
Socorro (HALCA, AT, VLBA)
- Correlator comparison
  - Penticton ( $\sqrt{2}$ \*1.07), Mitaka (\*1.07) error

# Correlator specification for VSOP2



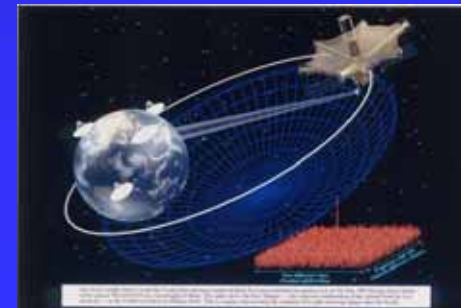
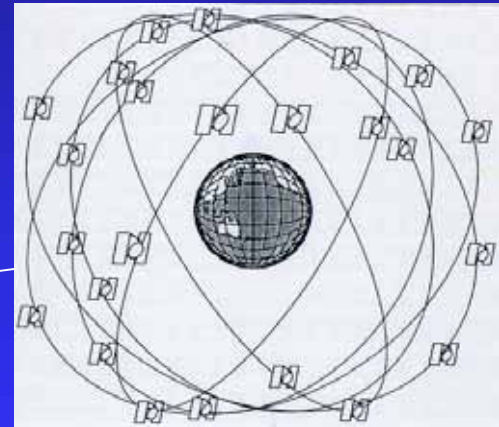
- Input stations  
16-20
- Correlation data rate
  - > 2 Gbps
    - VSOP-2 1 bit (1 Gbps) / Ground 2 bit (2 Gbps) mode
    - Speedup factor (OBS: 2 Gbps, Correlation 20 Gbps)  
Extend search window, field of view
- Frequency resolution
  - > 65536 ch @ 128 MHz
    - 0.05 km s<sup>-1</sup> resolution for H<sub>2</sub>O maser
    - Zooming, combine mode required
- Data output rate
  - 0.025 sec (= VSOP) ~ 0.5 sec
    - Pulsar observation? (no)
    - Navigation error ... better than VSOP

# Data transfer/correlator for VSOP-2



# Future aspect

## •Correlator Satellite !

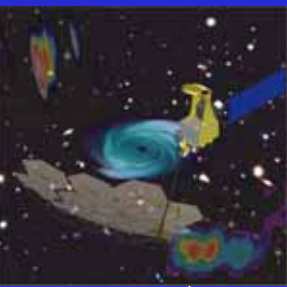


VSOP

Space Sub-mm Array  
(ALMA in space)

BH imager

VSOP-2



VSOP-4

VSOP-3

Sub-mm Telescope

