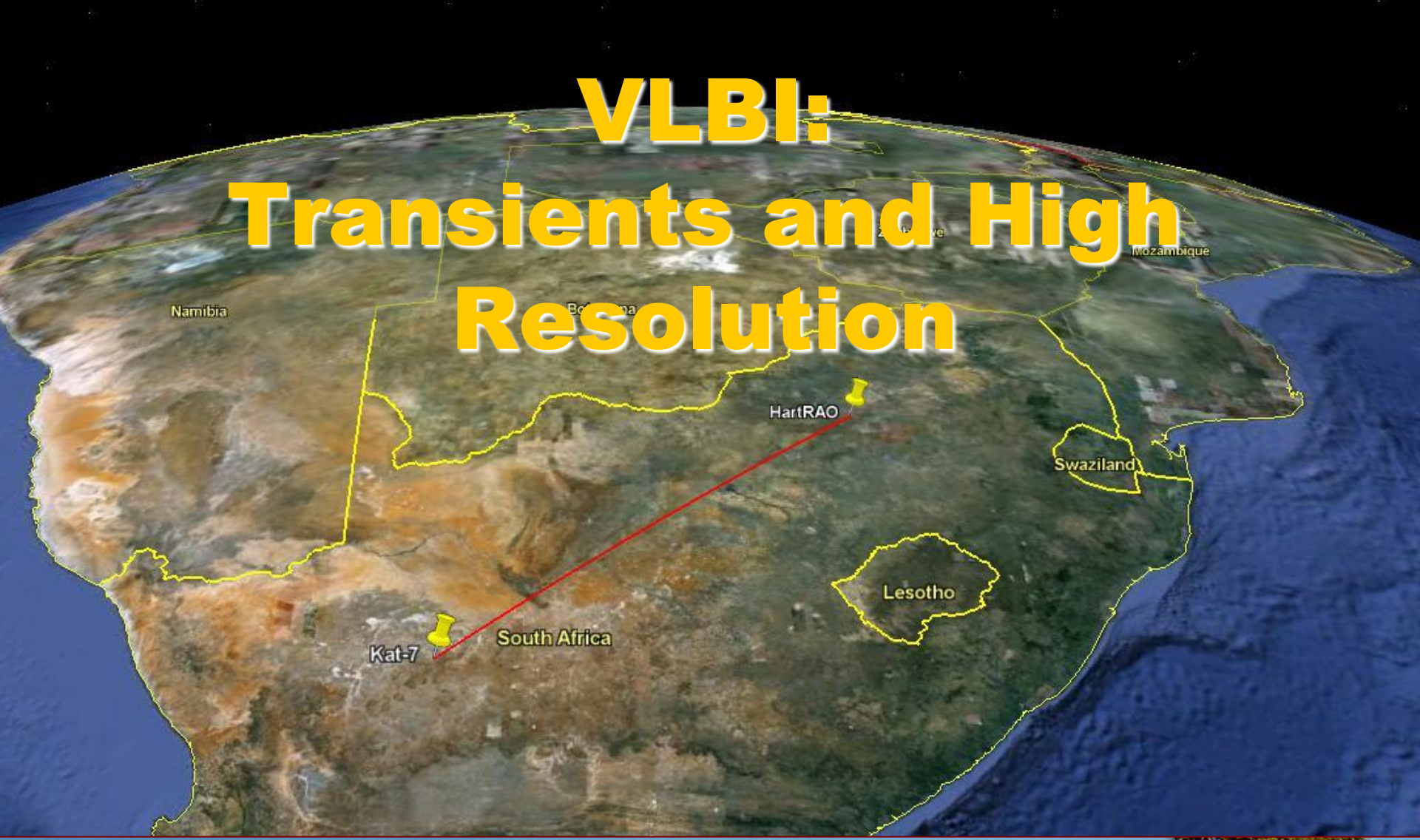
VLBI: Transients and High Resolution



Michael Bietenholz
Hartebeesthoek Radio Observatory

VLBI

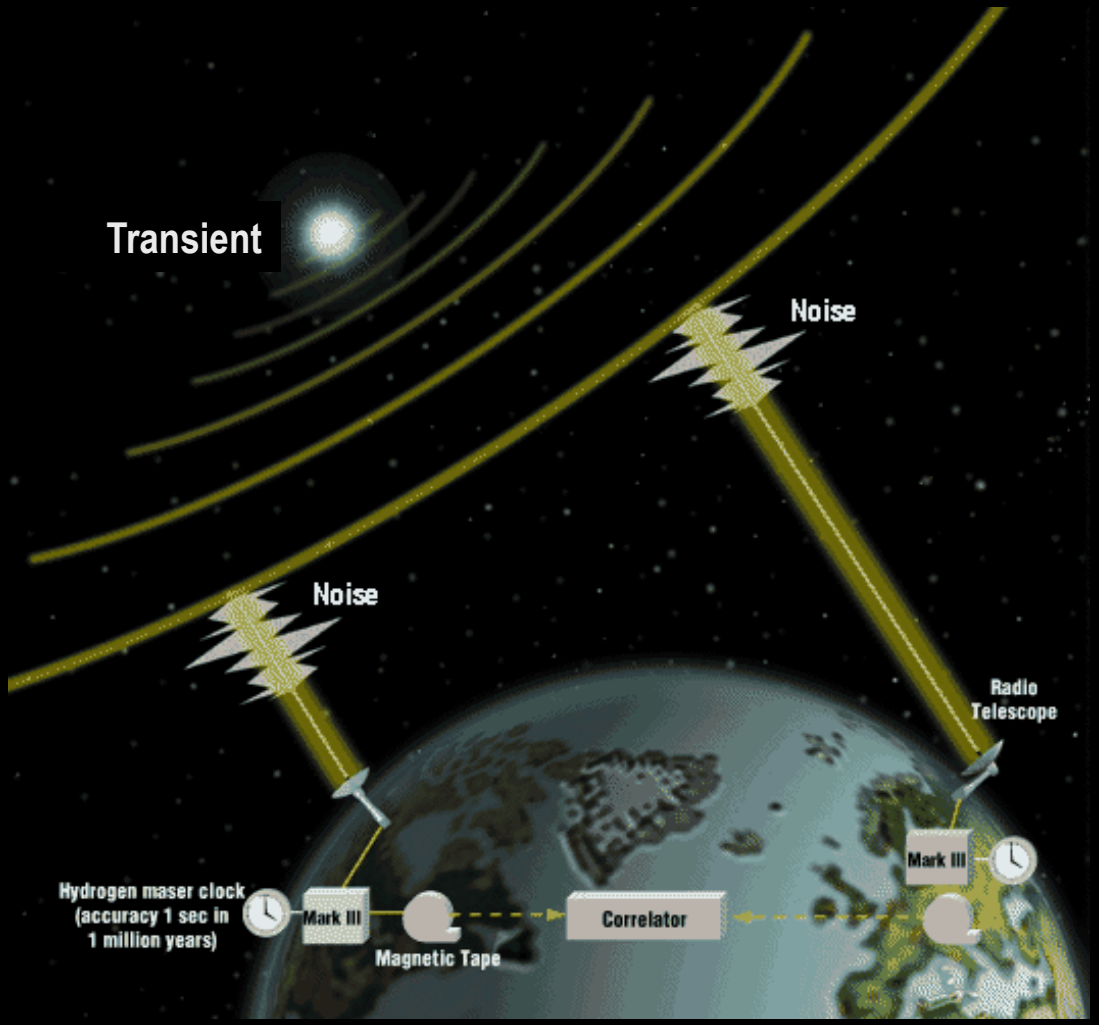


Image: NASA & the Geodetic Institute, Bonn

Very **L**ong
Baseline
Interferometry

→ Resolution of ~1 milli-arcsec at 8.4 GHz or λ = 4cm

1 milli-arcsec
~ width of a
human hair at
20 km

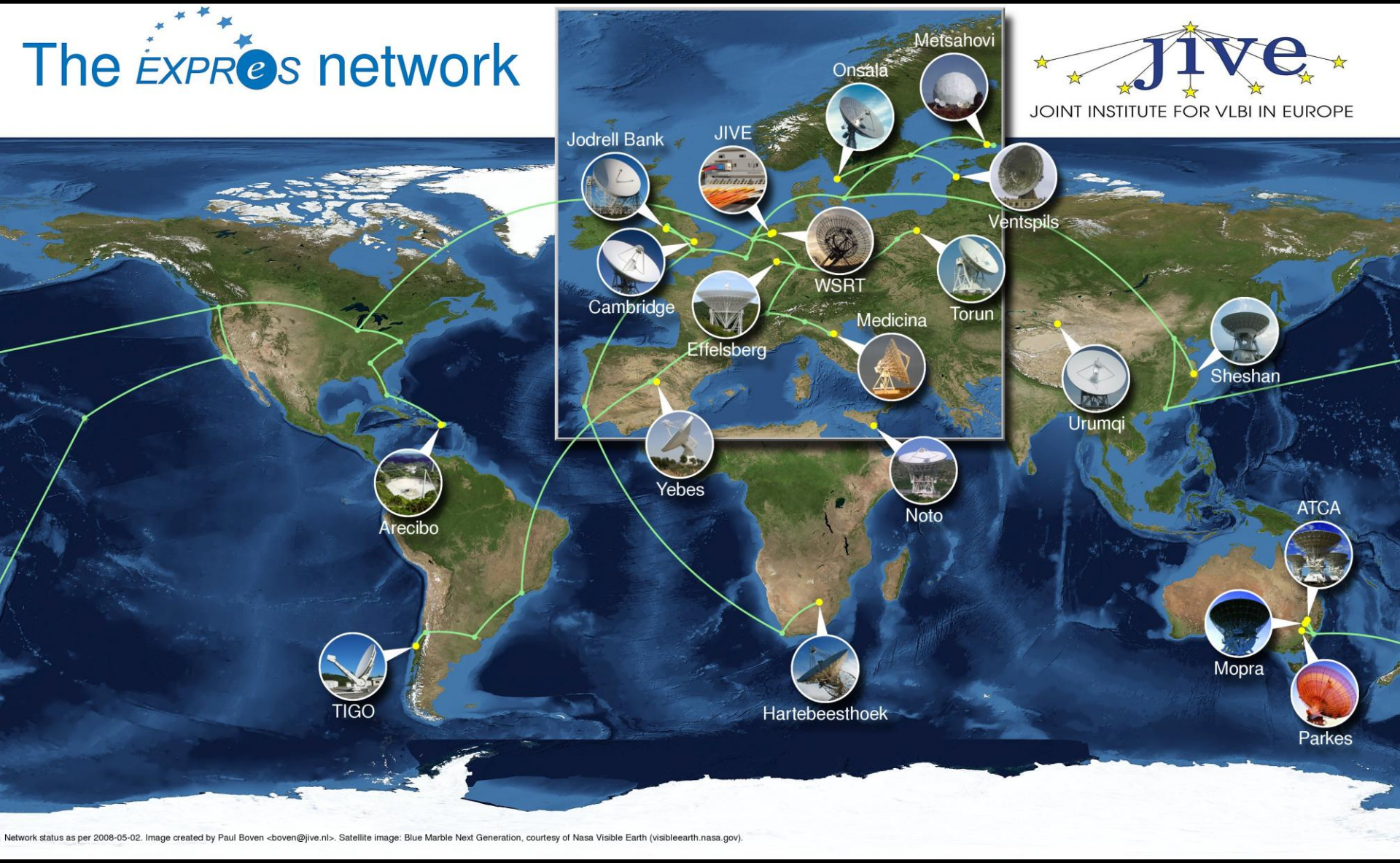


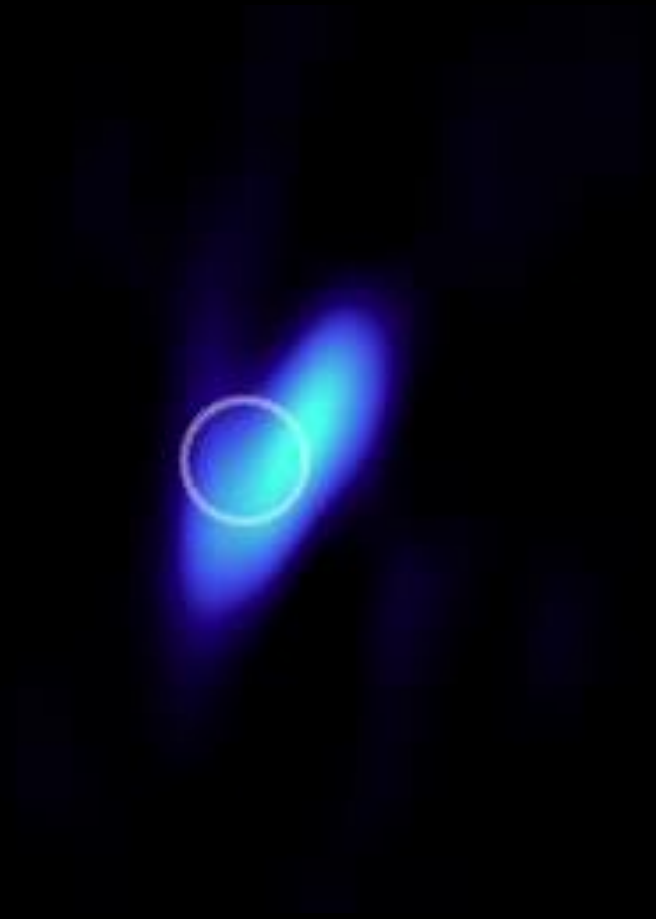
Image: Paul Boven

Why VLBI for Transients?

Speed	Distance	Typical for …	Angular velocity
20 km/s	10 kpc	Star	0.4 mas/yr
5000 km/s	10 kpc	Nova, CV	2 mas/week
c	10 kpc	Relativistic	0.7 mas/hour
20000 km/s	10 Mpc	Supernova	0.4 mas/yr
c	100 Mpc	Relativistic	0.6 mas/yr

Background: Hartebeesthoek Radio Observatory; Thomas Abbot

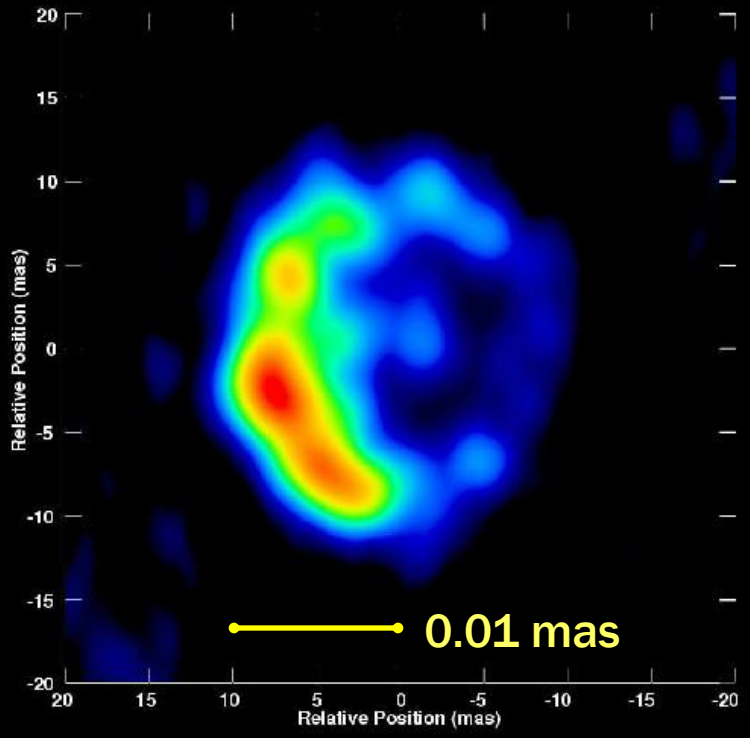
Stellar VLBI: IM Pegasi

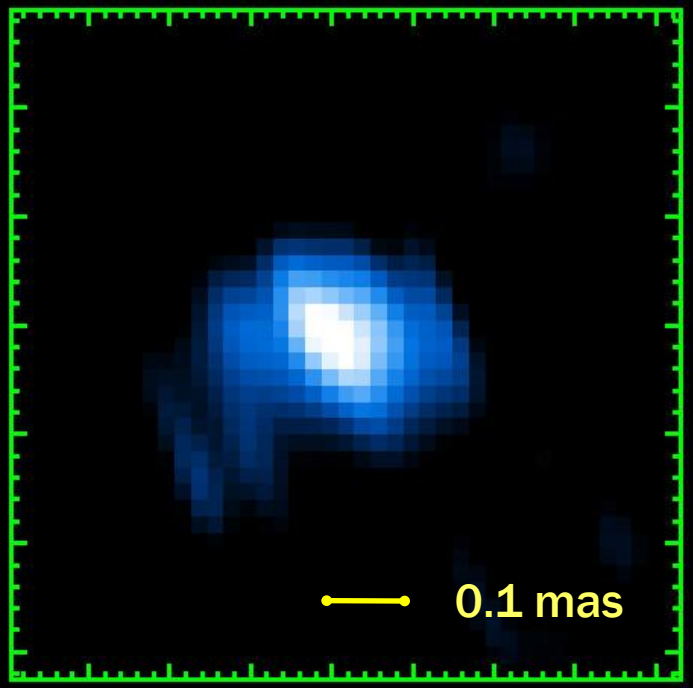


- RS Cvn active binary star; primary K2 III, 1.8 Msol, secondary ~1 Msol; binary period ~25 days; 96 pc
- Chromospherically active – radio emission: very variable <1 mJy to
- Observed as a reference source for the NASA/Stanford Gravity Probe B
- VLBI astrometry allows orbit determination as well as constraining emission mechanisms for active stars

Shapiro, Bartel, Bietenholz et al in prep

RS Oph



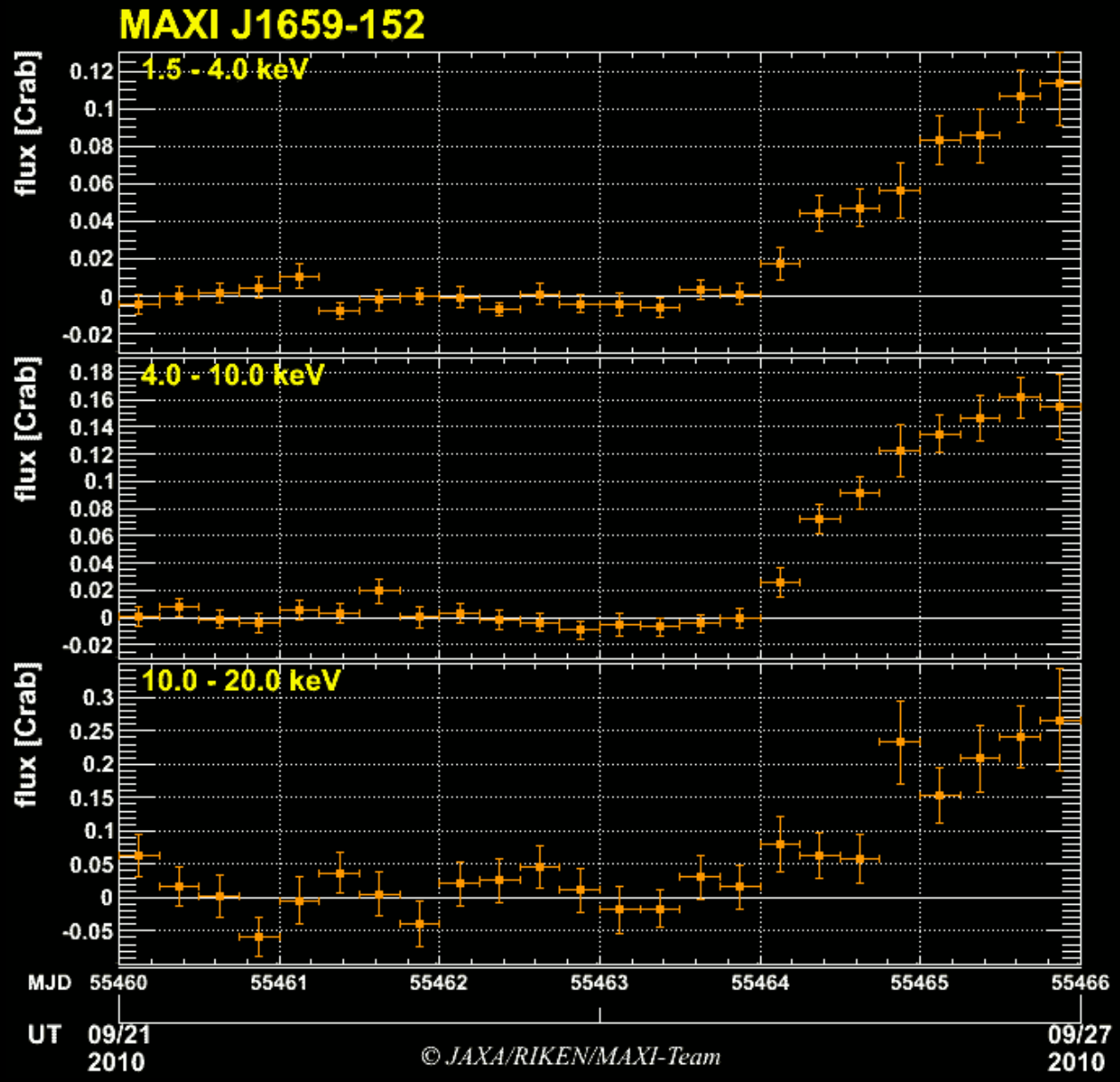


VLBA image, 14 days after outburst, 5 GHz

Merlin image: 86 days after outburst, 6 GHz

RS Ophiuci – recurrent nova with a white dwarf orbiting red giant; outbursts every 10-20 yrs.; radio flares; ejection speeds – ~5000 km/s. Asymmetric structure in red giant wind. Type Ia supernova progenitor?

MAXI J1659-152



- SWIFT/BAT trigger
- XRB
- A new black-hole candidate
- Possible 2.5-hr period: very short

[Previous | Next]

EVN e-VLBI detections of MAXI J1659-152

ATel #2906; *Z. Paragi (JIVE), A.J. van der Horst (NASA/MSFC/ORAU),J. Granot (Univ. Hertfordshire),G.B. Taylor (Univ. New Mexico), C. Kouveliotou (NASA/MFSC),M.A. Garrett (Astron), R.A.M.J Wijers (Univ. Amsterdam),E. Ramirez-Ruiz (Univ. Santa Cruz),E. Kuulkers (ESA/ESAC), N. Gehrels (NASA/GSFC),P.M. Woods (Corvid)*
*on **5 Oct 2010; 17:31 UT***
Password Certification: Zsolt Paragi (zparagi@jive.nl)

Subjects: Radio, Black Holes, Neutron Stars, Transients
Referred to by ATel #: 2918

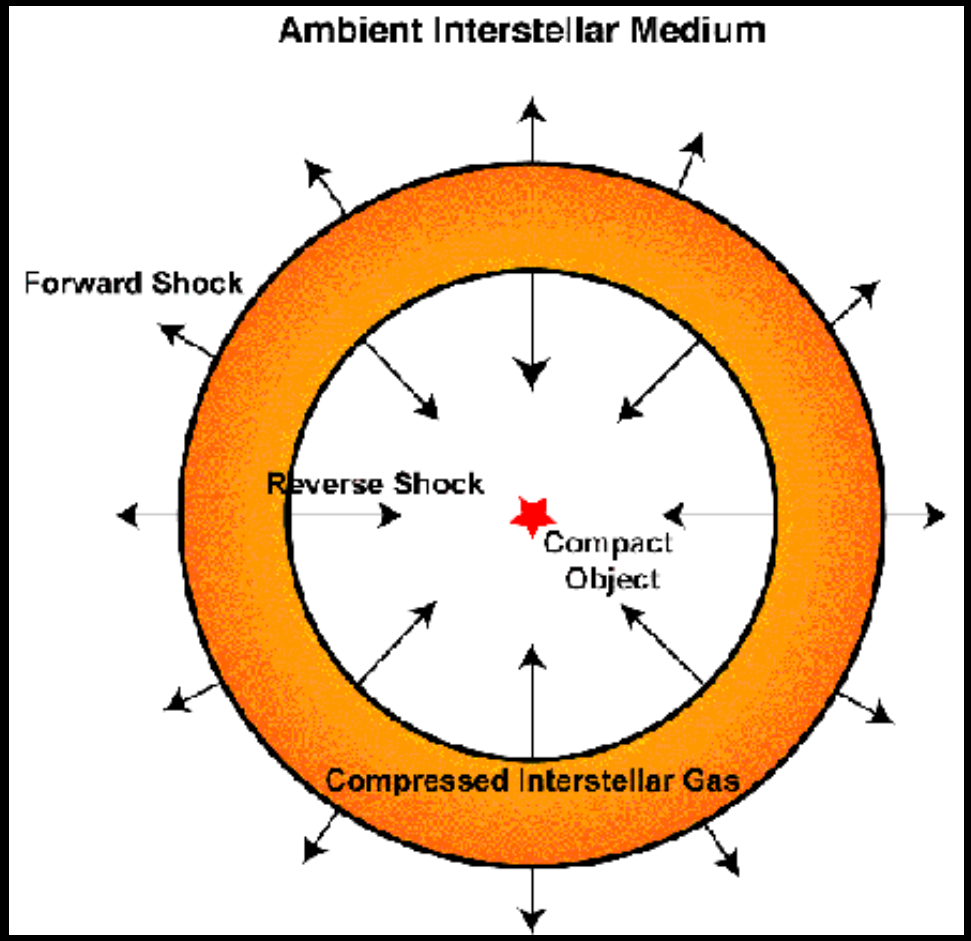
We observed MAXI J1659-152 (Negoro et al. 2010, ATel #2873; Mangano et al. 2010, GCN #11296) following its sub-millimeter and centimeter radio detections (de Ugarte Postigo et al. 2010, GCN #11304; van der Horst et al. 2010, ATel #2874) with the European VLBI Network (EVN) in real-time e-VLBI mode on 30 September 2010, from 13:30 to 18:30 UT at 4.9 GHz. The participating telescopes were Cambridge, Effelsberg, Jodrell Bank (MkII), Hartebeesthoek, Medicina, Onsala, Torun and Westerbork sending data at a rate of ~1024 Mbps to the EVN Data Processor at JIVE. The target was phase-referenced to the nearby source J1707-1415 (2.2 degrees away) which is apparently in outburst and serves as a very good compact calibrator. MAXI J1659-152 was detected at RA(J2000) 16 59 01.67709, DEC(J2000) -15 15 28.7324 (uncertainty about 1 mas), in agreement with the

Related
2927 Transition to the soft-intermediate state of MAXI J1659-152
2926 RXTE dips yield better orbital period determination for MAXI J1659-152
2918 Sudden radio flux decline in MAXI J1659-152
2912 MAXI J1659-152: the shortest period black-hole binary?
2906 EVN e-VLBI detections of MAXI J1659-152
2900 REM optical/NIR observations of MAXI J1659-152
2890 INTEGRAL shows MAXI J1659-152 further declines in hard X-rays
2888 INTEGRAL TOO observations of MAXI J1659-152
2887 XMM-Newton observations of MAXI J1659-152
2884 Optical variability in MAXI J1659-152
2881 MAXI J1659-152 is a BH candidate
2880 AGILE upper limits above 100 MeV regarding the

Pulsars

- Pulsars are also a key part of MeerKAT science case. VLBI measurements are crucial in providing parallax distances and proper motions for pulsars
- Pulsar astrometry is also the best means for tying together celestial and terrestrial reference frames.

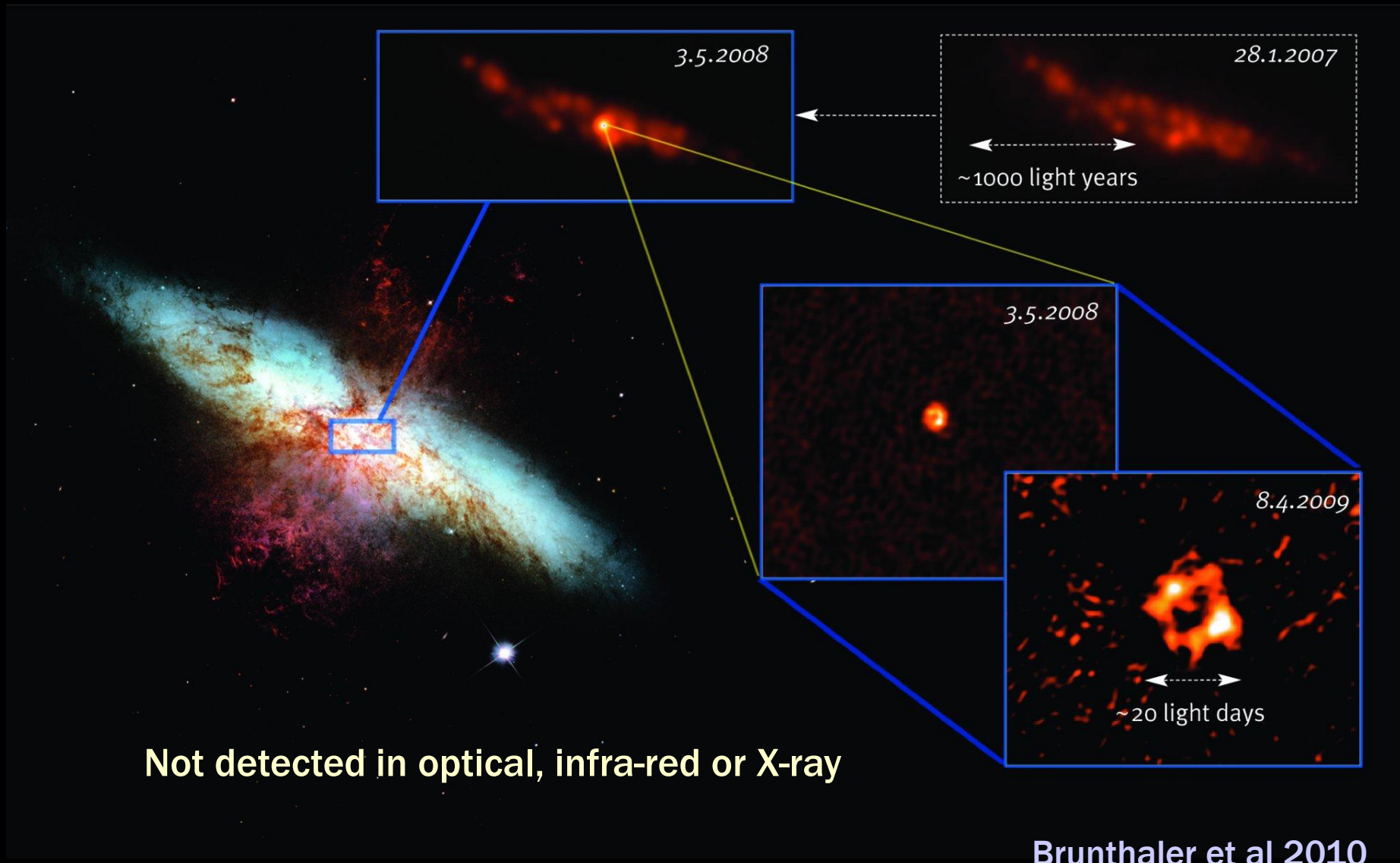
Core-Collapse Supernova



heasarc.gsfc.nasa.gov

- Only core-collapse SNe (Type II & Type I b/c) have been seen in radio
- Shocks accelerate particles and amplify magnetic fields → synchrotron emission
- Radio emission is due to interaction with circumstellar medium, usually the wind of the progenitor before it died
- Radio-bright SNe are relatively rare: ~40 supernovae (all core-collapse) have been detected in radio (> 1 mJy), and >100 have upper limits (e.g., Weiler et al.) Most are at <30 Mpc

SN 2008iz in M82



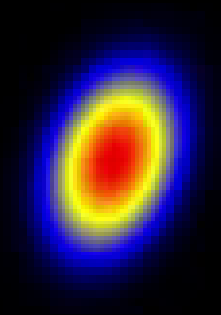
Not detected in optical, infra-red or X-ray

Brunthaler et al 2010

SN1986J

VLBI Images:
1987 to 2005

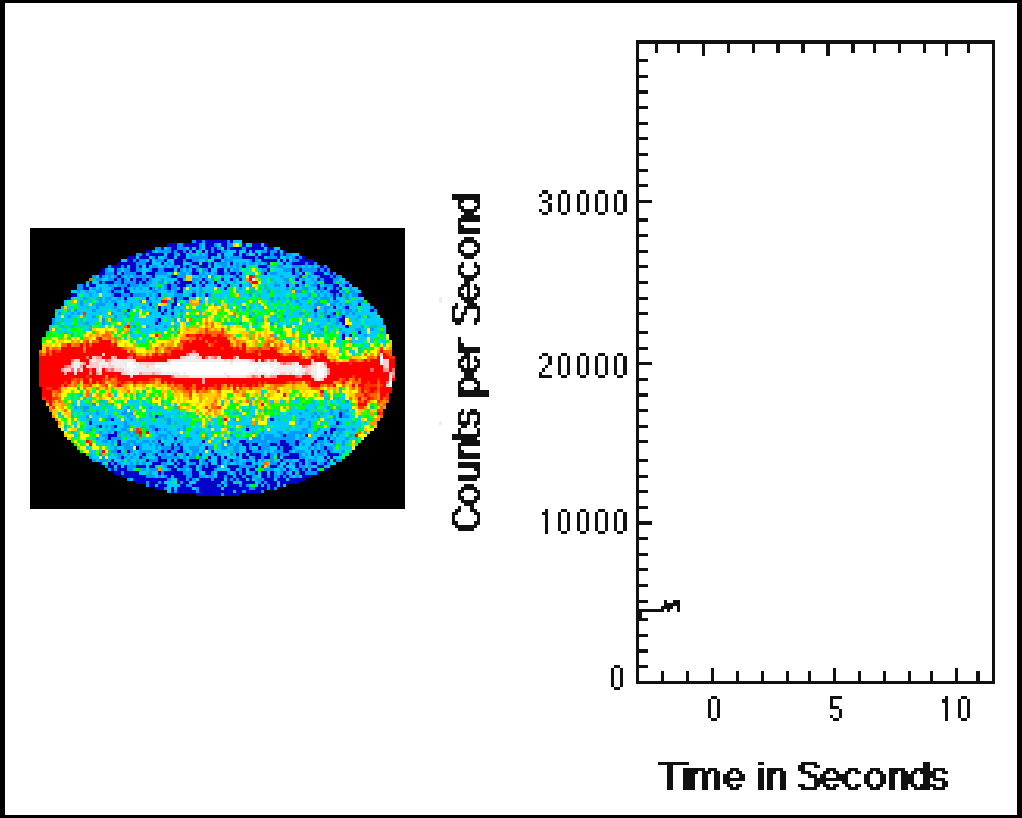
(and continuing…)



1 mas

Bietenholz et al 2010

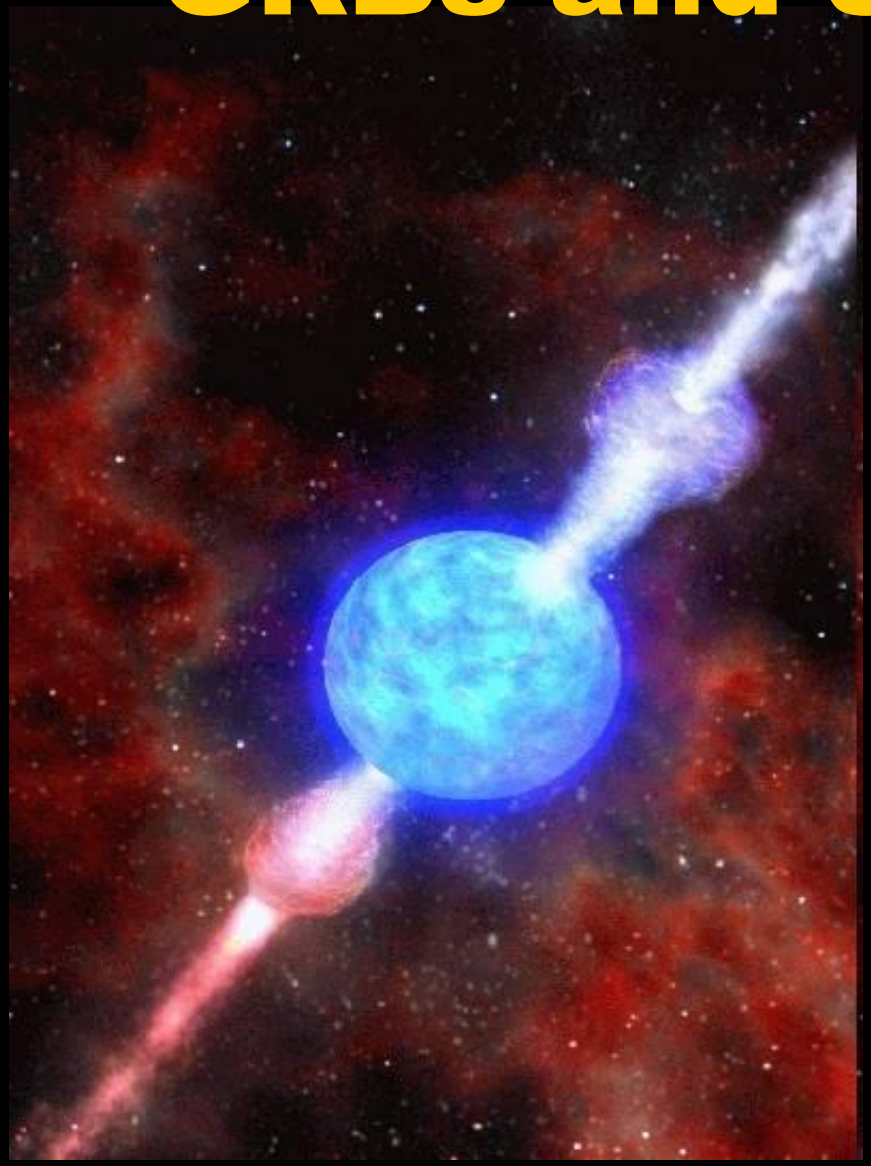
Animation of a Gamma Ray Burst



Animation: Nasa

Left-hand panel shows ***the whole sky*** in gamma-rays, with the plane of our Galaxy running horizontally across the middle

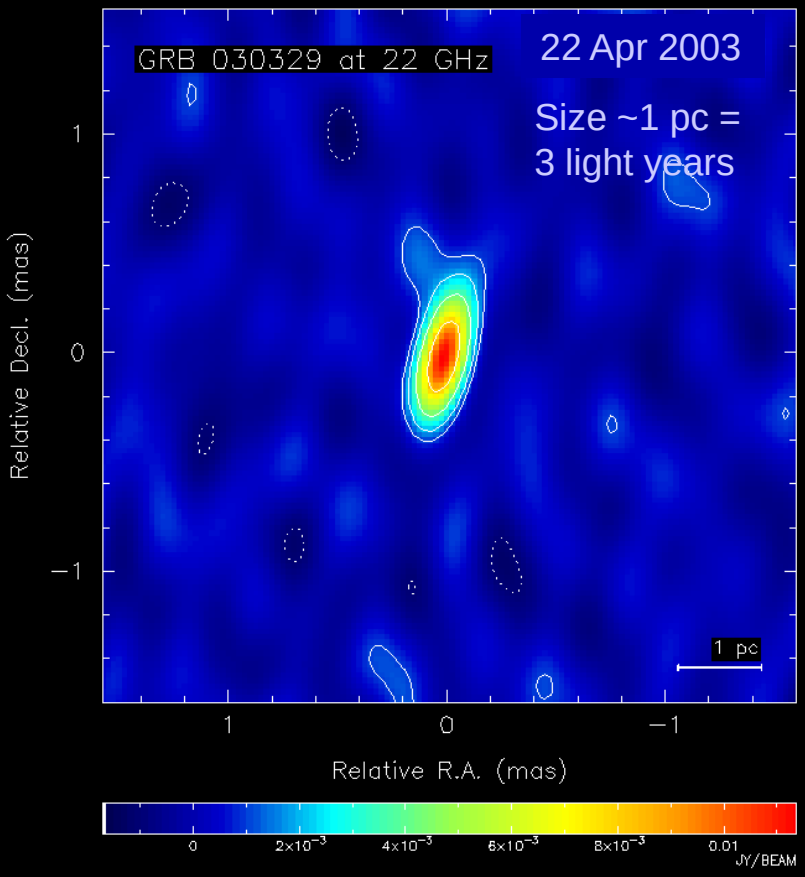
GRBs and Supernovae

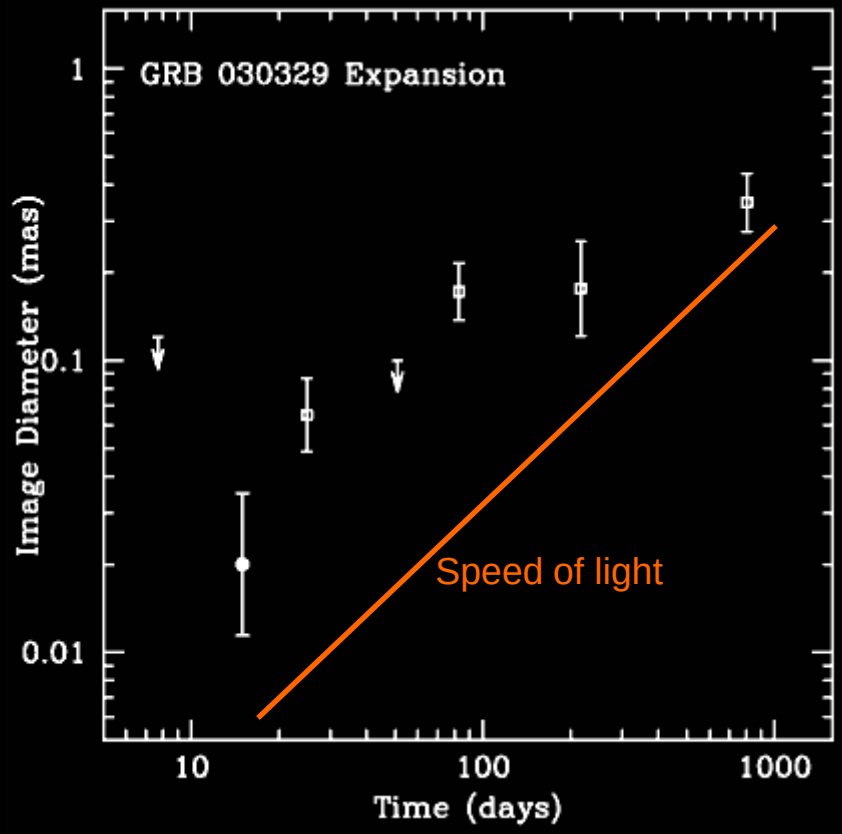


- GRB 980425 = Supernova 1998bw
- Only! 40 Mpc
- Type I bc supernovae – stars that have lost much of their envelope through stellar winds
- Several other nearby GRBs have now been associated with Type Ibc supernovae

Artist's impression of a Gamma Ray Burst. Image: Dan Berry, Skyworks Digital, USA

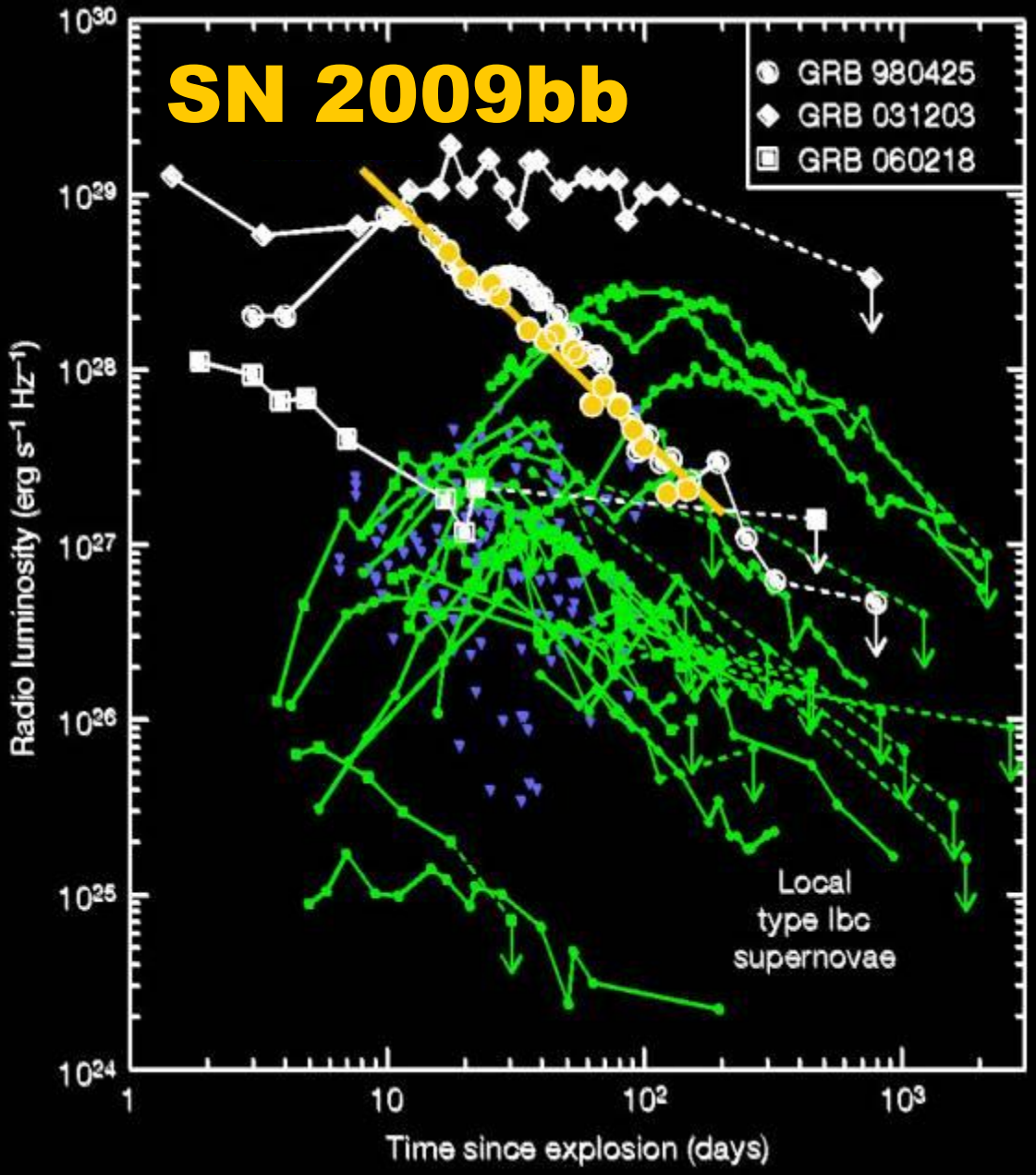
Relativistic Expansion: GRB 030329 (SN 2003dh)





VLBI Expansion Measurements: by Taylor et al. & Pihlstrom et al. show clear deceleration, with transition to non-relativistic regime at *t* ~ 1yr

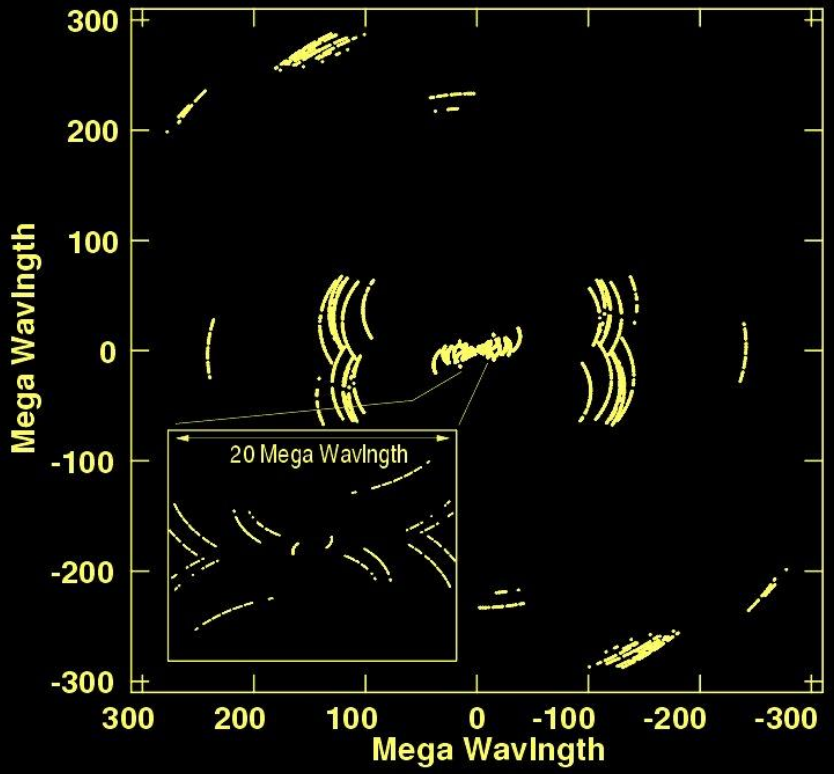
Taylor et al, 2004, 2005; Pihlstrom et al. 2007

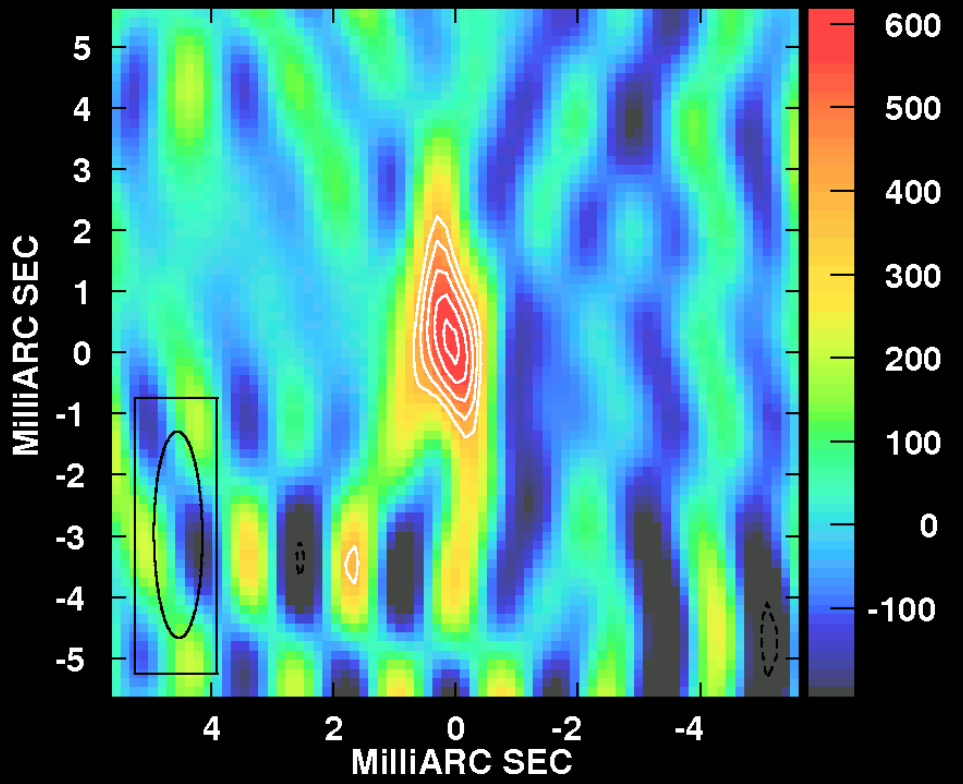


- Radio lightcurves of Type Ibc supernovae
- SN 2009bb very luminous (also in X-ray) – mildly relativistic ejection

Soderberg et al 2009

SN 2009bb VLBI



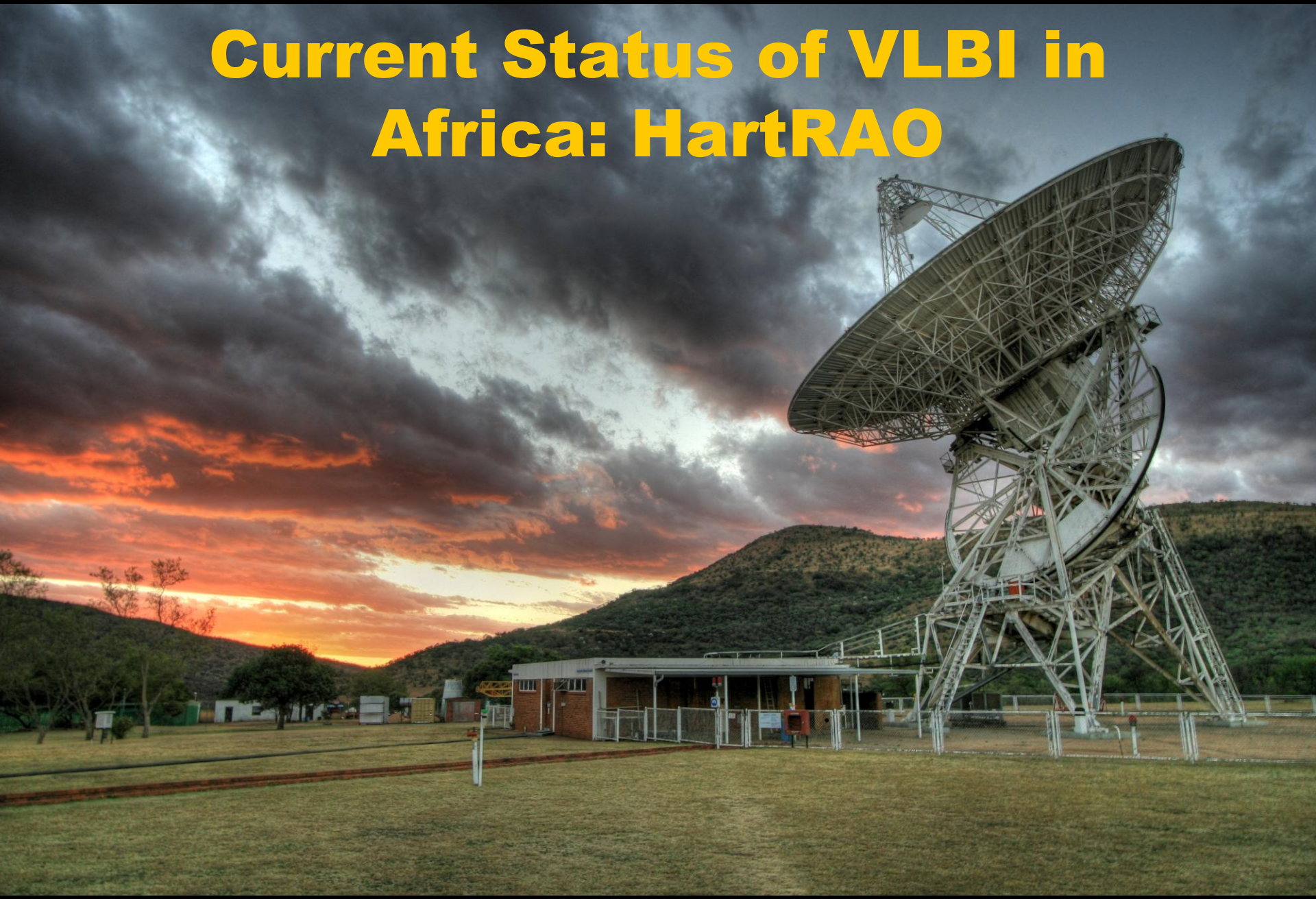


Type I b/c supernova, 40 Mpc high X-ray & radio luminosity suggest relativistic ejecta; VLBI observations at *t*=85 d constrain size to < 0.64 mas, and apparent expansion to <1.74*c* (Bietenholz et al 2010). Note poor uv-coverage available due to southern declination of -40°

SNe Observed with VLBI

Name	***Type***	***Host galaxy***	***Distance*** (Mpc)	***Peak*** (mJy at 8 GHz)	Reference
Several SN/SNR	?	M82	3.2		Beswick et al 2006
Several SN/SNR	?	Arp 299	40		Neff et al 2004
Several SN/SNR	?	Arp 220	77		Lonsdale et al 2006
SN1978K	II	NGC 1313	4	>100?	Smith et al 2007.
SN1979C	II	M100	16	6	Bartel & Bietenholz 2008
SN1980K	II	NGC6946	6	2	Bartel 1985
SN1986J	II	NGC891	10	100	Bietenholz et al 2004
SN1987A	II	LMC	0.05	80	Jauncey, Gaensler, Manchester
SN1993J	II	M81	4	100	Bietenholz, Bartel, Marcaide
SN1994I	Ic	M51	8	20	Bietenholz & Bartel, unpublished
SN1996cr	II	Circinus	3.6	~100	Bauer et al 2008.
SN2001em	Ib/c	NGC 7112	80	4	Bietenholz, Paragi, Schinzel
SN2001gd	II	NGC 5033	13	4	Pérez-Torres et al 2008
SN2003L	Ib/c	NGC 3506	92	3	Soderberg et al 2005
SN2004et	II	NGC 6946	6	2	Martí-Vidal et al 2007
SN2007gr	Ib/c	NGC 1058	10	<~ 1	Paragi et al 2007
SN2008D	Ib/c	NGC 2770	27	3	Soderberg et al , Bietenholz et al
SN2008ax	IIb	NGC 4490	8	4	Martí-Vidal et al 2008
SN2008ix	II?	M82	4	50	Brunthaler et al 2010
SN2009bb	Ib/c	NGC 3278	40	30	Bietenholz et al, 2010

Current Status of VLBI in Africa: HartRAO



Picture: Thomas Abbott

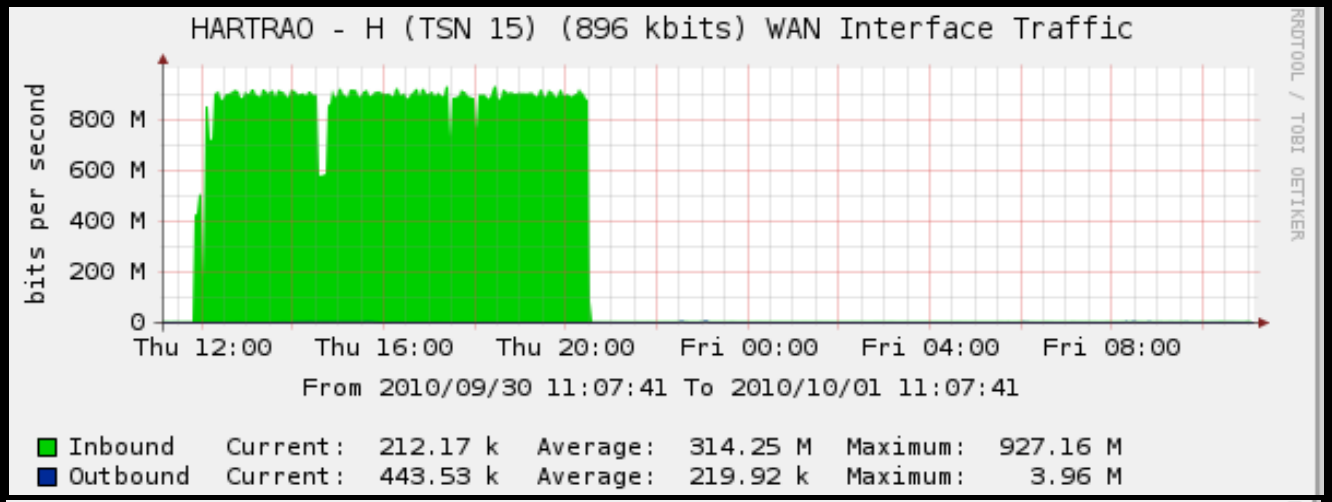
THE OLD BEARING

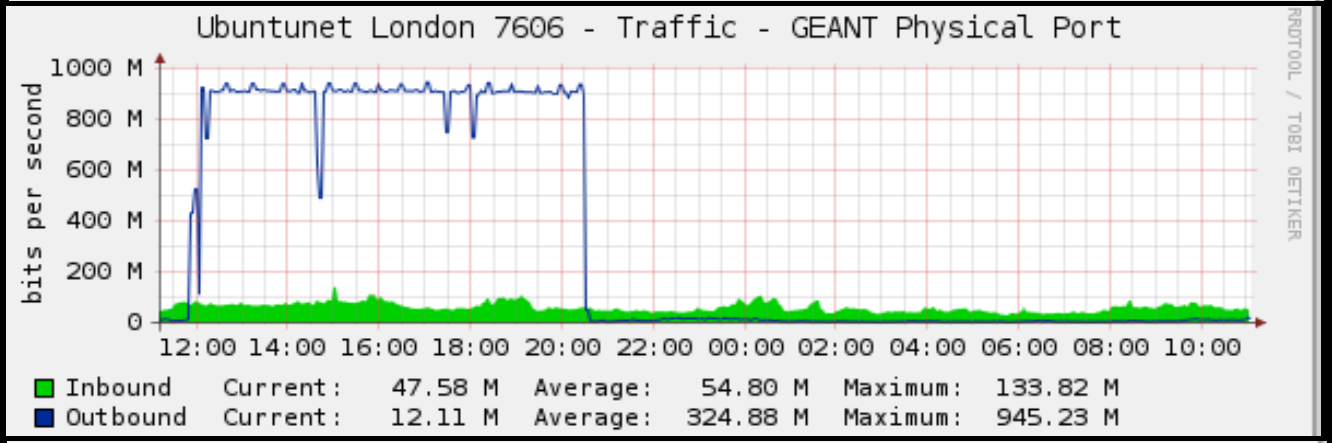
Current Status of VLBI in Africa: HartRAO

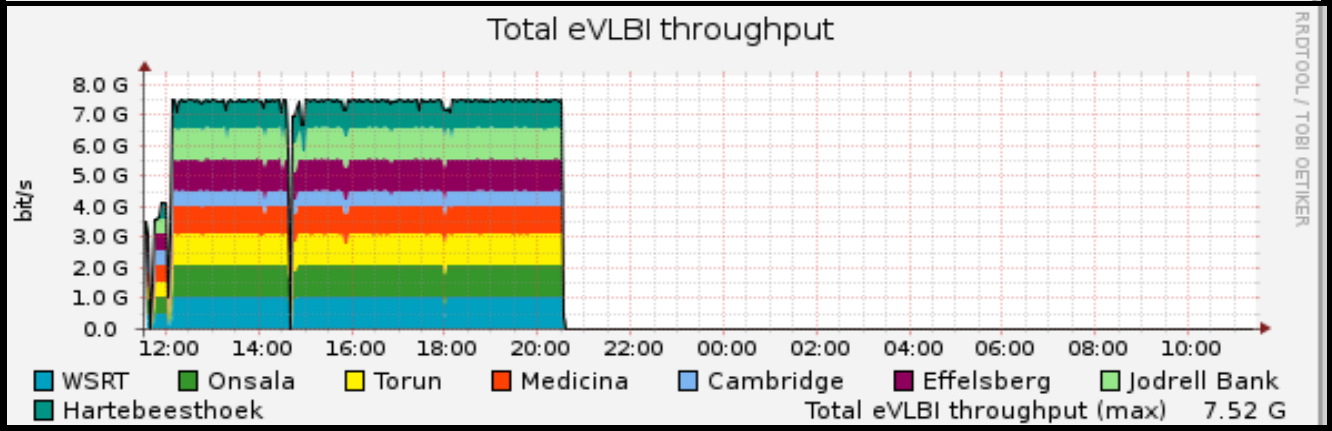
- HartRAO 26-m dish is fully operational again – bearing has been replaced
- Regularly taking part in VLBI sessions with EVN and LBA (1.7 - 22 GHz)
- Monthly e-VLBI sessions with EVN at 1 Gbps
- XDM, a 15-m composite dish, will take over some geodetic observations

Picture: Thomas Abbott

EVLBI at Hartebeesthoek







Progress towards VLBI with MeerKAT:

- First VLBI fringes have been obtained between HartRAO and one KAT-7 antenna: ~900 km, 3C 273, 1.7 GHz
- VLBI observations with KAT-7 phased-array should be possible by the end of 2011
- VLBI-friendly VDIF format $\rightarrow$ DiFX correlator
- 10 Gbps connection coming later this year, e-VLBI first quarter next year.

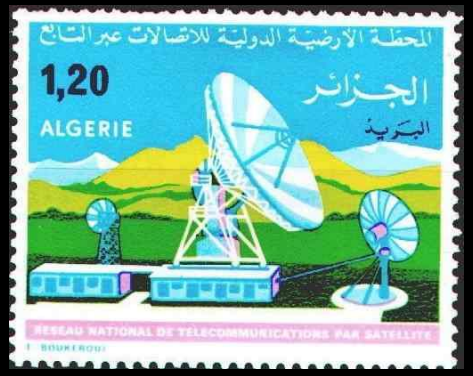
HartRAO – MeerKAT Baseline

~900 km

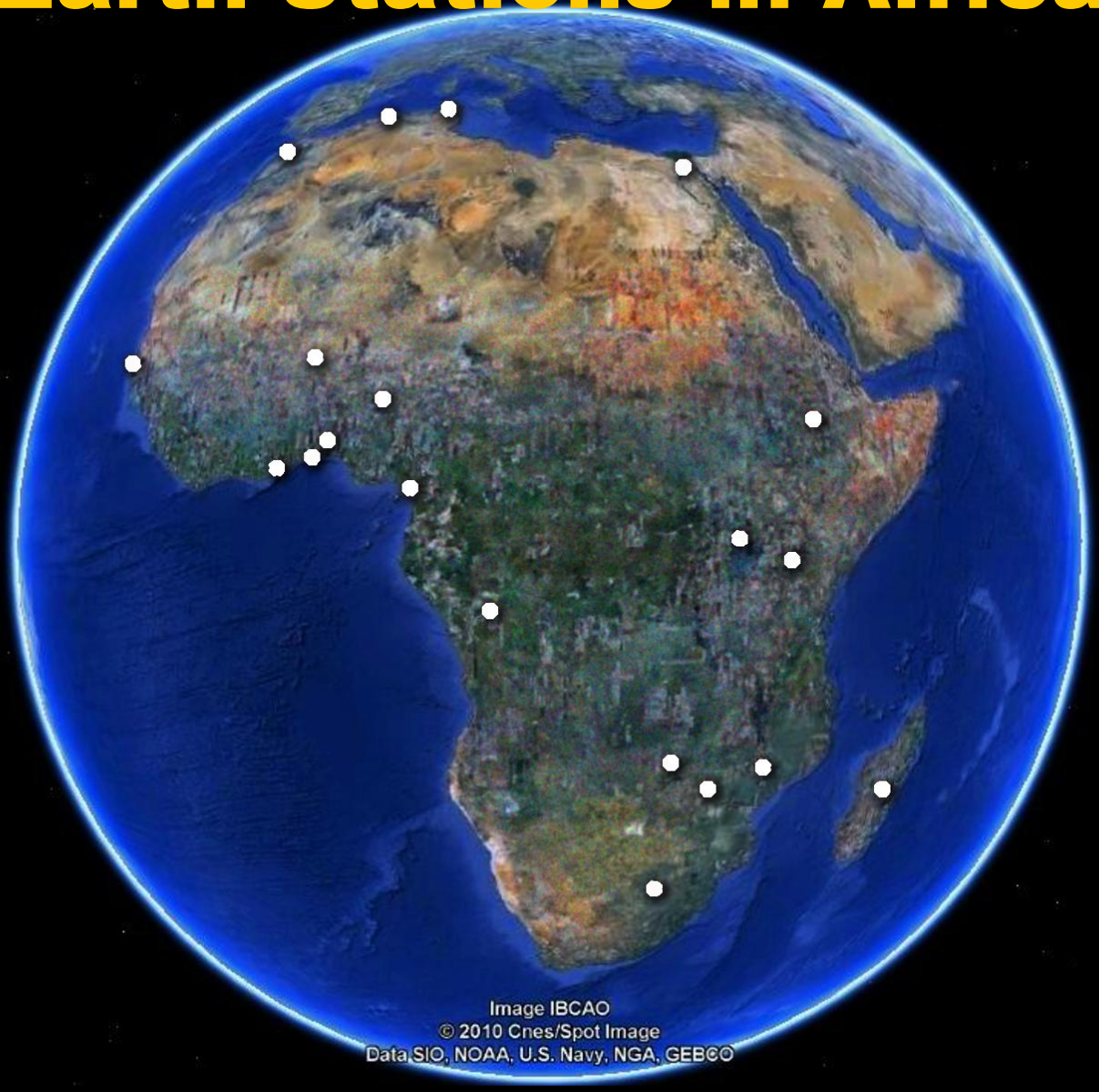
J. Horrell, S. Ratcliffe, L. Schwardt

Re-use of Satellite Ground Stations for Radio Astronomy

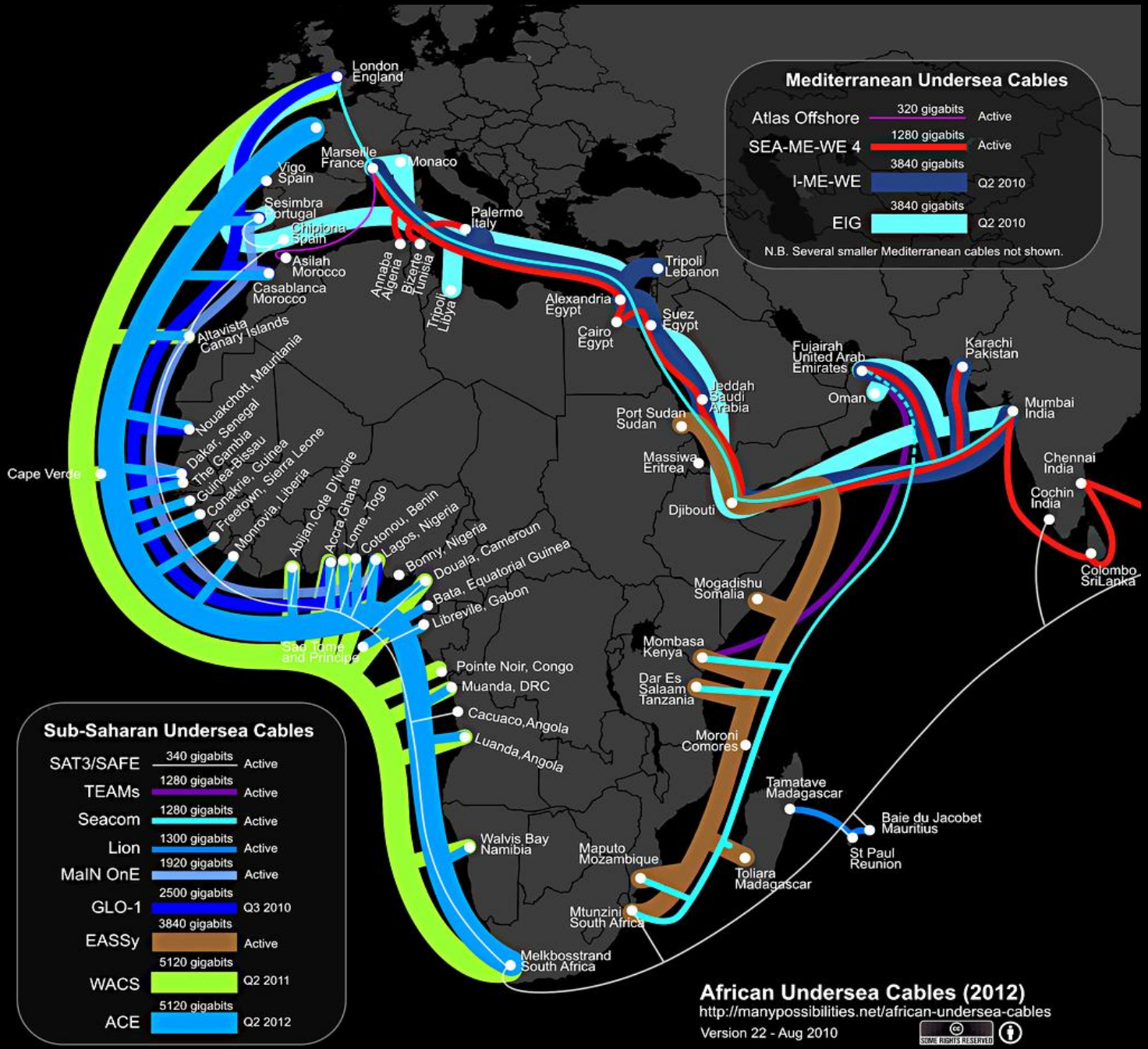
- There are a considerable number of satellite ground stations in Africa
- Fully steerable 20 - 32 m dishes
- Surfaces accurate enough for use at least 10 GHz
- These stations are rapidly becoming redundant due to the proliferation of undersea optical fibre links, which have much higher bandwidth
- There is therefore a possibility to re-use some of these stations for radio astronomy, particularly for VLBI



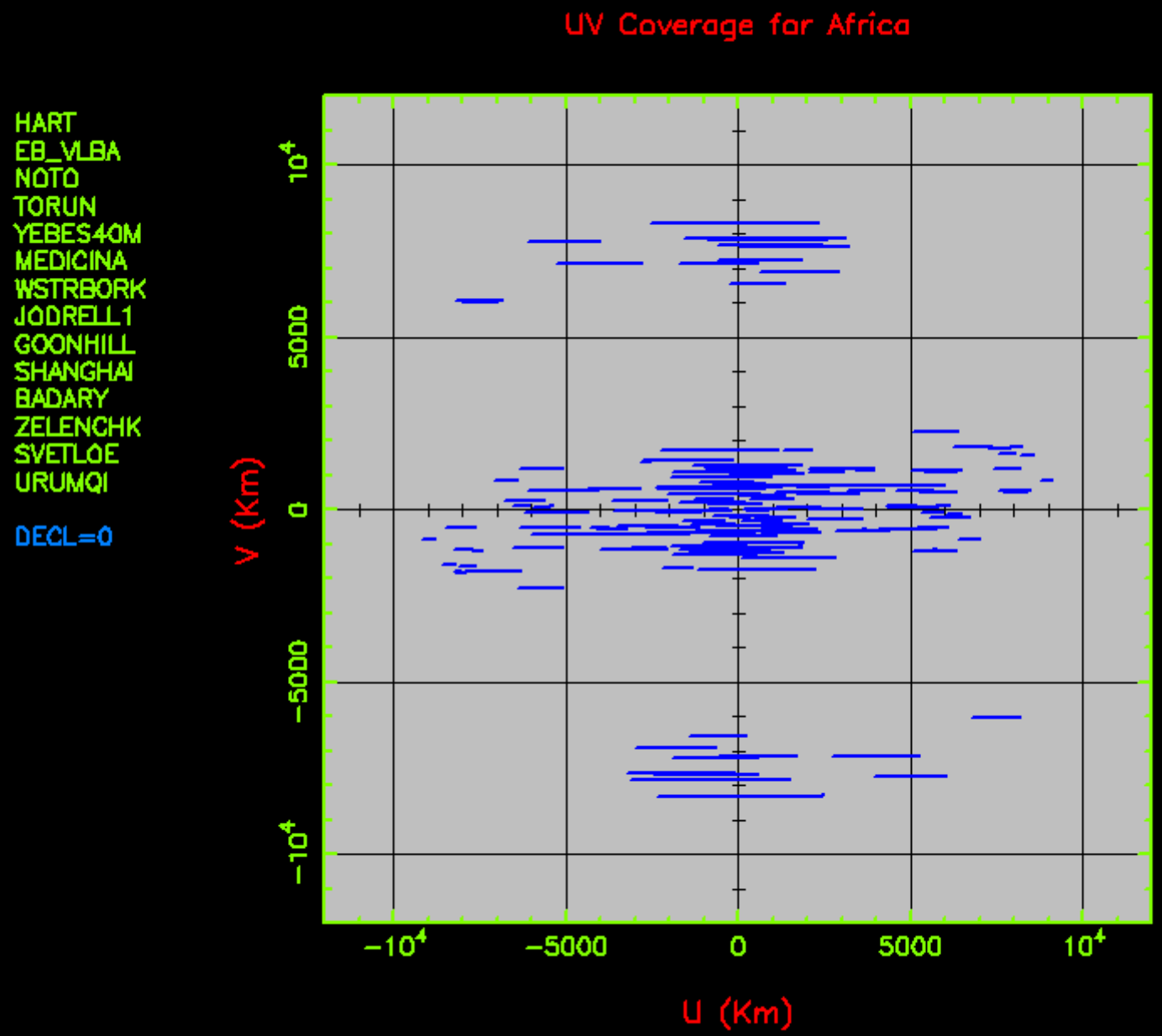
African VLBI Network: Satellite Earth Stations in Africa



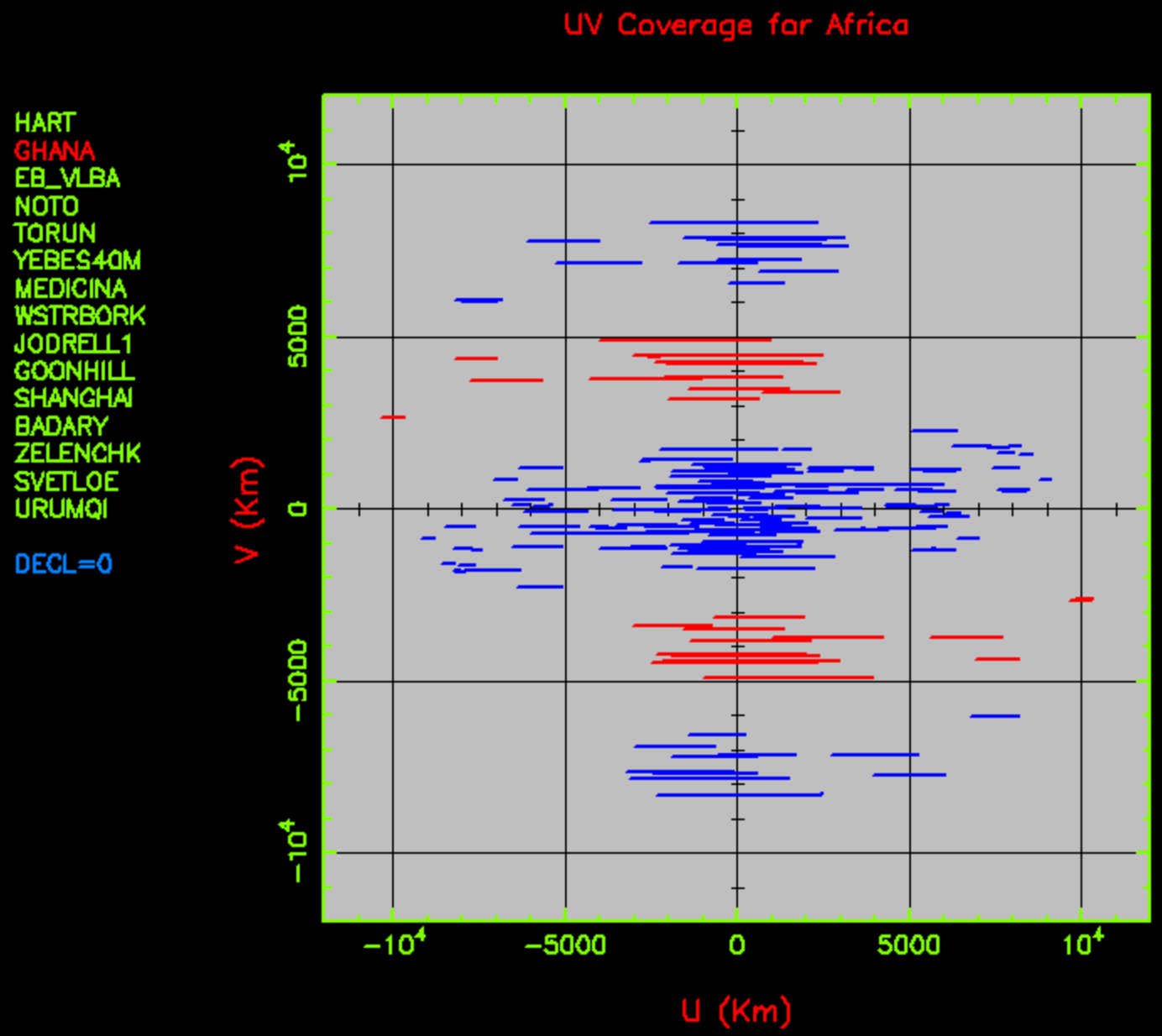
Fibre Connections to Africa



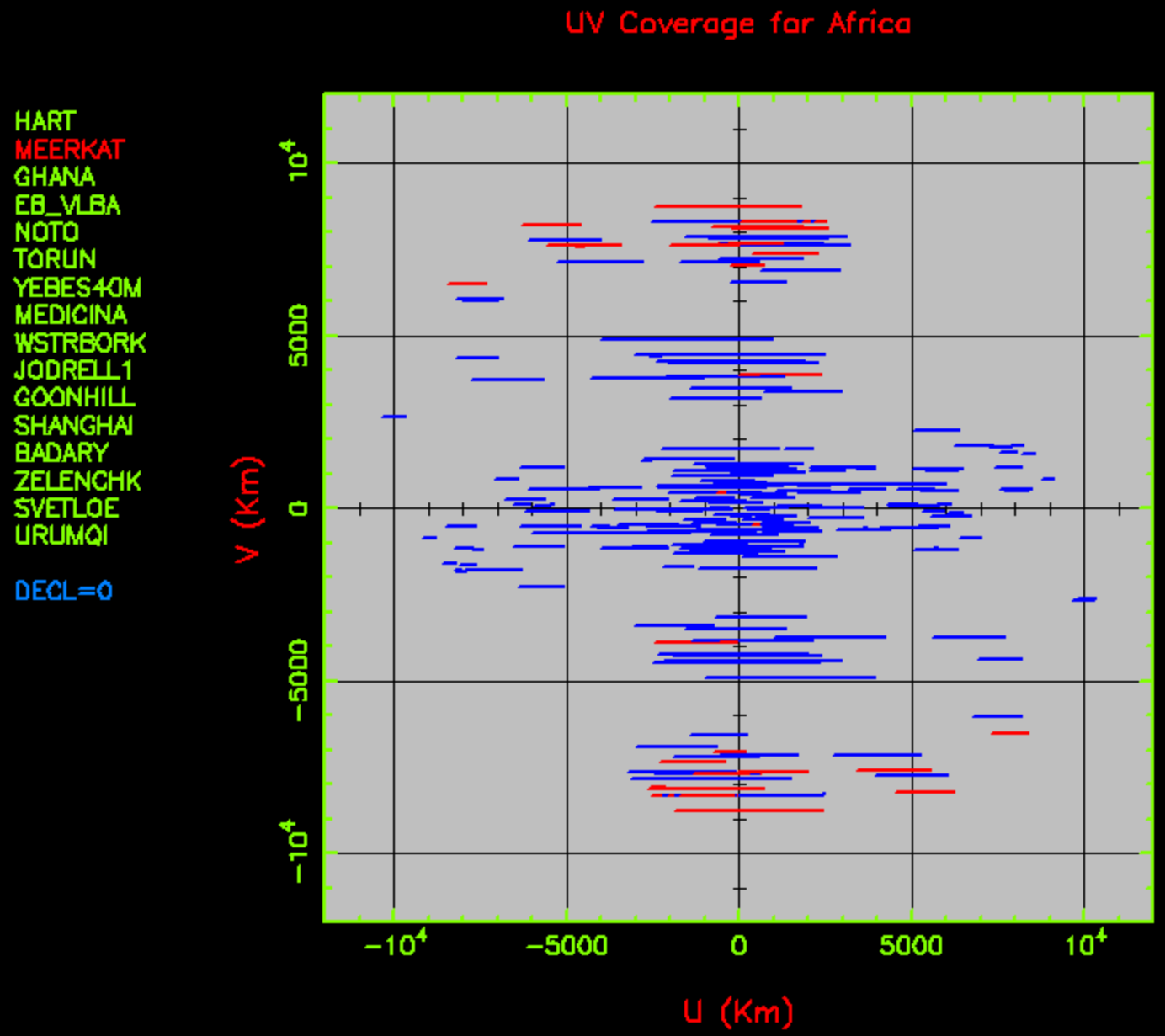
VLBI with MeerKAT & Africa Array



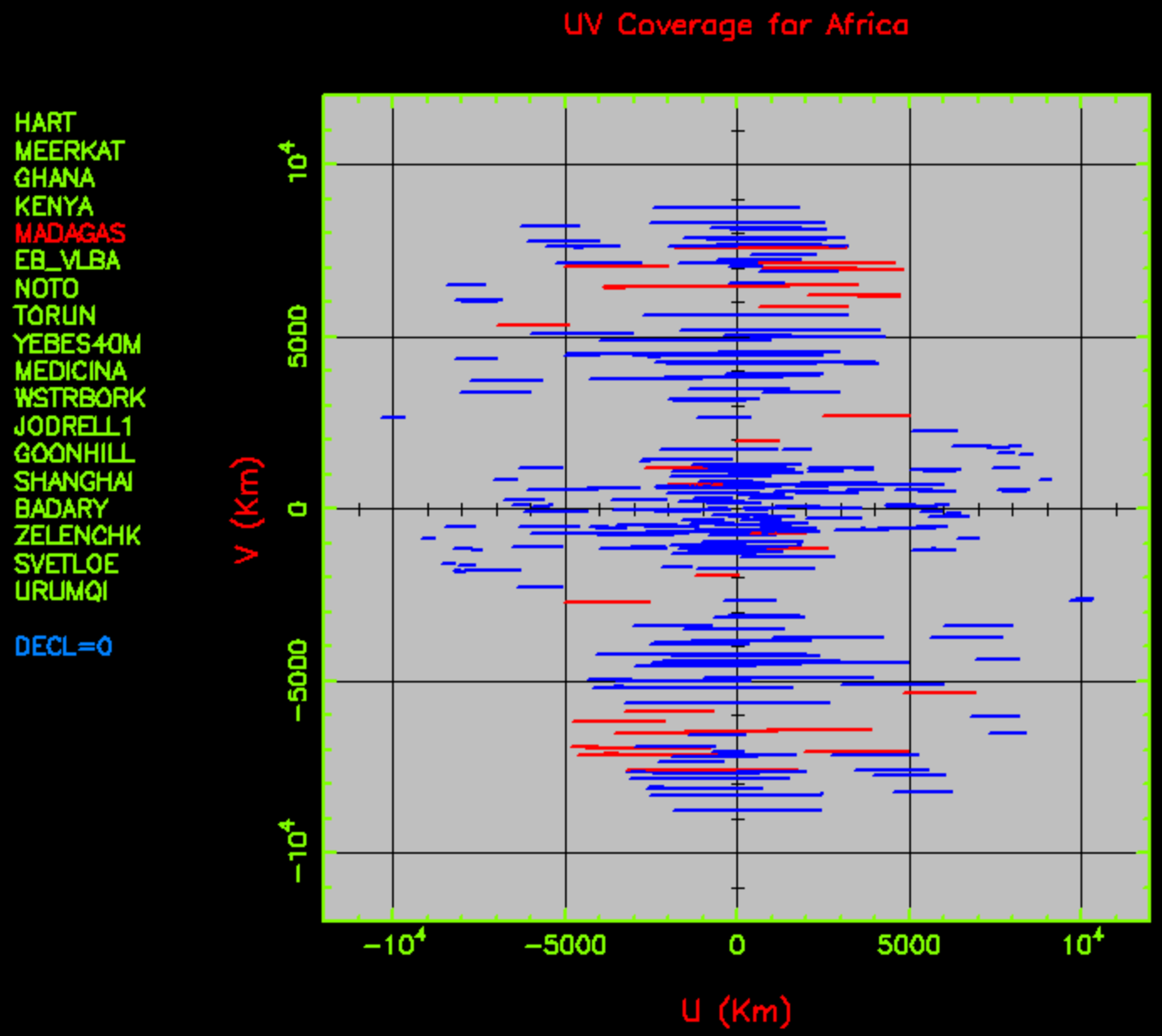
VLBI with MeerKAT & Africa Array



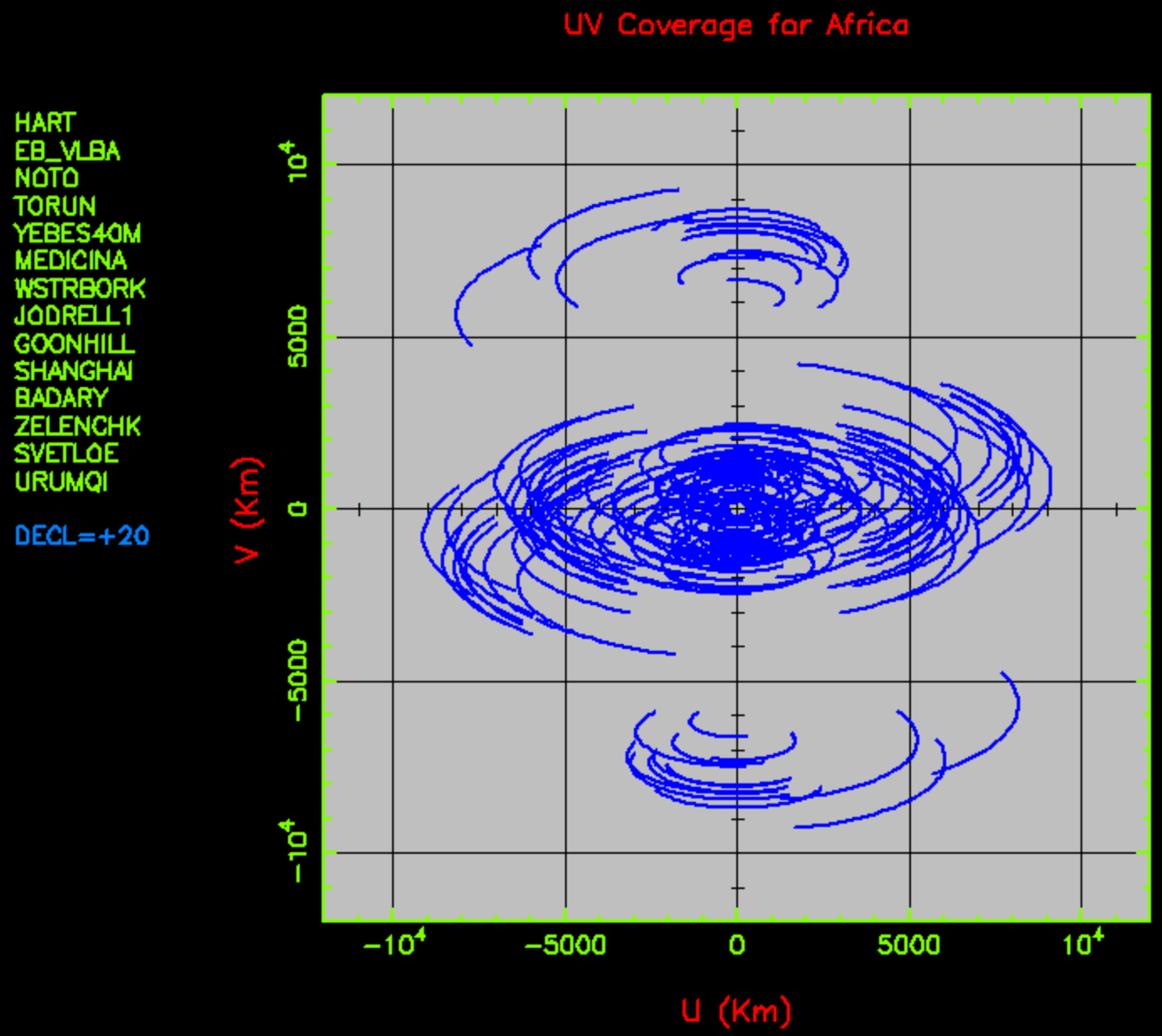
VLBI with MeerKAT & Africa Array



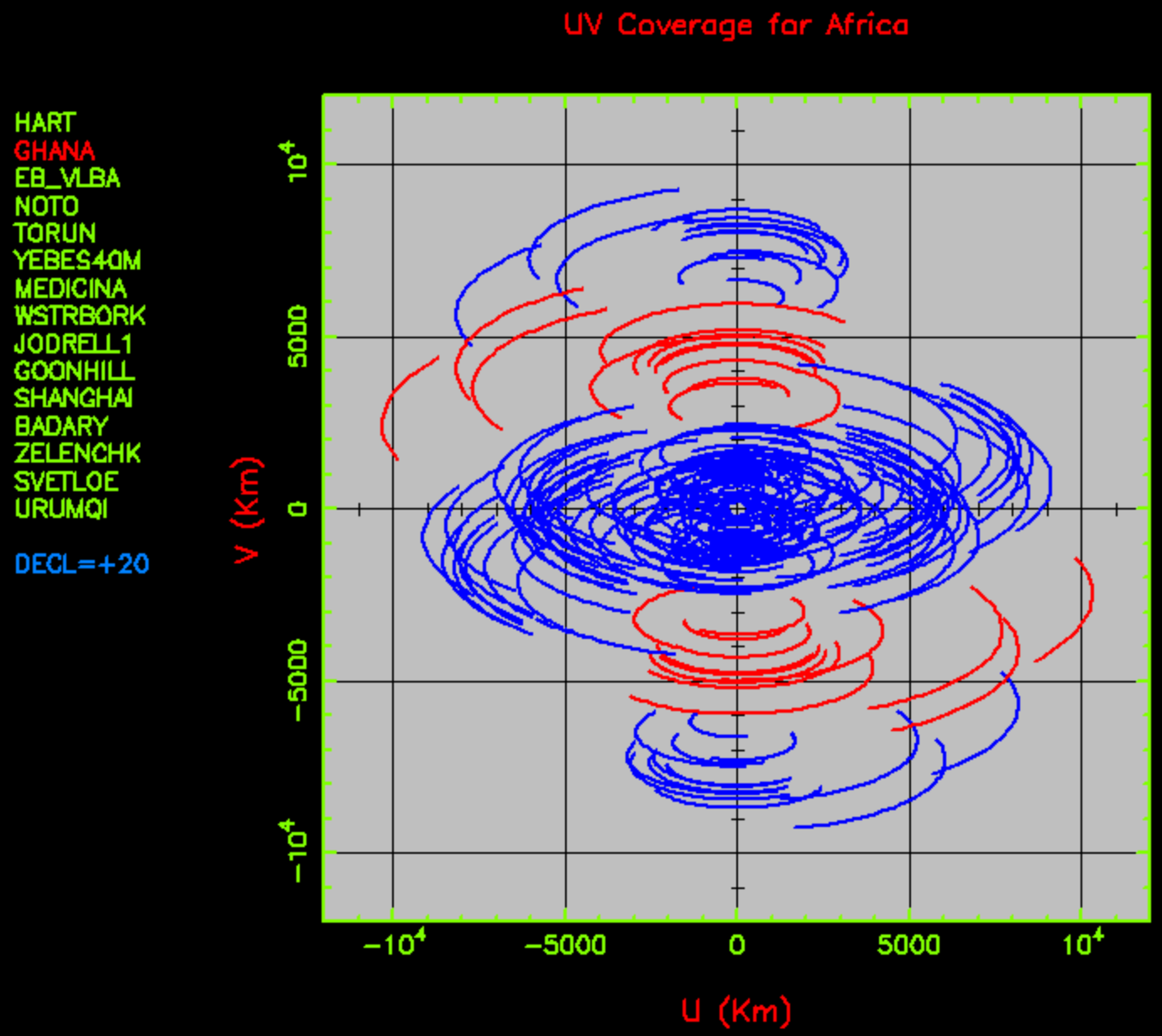
VLBI with MeerKAT & Africa Array



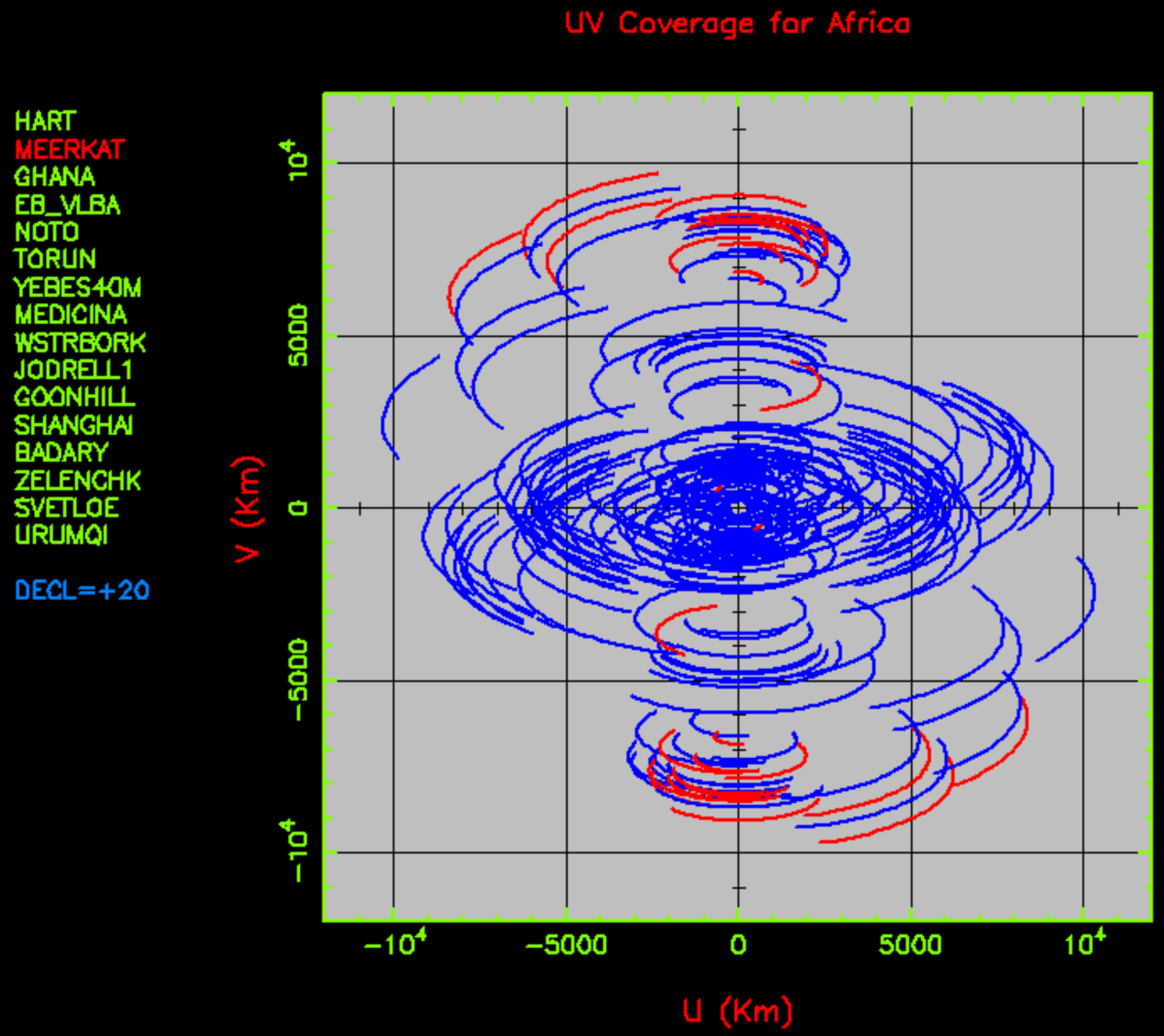
VLBI with MeerKAT & Africa Array



VLBI with MeerKAT & Africa Array



VLBI with MeerKAT & Africa Array



VLBI with MeerKAT & Africa Array