Extended Southern Hemisphere Asteroid Radar Program (eSHARP)

Shinji Horiuchi
Canberra Deep Space Communication Complex (CDSCC), Tidbinbilla, ACT
CSIRO Space & Astronomy

Radar astronomy for Near Earth Asteroids (NEAs)

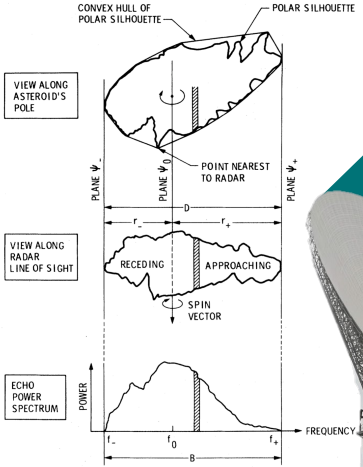
- Helping understand the origin/evolution of the Solar System & life
- Understanding the dynamics & characteristics of asteroids
- Tracking asteroids that can potentially hit Earth

Image Credit: Chemistry World

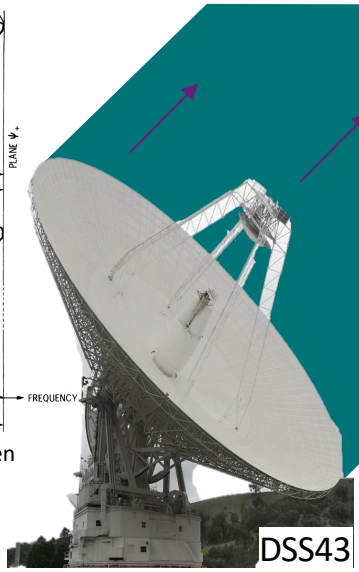
Bistatic Radar using NASA DSN stations

- Transmit to objects from CDSCC (transmit in RCP (SC))
- Receive at ATCA in Narrabri (receive RCP & LCP (OC))
- Transmission frequency shifted to ensure echoes are always received centered at 7159.45MHz

What is SHARP? (Southern Hemisphere Asteroid Radar Project)

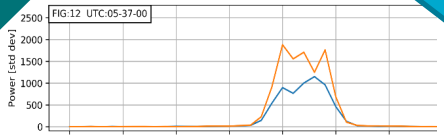


Geometric relation between asteroid shape and echo power spectrum. (Ostro, 1993)



Only facility in the Southern Hemisphere that can do this!
5% NEAs only observable by us!

*Not to scale



Received (& Processed) Signal

Radar echoes provide 2-Dimensional info

- Doppler spread – rotation and spatial extent perpendicular to line of sight

- Delay (ranging) – spatial extent along line-of-sight
  (not available yet for SHAPRP)

-> Delay-Doppler image
('fake' image)
  (not available yet)

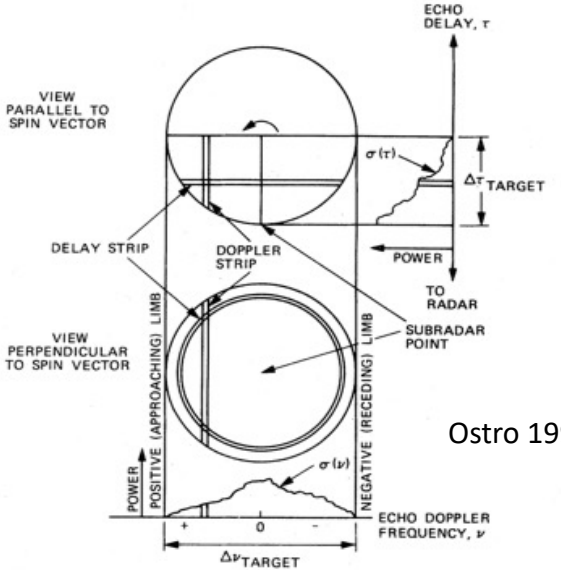
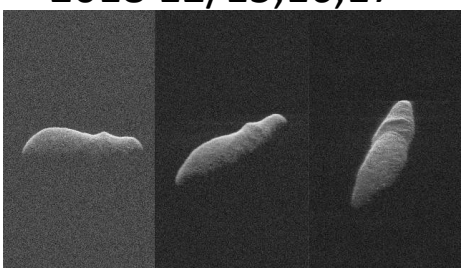


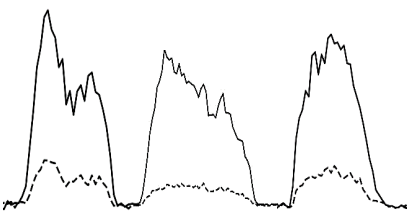
FIG. 13. Time-delay and Doppler-frequency resolution of the radar echo from a rotating spherical target.

Ostro 1993

2018 12/15,16,17



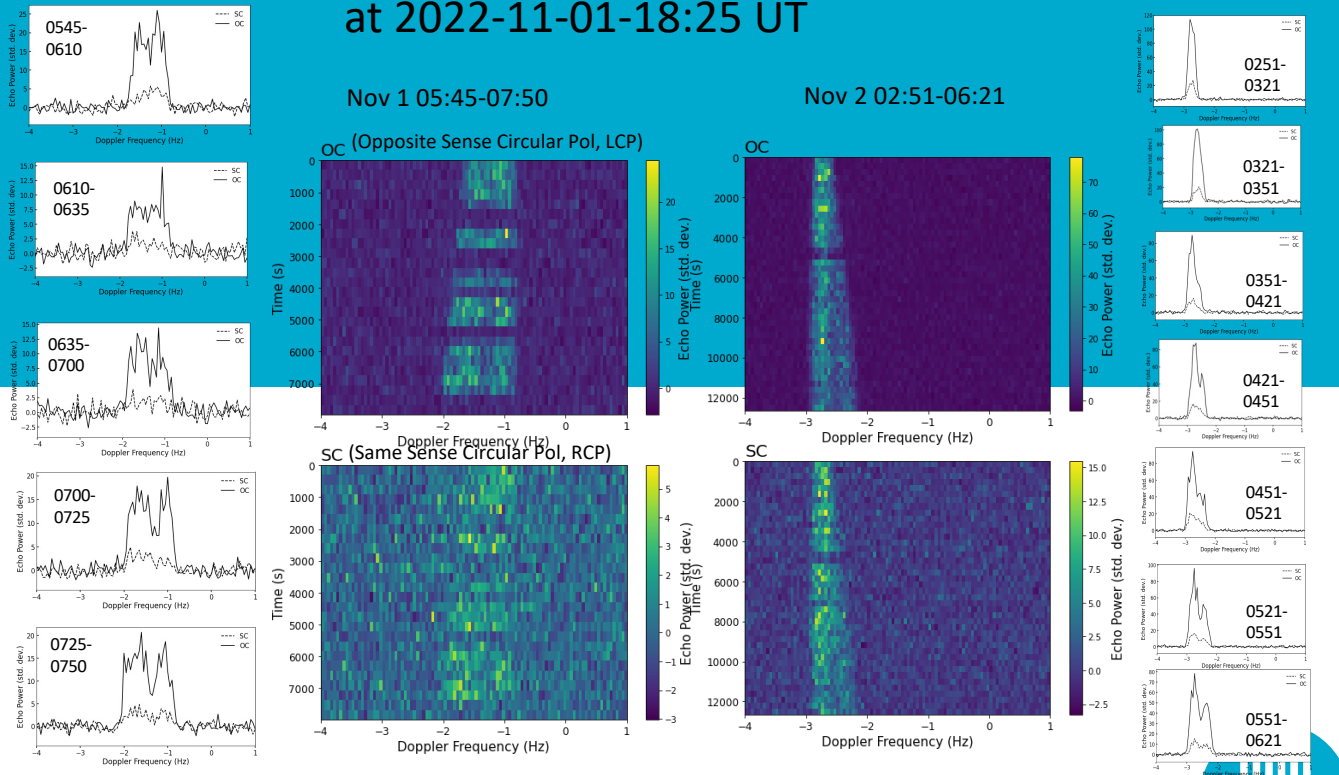
12/21,22,23



NEA 2003 SD220 Goldstone/GBT

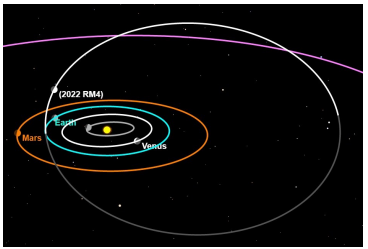
Tidbinbilla/ATCA

Recent highlight: Near Earth Asteroid 2022 RM4, 400m size, The nearest approach to Earth 0.01538 AU (6 Luner Distances) at 2022-11-01-18:25 UT



Tx: DSS-43 (Tidbinbilla), Rx: ATCA (Narrabri)

Doppler astrometry: 2022 RM4 radar allow to predict Earth encounters over 10 centuries



Date (TDB)	Body	CA Dist (au)	MinDist (au)	MaxDist (au)	Vrel (km/s)	TCA3Sg (min)	Nsigs	P_i/p
1399 Oct 18.48458	Earth	.061418	.052681	.344822	23.453	29623.	5.57E5	
....								
1553 Oct 16.05930	Earth	.060699	.027186	.180820	23.233	11105.	3.17E5	.000000
1734 Oct 28.97724	Earth	.019532	.014868	.024197	23.176	383.63	4657.2	.000000
1757 Nov 04.10308	Earth	.089539	.064549	.114798	23.846	2116.2	7.31E5	.000000
2022 Nov 01.76837	Earth	.015357	.015357	.015357	23.476	0.00	3.44E5	.000000
2095 Nov 06.54184	Earth	.095514	.091260	.099768	23.380	335.27	2.67E5	.000000
2238 Oct 28.91557	Earth	.084926	.073295	.096583	23.694	971.87	5.06E5	.000000
2296 Nov 06.44359	Earth	.081789	.046229	.118168	22.712	2863.1	3.57E5	.000000
2400 Nov 04.95968	Earth	.033942	.016222	.054150	23.265	1805.2	3.90E5	.000000
2570 Oct 31.23701	Earth	.067064	.033799	.113898	23.579	4539.8	5.27E5	.000000
....								
2663 Nov 03.67723	Earth	.045359	.043851	.813482	23.251	78386.	5.85E5	.000000

(Computed by Jon Giorgini, Solar System Dynamic, NASA/JPL)

e = 0.596
a = 2.447 au
q = 0.944 au
i = 38.3
Period = 3.83yr

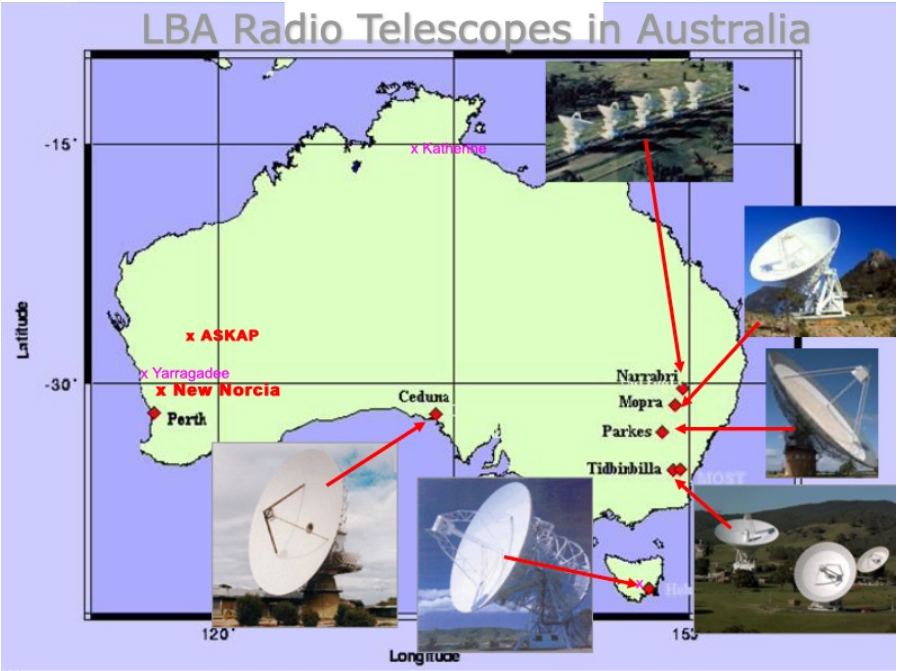
The encounter this time was the nearest one for this +/- 500 years

The second closest encounter was in 1734

Cf. https://ssd.jpl.nasa.gov/tools/sbdb_lookup.html#/?sstr=2022%20RM4

Possible expansion with more telescopes

- Parkes UWB-High?
- Mopra C/X upgrade?
- New Norcia(ESA 35m)?
- ATCA+CA06 subarrays?
- Hobart and Katherine (AuScope 12m dishes)

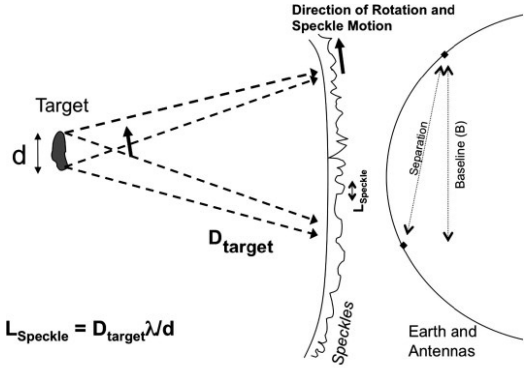


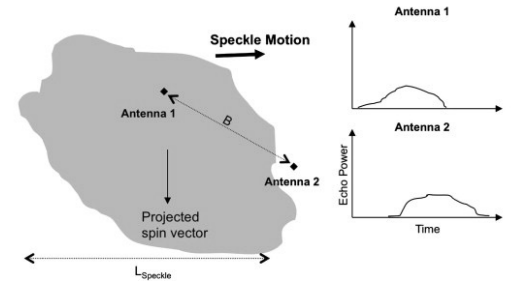
"Multistatic" radar?

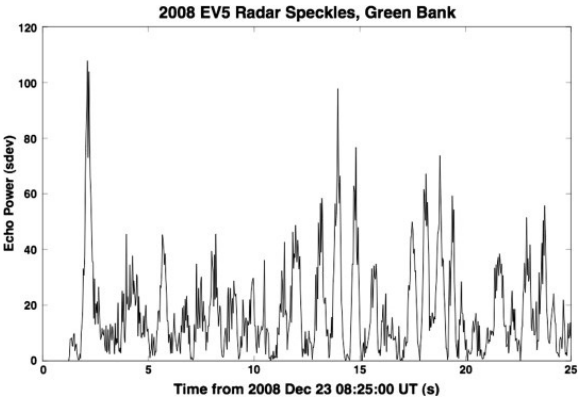
Historically all VLBI attempts failed due to **radar speckle** – interference of reflections from difference parts of the surface

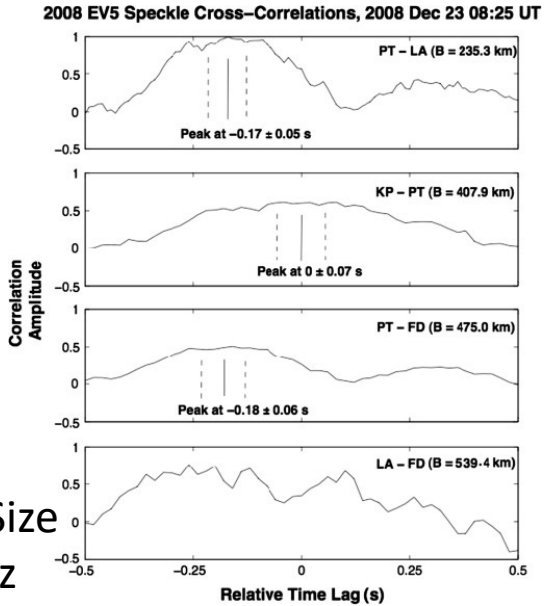
However, ….

Determination of NEA Spin Axis using VLBA for Radar Speckle (Busch et al. 2010)









Speckle Length = Distance*wavelength/Size
= 61 km * (R AU/0.01)/(D km) for 7.1 GHz

Why is spin axis determination important?

- Asteroids' spin states are coupled to their orbits and shapes through the Yarkovsky and YORP effects: the radiation pressure produced by an object's thermal emission

Requirements for Speckle Measurements?

- Short Sensitive Baselines are ideal: e.g.,

  ATCA – CA06 ~5km

  ATCA – Mopra ~120 km,

  ATCA – Parkes, Tidbinbilla – Parkes ~270-300 km
- None of those baselines are yet possible

(Parkes/Mopra cannot receive at 7.1 GHz!)

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Towards Spin Axis Determination

- Parkes UWB-High and/or Mopra CX-upgrade needed

(These will be also backup when ATCA is not available)

- Other telescopes?

    e.g., JAXA-Misasa/Usuda and Ishioka ~200km

Another possible expansion of SHARP

- Currently Canberra-DSN antennas are heavily subscribed
- Access to ESA-New Norcia 35m 7.1 GHz 20kW transmitter may increase our ability to track NEAs discovered for short notice, if available
- Acquiring an arbitral waveform generator for Tid transmitter will allow delay-Doppler measurements and imaging

Thank you!

Dr. Shinji Horiuchi

shiinji.horiuchi@csiro.au