Detection of *Three* Near-Earth Asteroids with a Southern Hemisphere Planetary Radar System

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Outline

- Near Earth Objects & Potentially Hazardous Asteroids
- Planetary Radar Systems
- Southern Hemisphere demonstrations
- Conclusions and future work

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Near Earth Objects

Each day ~100 tons of interplanetary material hits the Earth, mostly dust and small objects

Larger Objects reaching the Earth's surface:

frequency	*size*	*disaster level*
~10,000 yr	~100 m	regional
~100,000 yr	~1 km	global

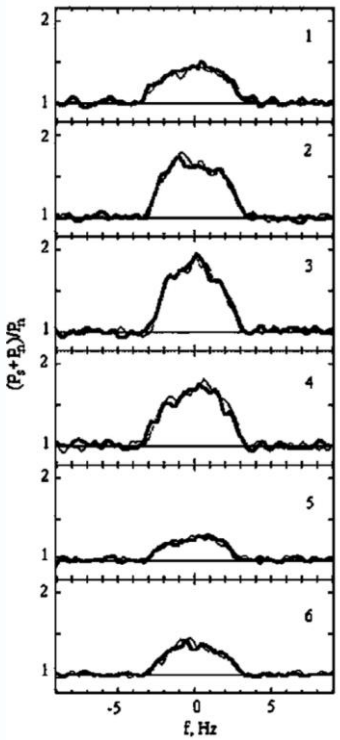
cneos.jpl.nasa.gov

Monitoring NEOs population will help:
- understand parent population
- characterise individual objects
- assess suitability as targets to visit
- determine orbits
- identify Potentially Hazardous Asteroids

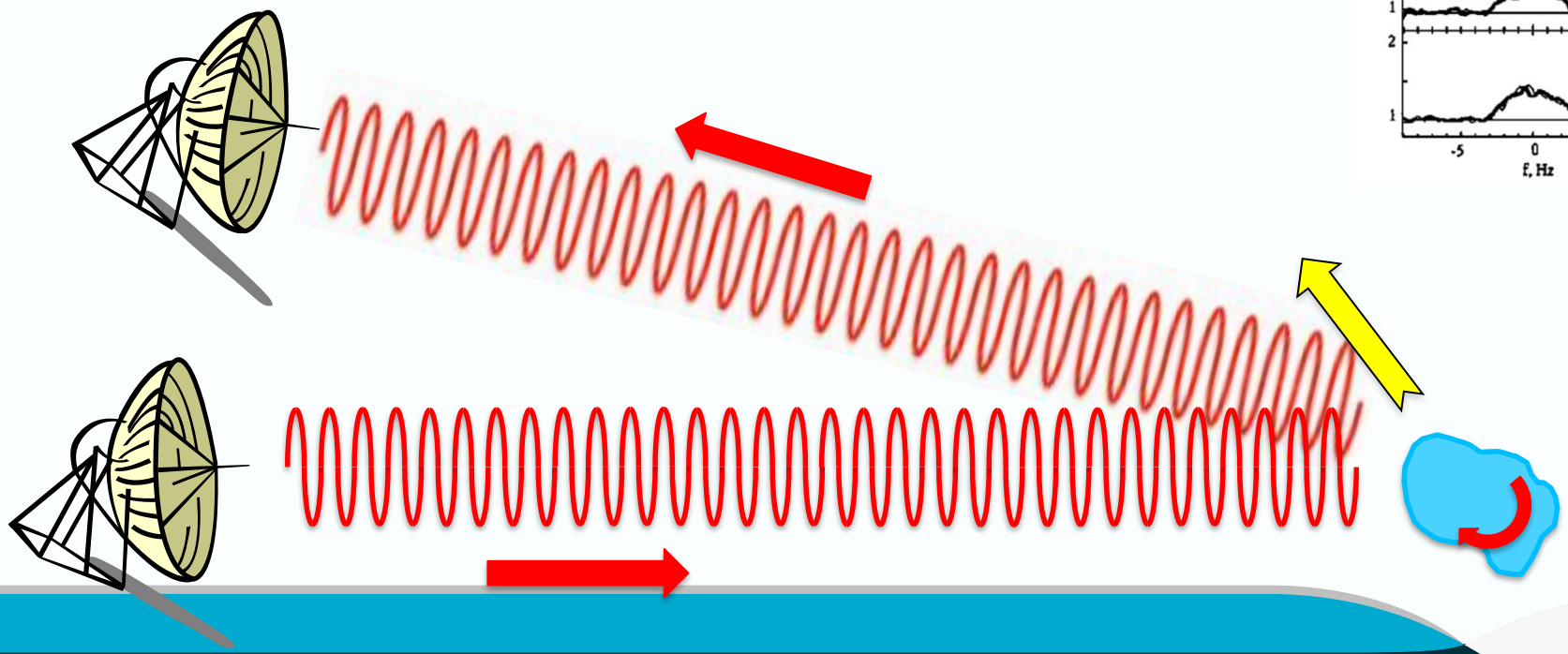
There are approximately
- 500,000 asteroids known
- 16,000 NEAs known
- 1,800 PHAs known

Bistatic Planetary (Asteroid) Radar

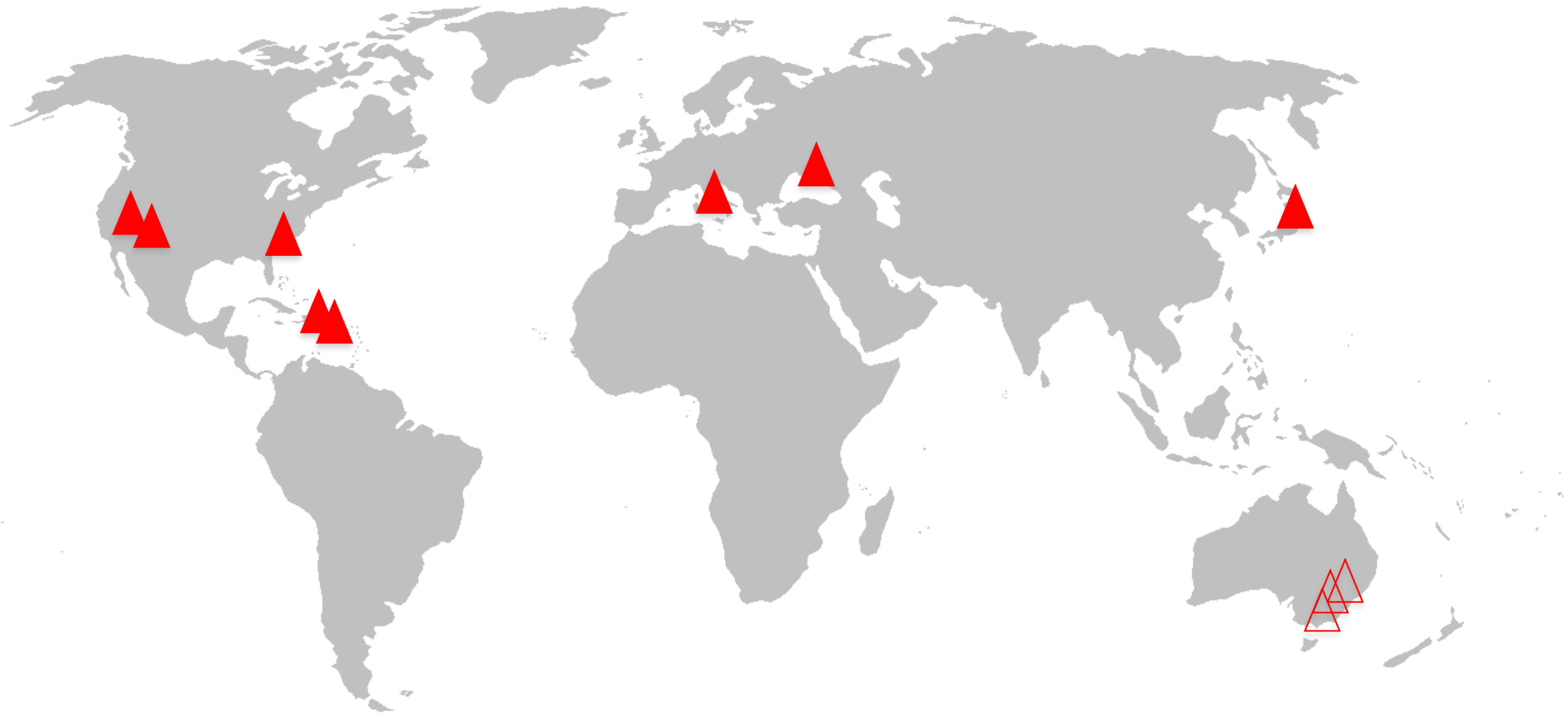
Continuous Wave (CW) gives Doppler spread only



Martino et al, 2004, Results of the first Italian planetary radar experiment, Planet. & Sp. Sci.



Planetary (Asteroid) Radar



Shantanu et al., Capabilities of Earth-based radar facilities for near-Earth asteroid observations, 2016, http://arxiv.org/abs/1604.01080
Ostro et al. 2002, Asteroid Radar Astronomy, in Asteroids III
Martino et al. 2004, Results of the first Italian planetary radar experiment, Planetary and Space Science

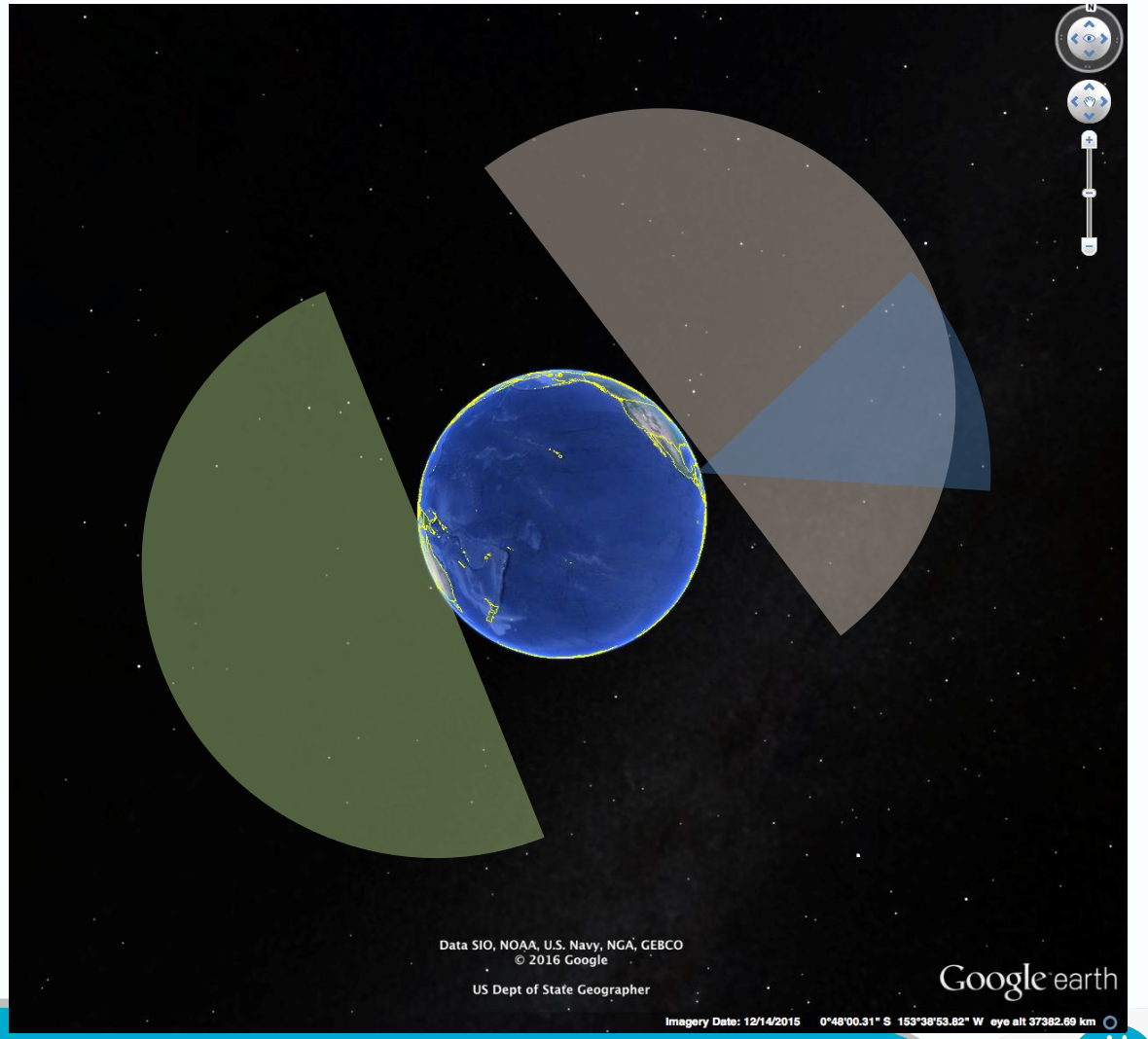
Earth Image: Wikimedia

Radar System Coverage

Goldstone, 35° N, 450kW

Arecibo, 18° N, 1MW, limited el.

Tidbinbilla, 34° S, <100kW



Goals

Demonstrate a capability for Southern Hemisphere Radar observations

Compare VLBI recordings to PRSR

- Simplifying logistics for future work

Build Australian science capability in Space Radar

Refine orbit

- prevent loss of correlation between Earth approaches

Estimate properties

- Size
- Shape
- Rotation rate
- Polarisation ratio (roughness)
- Radar albedo

2015 Campaign

Two NEAs

•2005 UL5 (closest approach 2015 November 20, ~6 lunar distances)

•1998 WT24 (closest approach 2015 December 11, ~11 lunar distances)

Transmit CW from DSS-43, 70m at Tidbinbilla

- 2.114 MHz nominal frequency – Doppler shifted for Parkes
- ~70 kW, limited to avoid risk of damage to Tx
- Pointing and Doppler predicts supplied by JPL

Primary receive at Parkes 64m

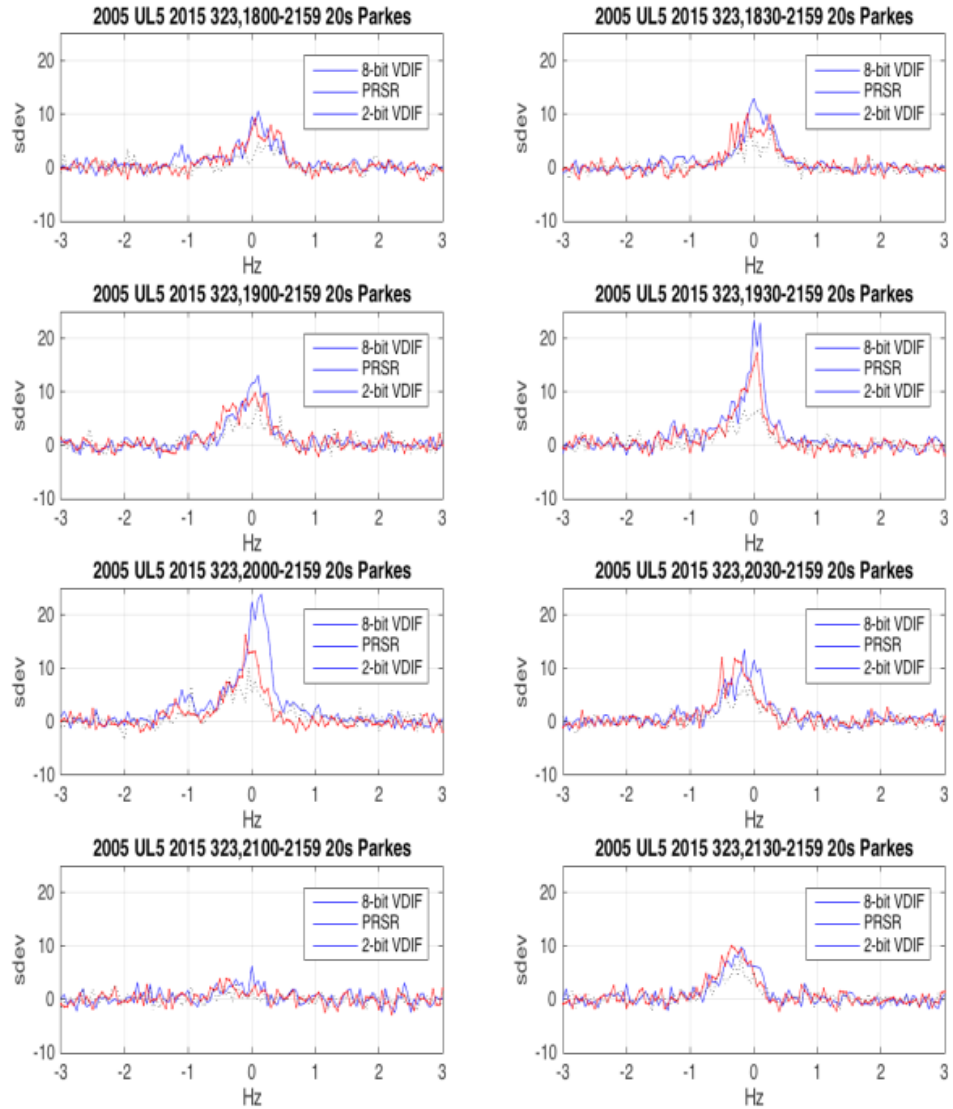
- ‘Galileo’ receiver
- JPL Portable Radio Science Receiver (PRSR)
- Parallel recording of 2&8-bit 8Msps Long Baseline Array data

Secondary receive at Australia Telescope Compact Array (ATCA) 5x22m

- Requires variably shifting signal to tune to 0 Hz
- About 3dB less sensitive than Parkes

2005 UL5 Results

- Local processing of PRSR data consistent with JPL processing
- Good agreement between PRSR data and VLBI data
- Variations in return signal strength over the 4 hours
- 8-bit VLBI data better than 2-bit VLBI data
- Dual-polarisation VLBI data indicated SC/OC ratio ~0.2

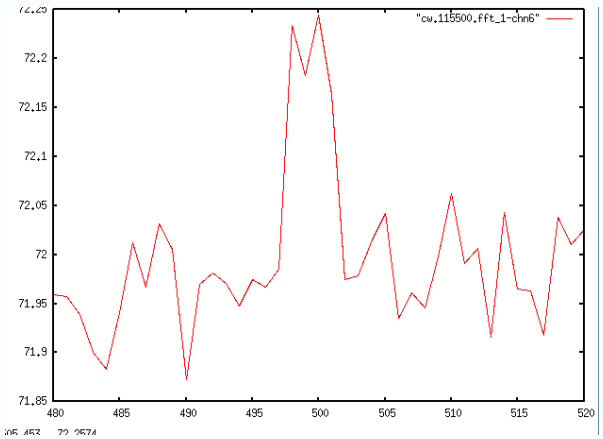


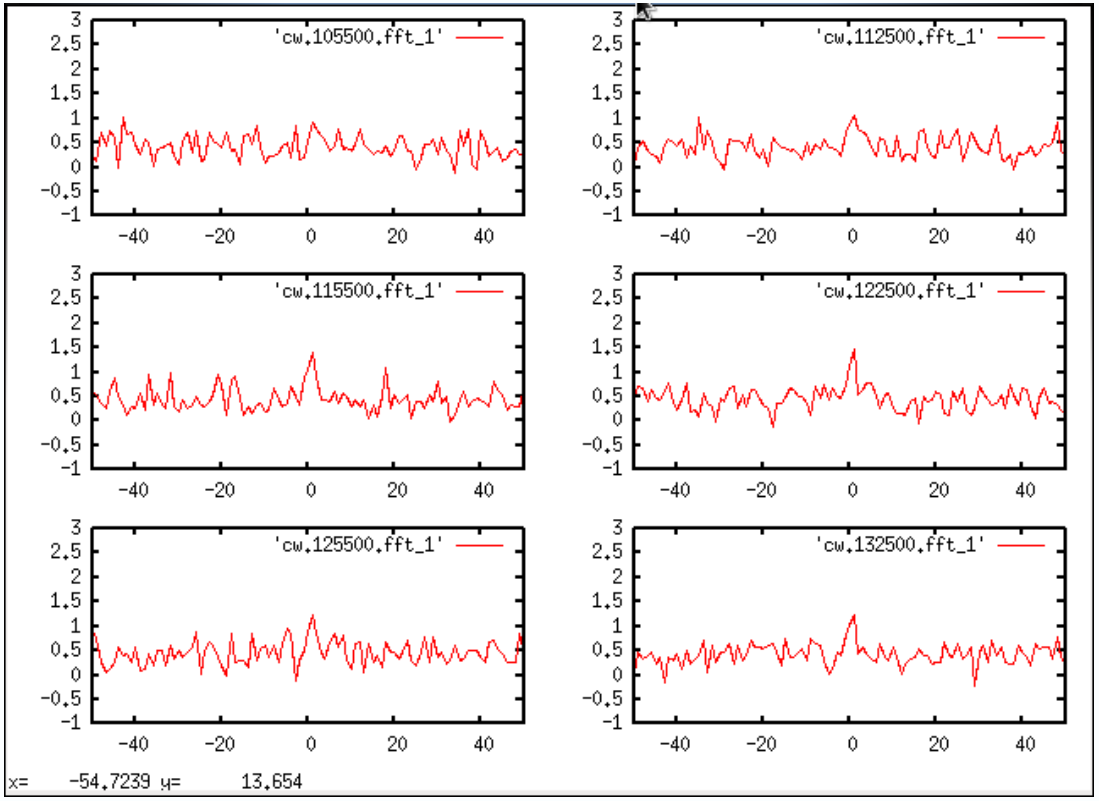
(Benson et al 2017, Radio Science, in press)

8-bit (blue), 2-bit (dotted), PRSR (red)

1998 WT24 Results

Weaker signal, detected in Parkes PRSR data only





2017 Campaign

One NEA

•3122 Florence (closest approach 2017 September 1, ~18 lunar distances)

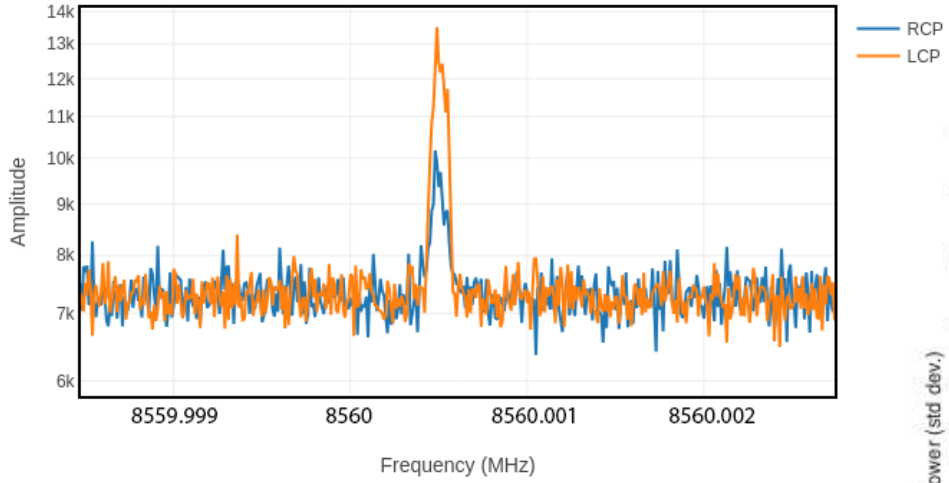
Transmit CW from DSS-35, 34m at Tidbinbilla

- 7.059 MHz nominal frequency – Doppler shifted for ATCA
- 20 kW Tx
- Pointing and Doppler predicts supplied by JPL
- Additional test CW transmission at 8.56 GHz from Goldstone DSS-14 at 450kW

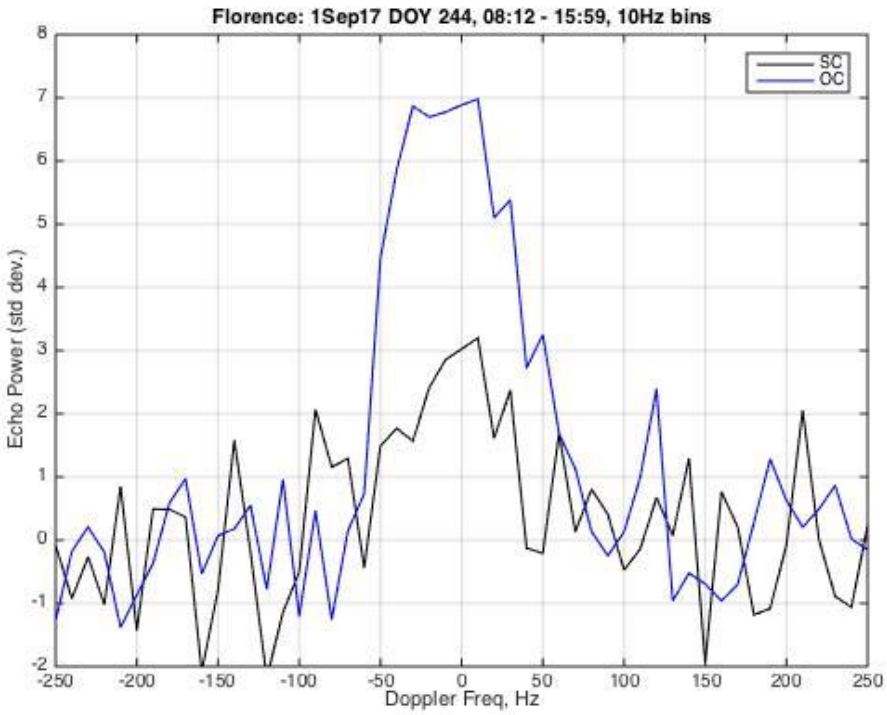
Receive at ATCA 5x22m

- Parallel recording of single-dish and tied-array 8-bit 8Msps VLBI format data

Florence results



1 minute scan with Goldstone 70m



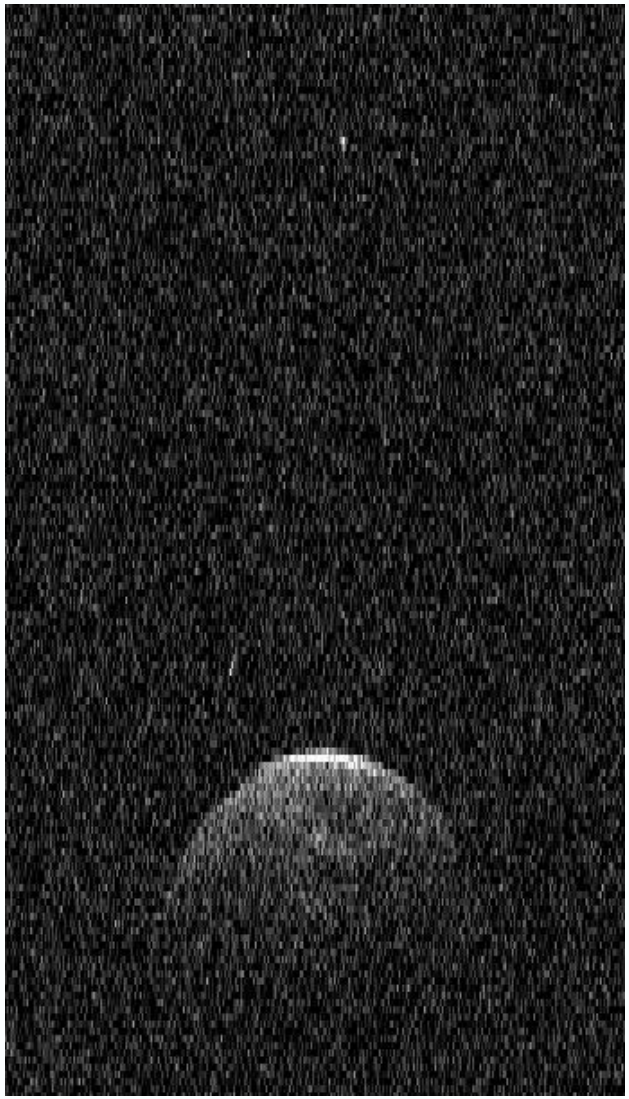
8 hours data with Tidbinbilla 34m

Planetary (Asteroid) Radar

Use of a coded Waveform provides information on Doppler spread and Range Resolution, allowing imaging

$$R_{res} = \frac{c}{2B}$$

https://cneos.jpl.nasa.gov/news/news199.html



Achievements & Future Plans

Achievements:

- Confirmed detections of NEAs
- Demonstrated viability of 8-bit VLBI recording for planetary radar
- Australian code to process data, remove RFI and extracting features
- Simplifies future Australian observations (including ITAR issues)
- Demonstrated planetary radar capability at 2.1 and 7.1 GHz
- Benson et al. 2017, Radio Science, in press

Issues:

- RFI and receiver artifacts
- New Parkes UWB receiver will do away with need to install 2 GHz rx
- Low SNR – upgrade Tidbinbilla 7 GHz transmitter from 20 to 80 kW
    - Goldstone/Green Bank about 10dB better than Tidbinbilla/Parkes

Next observation:

- 2012 TC4 will approach within 7 Earth radii on 2017 October 12

Thank you

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