Preliminary work on promoting radar astronomical study

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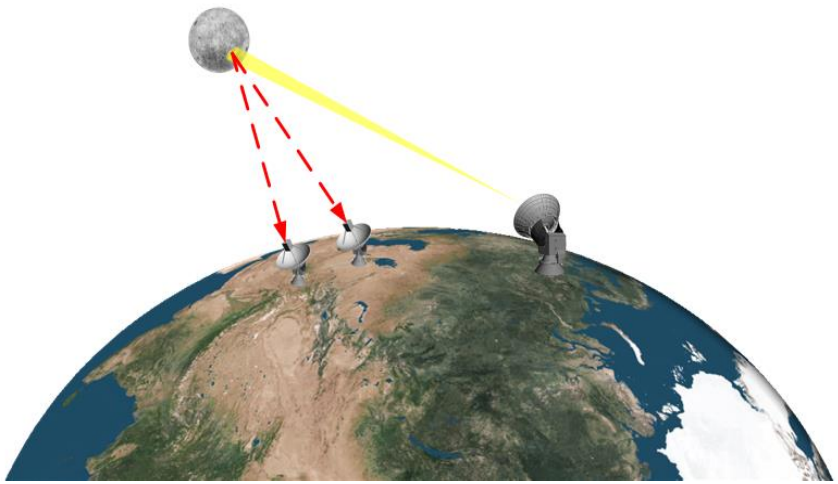
Introduction



Orbit refinement

Table 2. The posterior precision estimate of orbital elements obtained with use of optical data only and of both optical and VLBI radar data. GEO-object 1982-044A

Parameter	Error of determination	
	The optical data	The optical and VLBI radar data
Period (s)	0.00039	0.00016
Eccentricity	0.000001289	0.00000011
Inclination (degree)	0.0000397	0.0000385
Longitude of node (degree)	0.0001523	0.0001443
Argument of perigee (degree)	0.3186443	0.0553811
Time of perigee (s)	0.08468	0.03756

Igor Molotov. International Radar Space Debris Research. 2005.

Imaging

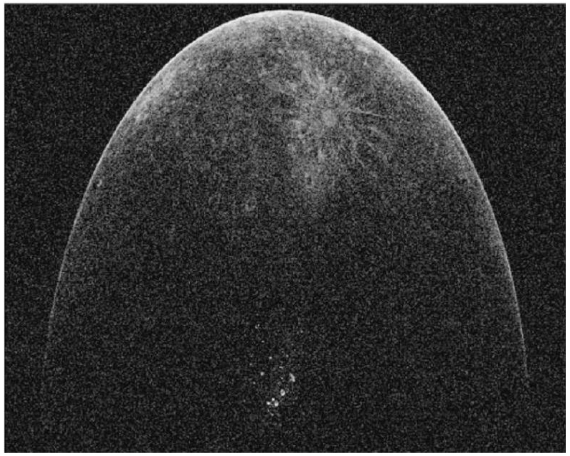
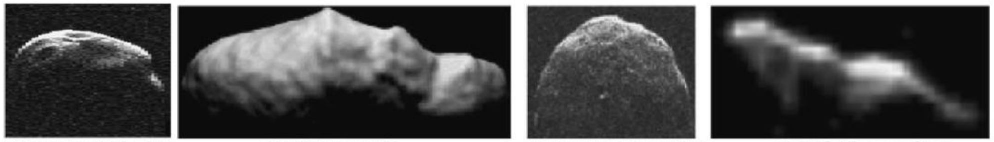


Fig. 5. ***Delay-Doppler map of Mercury obtained on June 16, 2000, at Arecibo. The leading edge of the radar echo is the parabolic locus that is brightest at the top. The North Pole craters that are filled with radar-bright material (putatively water ice) are at the bottom center. The delay resolution is 3 km. (From [3].)***



(53319) 1999 JM8 radar image | (4179) Toutatis radar-derived model | (100085) 1992 UY4 radar image | (1620) Geographos radar image

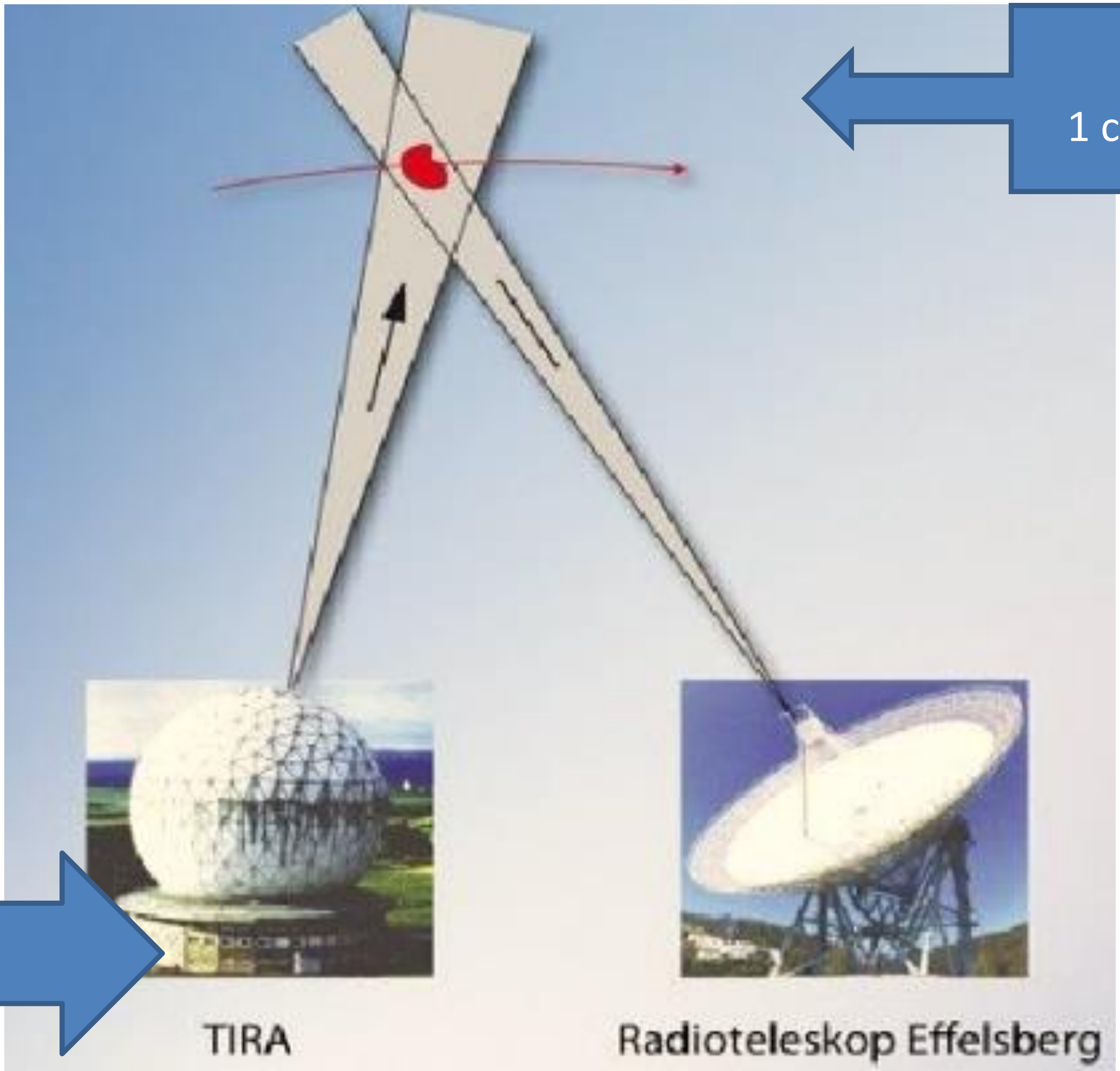
Martin A. Slade. Goldstone Solar System Radar Observatory Earth-Based Planetary Mission Support and Unique Science Results. 2010.

Development in the US

70 m
500 kW
X band

350 m
900 kW
P/S band

Development in the EU



Debris:
1 cm, 1000 km

TIRA(Tracking and Imaging Radar),
34 m,
L band,
Pulse signal

Development in the EU

The project of the Low Frequency VLBI Network (LFVN) was started in 1996 in order to arrange the international VLBI cooperation with participation of former USSR radio telescopes [1]. One of the LFVN goals is developments of the VLBI radar (VLBR) for the investigations of the Solar system bodies.

[1] *Central Astronomical Observatory at Pulkovo, Russia*
[2] *Radiophysical Research Institute, Russia*
[3] *Institute of Radio Astronomy, Ukraine*
[4] *Keldysh Institute of Applied Mathematics, Russia*
[5] *Istituto di Radioastronomia, Italy*
[6] *Osservatorio Astronomico di Torino, Italy*
[7] *Special Research Bureau, Russia*
[8] *Jet Propulsion Laboratory, USA*
[9] *International Vimpel Corporation, Russia*
[10] *Crimean Astrophysical Observatory, Ukraine*
[11] *Urumqi Astronomical Observatory, China*
[12] *Pushchino Radio Astronomy Observatory, Russia*
[13] *Institute of Astronomy, Latvia*

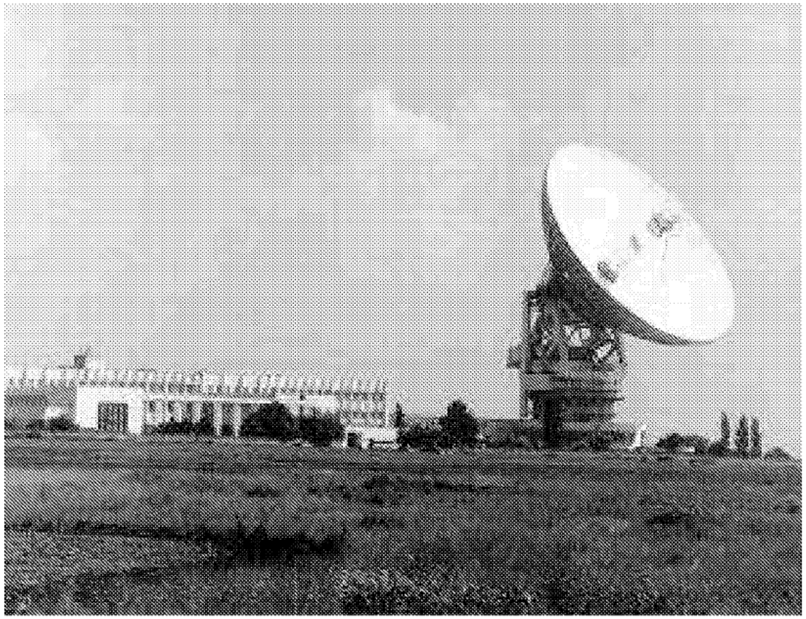


Figure 1. 70-m antenna near Evpatoria with 200 kW continuous power transmitter at 5010 MHz, National Control and Space Facilities Test Center, National Space Agency of Ukraine.

Development in the EU

Orbit refining; rotation period; sizes of objects

Mars
Venus (2007)
asteroid 2004XP14 (2006); 2012 DA14 (2011)
space debris objects (rocket stages, inactive satellites, …) at HEO and GEO

Transmitting antennas

RT-70 (Evpatoria, Ukraine)
5010.024 MHz

RT-70 Goldstone
8560.0 MHz

Receiving antennas

Ventspils (RT-32)
Urumqi (RT-25)
Medicina (RT-32)
Simeiz (RT-22)
Irbene (RT-32)

BW: 2 MHz

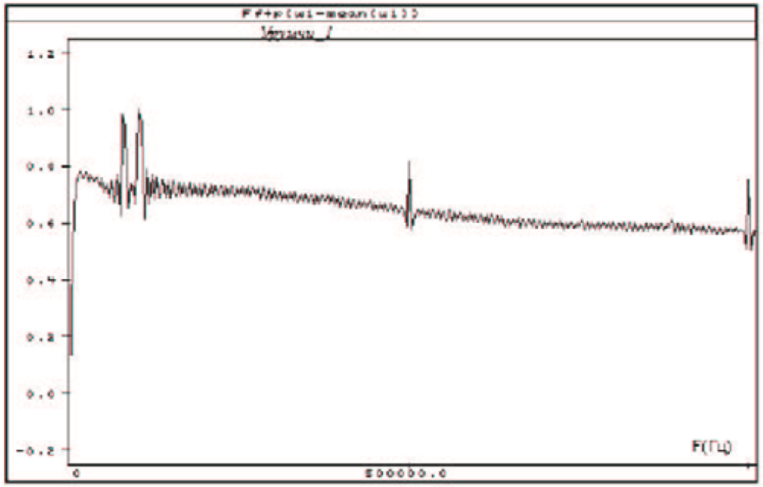
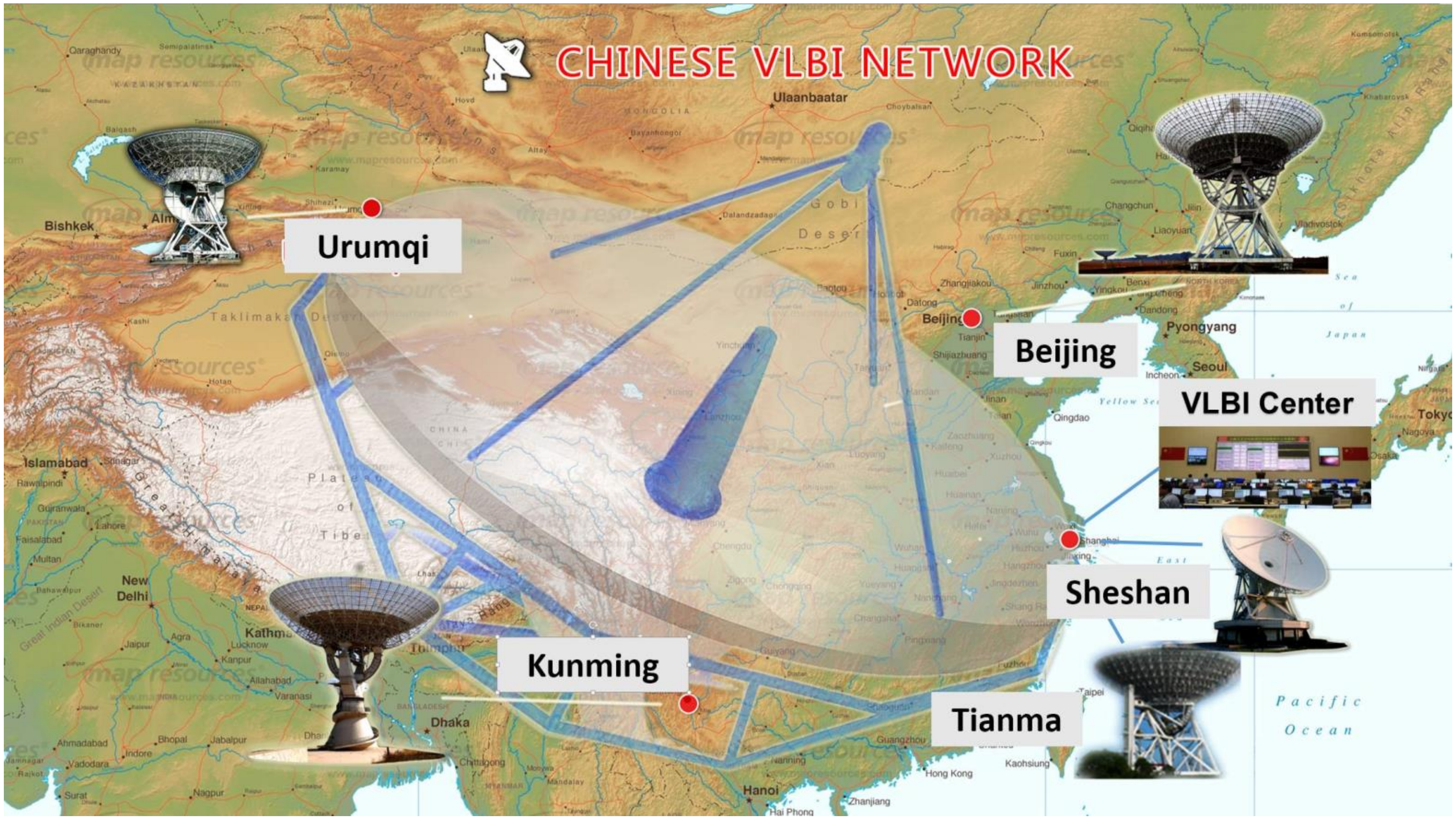


Fig. 4. Spectrum of echo-signals received at Urumqi (second peak from the left), May 27 2001, 23:35 UT, GEO object 20696

Development in the RU

NEO	Epoch of observation	D, m	P, h	R, au	B, Hz	RTT, sec	SNR/RTT
2003 SD220	2018 Dec 17	800	287.0	0.050	0.3	25	34
2017 VR12	2018 Mar 05	138	1.4	0.012	10	12	6
3200 Phaethon	2017 Dec 17	5100	3.6	0.069	140	69	3
3122 Florence	2017 Sep 04	4500	2.4	0.052	187	52	13
2003 BD44	2017 Apr 19	1400	80.0	0.057	5	57	8
2014 JO25	2017 Apr 18	650	4.5	0.024	14	24	14
2003 YT1	2016 Oct 31	1100	2.3	0.035	47	35	8
2003 TL4	2016 Oct 29	380	27.2	0.029	2	28	11
2011 UW158	2015 Jul 18	320	0.6	0.017	52	16	8

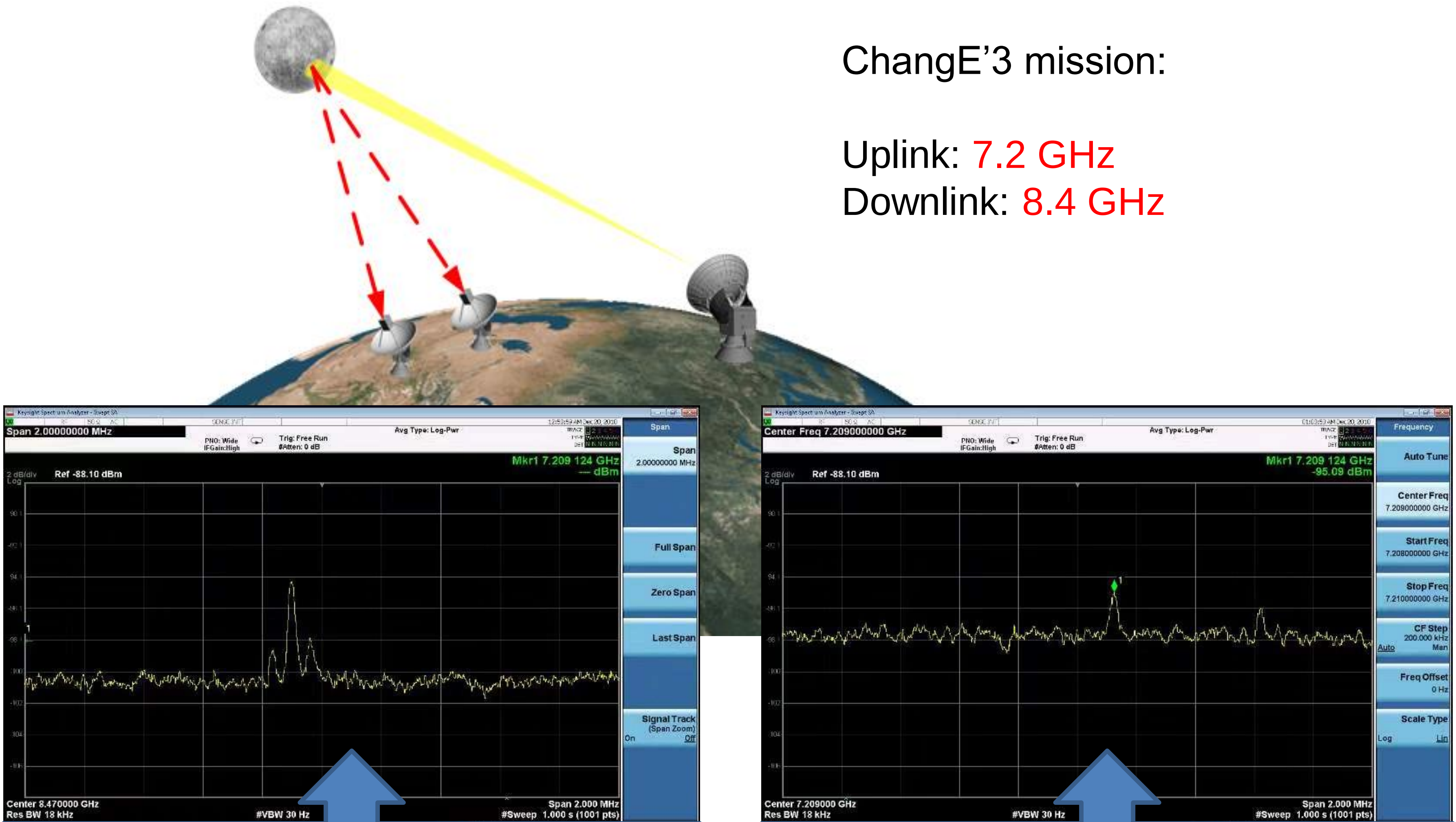
Available antennas in the China



Transmitting antennas
JMS(65m) KS(35m)

Receiving antennas
BJ(50m), SH(65m/25m/13m/13m), UR(25m/13m/110m), KM(40m), KS(13m), JL(13m), SY(13m)

Testing experiments - 1



ChangE'3 mission:

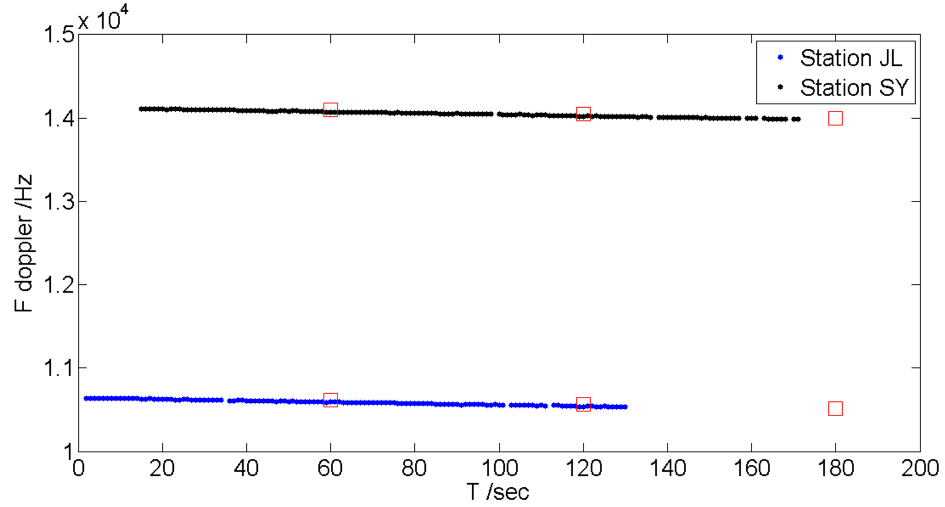
Uplink: 7.2 GHz
Downlink: 8.4 GHz

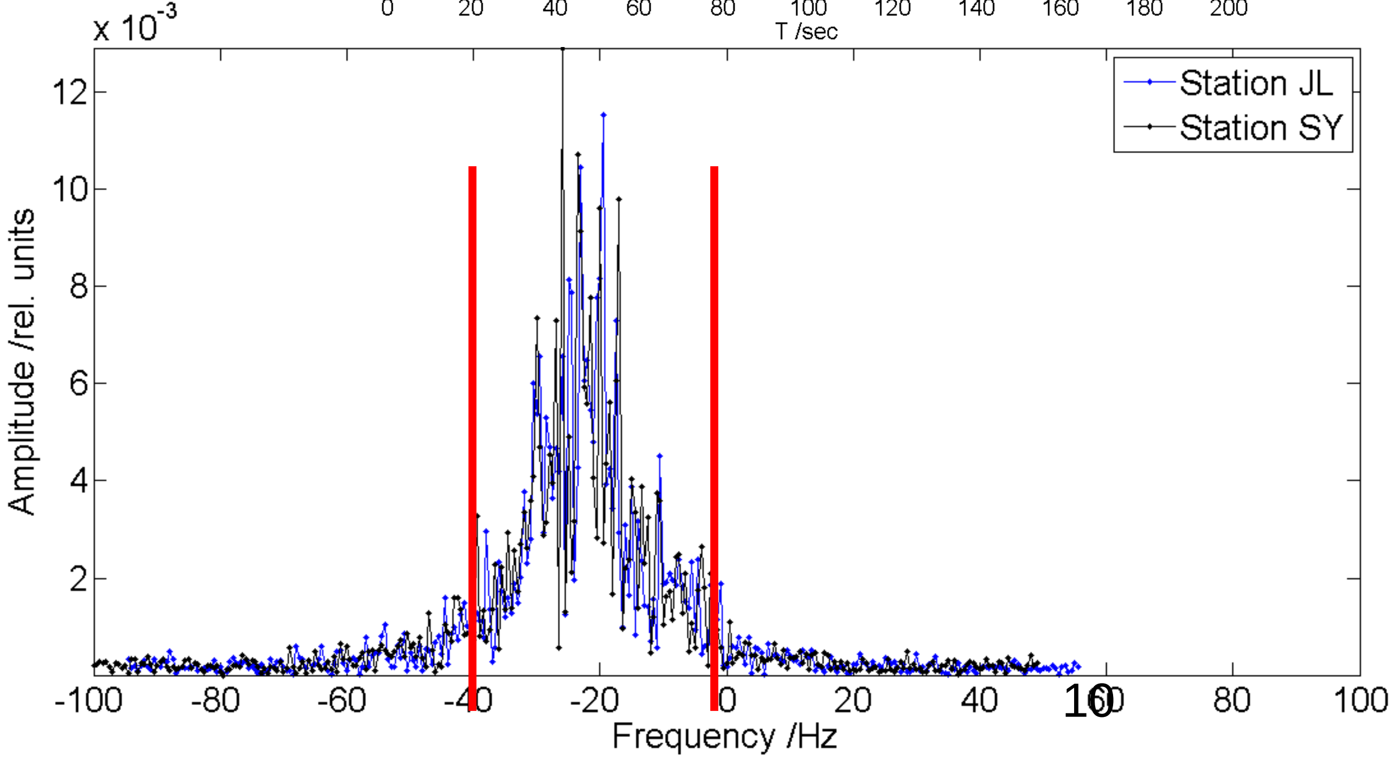
Downlink signal from ChangE'3 lander

Echo signal from ChangE'3 lander

Testing experiments - 1

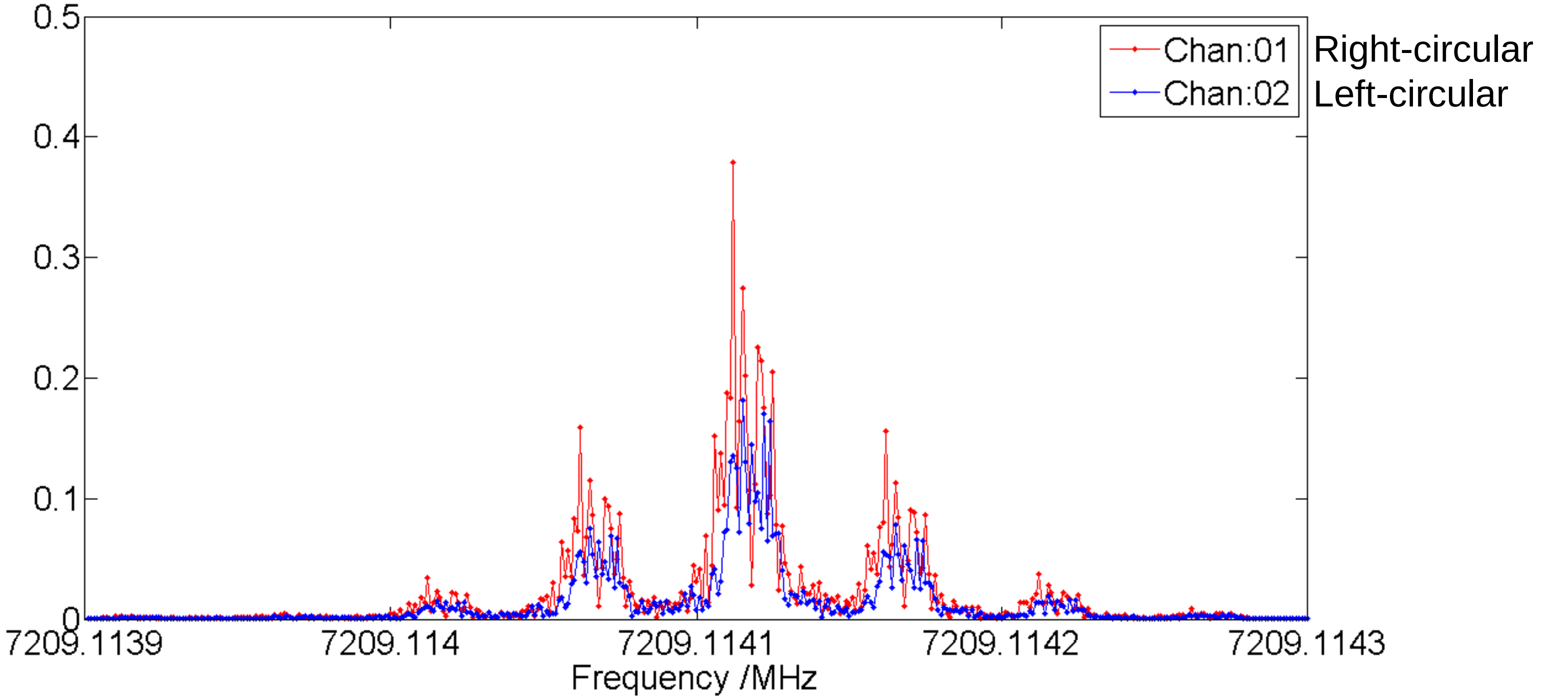
Transmitting	Receiving
JMS(65m)	JL(13m) SY(13m)
CW (500 w) Left-circular	Right-circular 32MHz, 2bit, Mark5B





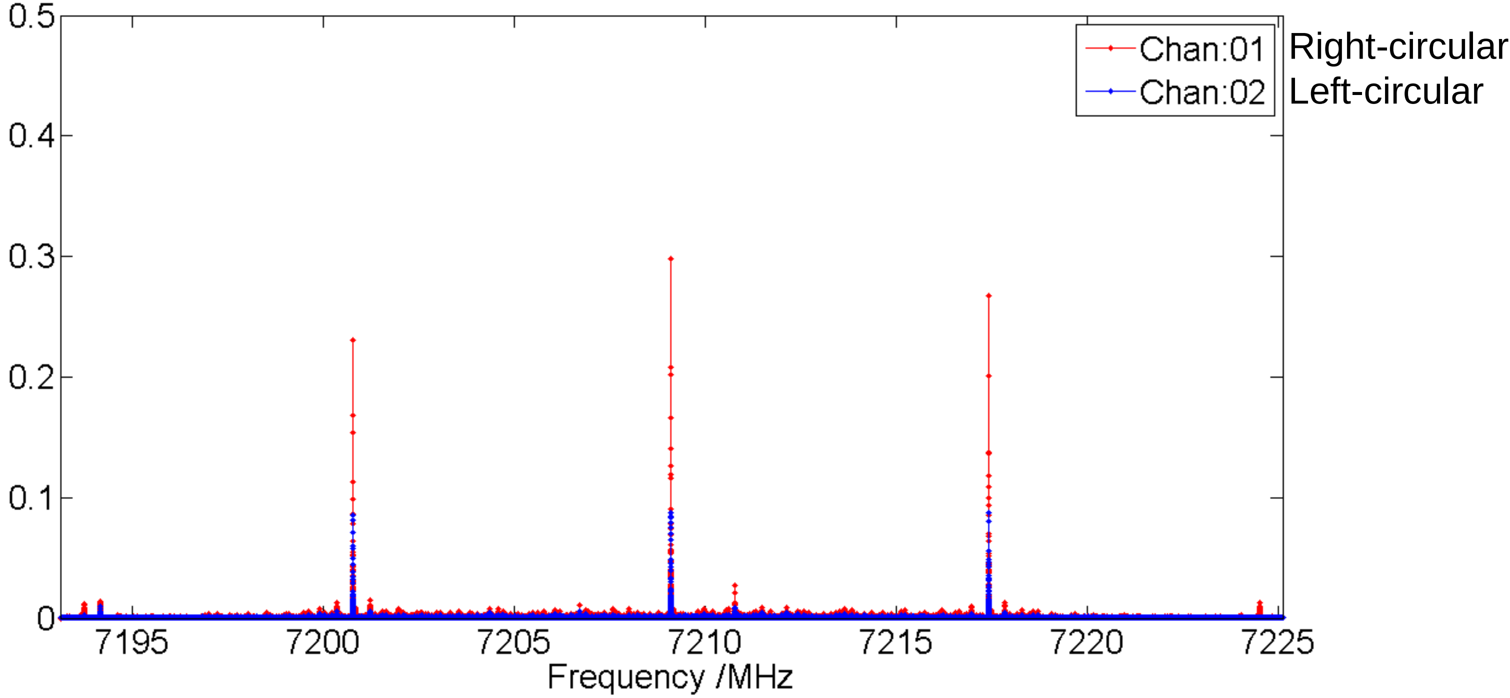
Testing experiments - 2

Transmitting	Receiving
JMS(65m) CW (6000 w) Left-circular	KM(40m) Left/Right-circular 32MHz, 2bit, Mark5B



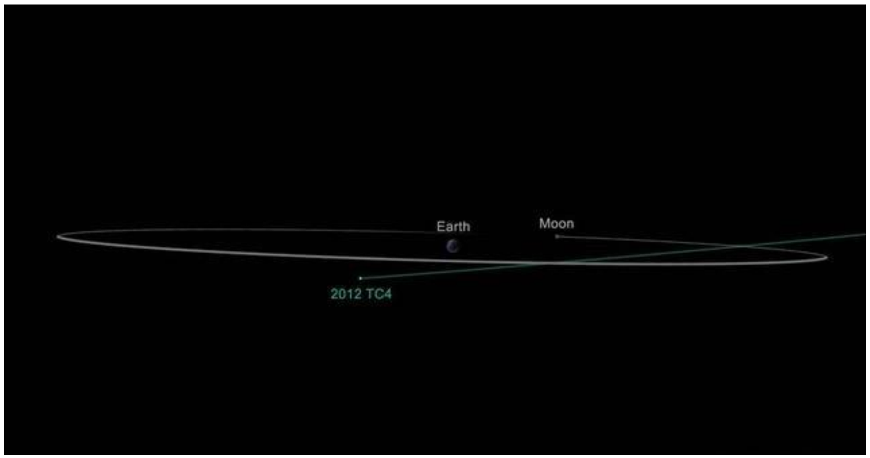
Testing experiments - 3

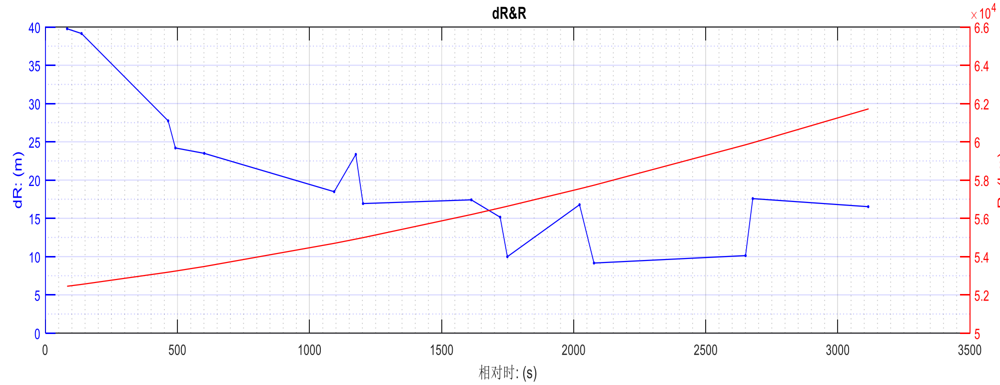
Transmitting	Receiving
JMS(65m) CW+T4B/T2B (6000 w) Left-circular	KM(40m) Left/Right-circular 32MHz, 2bit, Mark5B

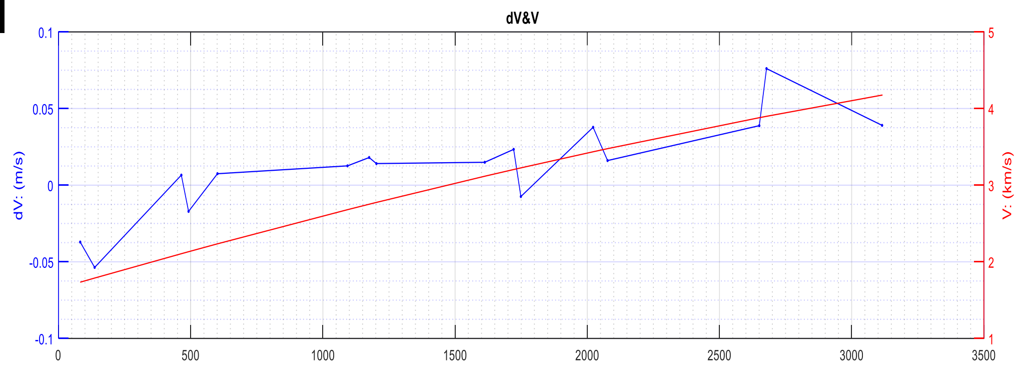


Testing experiments - 4

✓ Pulse echo from the asteriod 2012 TC4 received at station ML (40-m antenna)



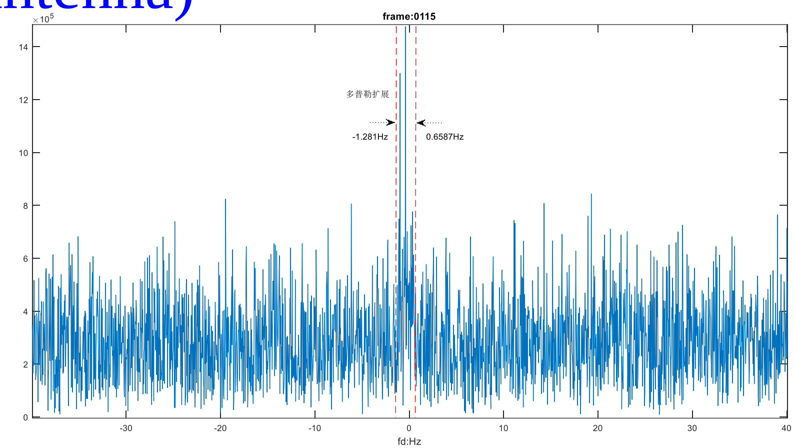


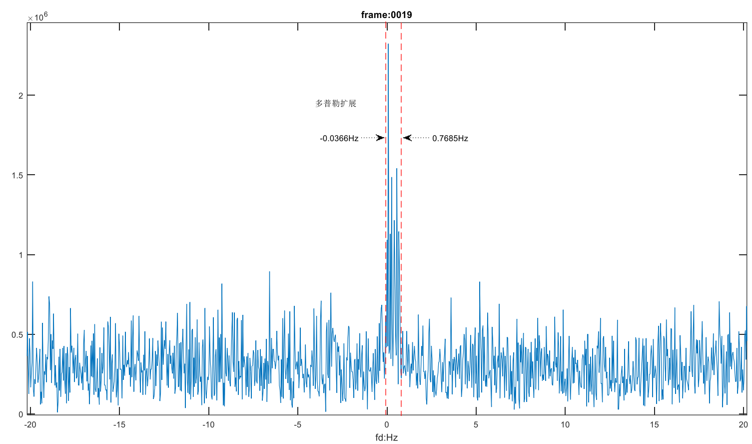


Predicted values of 2012 TC4 radial distance and radial velocity based on the ephemeris published by NASA JPL and its residual curves compared with radar measurements.

Testing experiments - 4

✓ Pulse echo from the asteriod 2012 TC4 received at station ML (40-m antenna)





1.396Hz ⟷ 10.54m

0.8051Hz ⟷ 4.38m

2012tc4.astro.umd.edu/2012TC4_properties.shtml

NEA 2012 TC4 –– Physical Properties

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2017 Apparition
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Observations
Orbit
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What is Known about 2012 TC4?

Because 2012 TC4 was only observed for seven days in 2012, little was known about its physical properties. With its 2017 recovery and close approach to the Earth, additional properties are being measured and reported here as they are announced.

The rapid rotation and lightcurve amplitude suggest that the 2012 TC4 is an elongated, monolithic body (a rubble pile would have spun itself apart). Non-principal axis rotation suggests that it probably has a complex (non-ellipsoidal) shape.

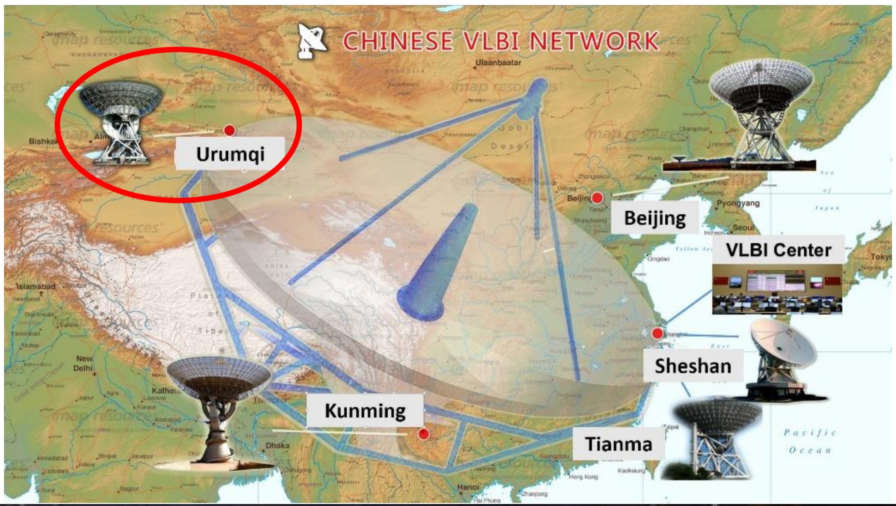
Physical Properties

Property	Value	Reference[1]
Effective Diameter	7-13 m from H=27.0, albedo 0.25-0.45	Ryan & Ryan, PDC 2017 conference results

Next steps

1. Cross-correlation in VLBI mode (CW + T4B/T2B)

2. QTT (more compatible with current and future radar facilities)



3. Construction of new transmitting radar antenna

Thanks for your attention!

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