Shape and Mutual Orbit of Near-Earth Asteroid Triple 3122 Florence

Sean Marshall[1] (presenting author, Sean.Marshall@ucf.edu),
Luisa Zambrano-Marin[1], Marin Ferrais[1], Marina Brozović[2], Jon Giorgini[2], Lance Benner[2],
Michael Busch[3], Shantanu Naidu[2], Patrick Taylor[4], Anne Virkki[5], and Flaviane Venditti[1]

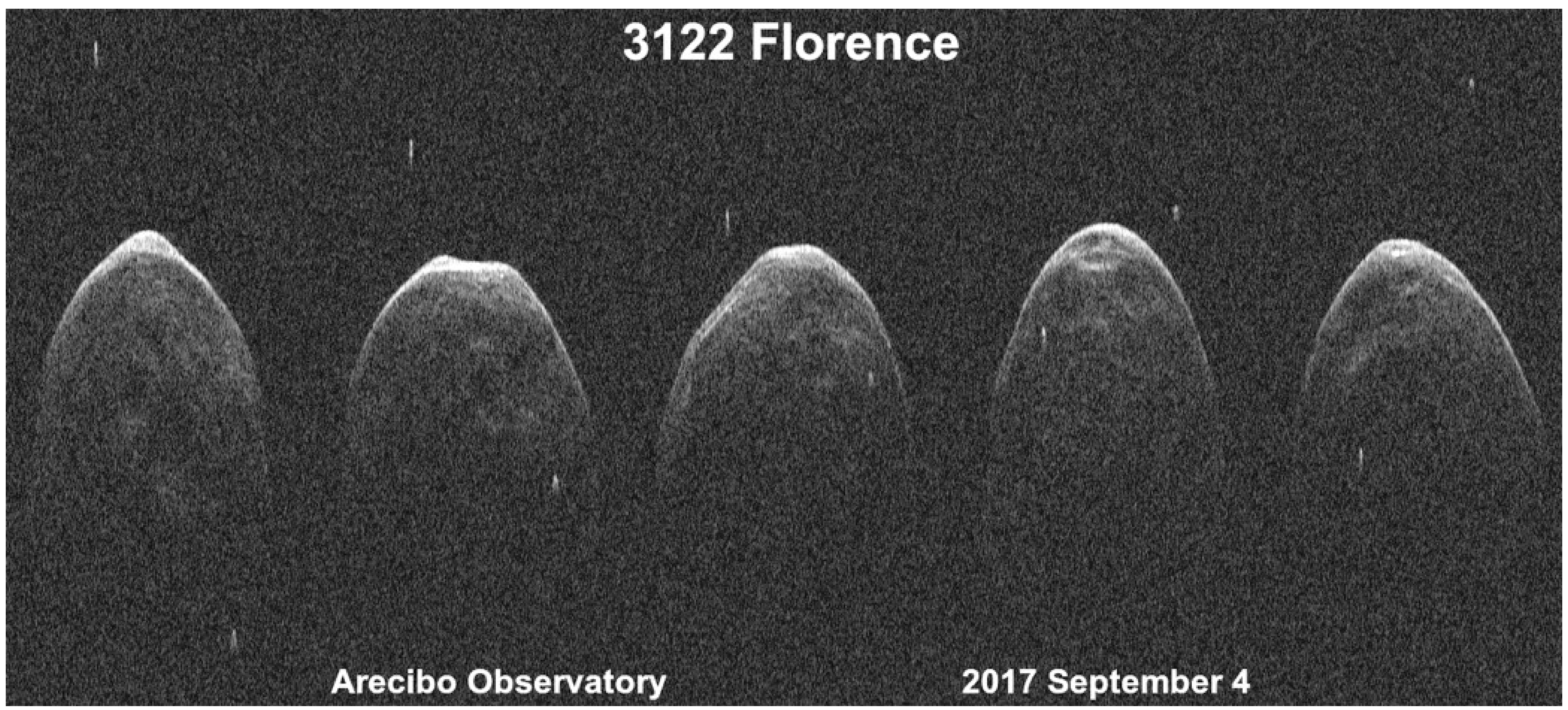
[1]Florida Space Institute, University of Central Florida, Orlando, United States of America
[2]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, USA
[3]SETI Institute, Mountain View, USA
[4]National Radio Astronomy Observatory, Charlottesville, USA
[5]University of Helsinki, Helsinki, Finland

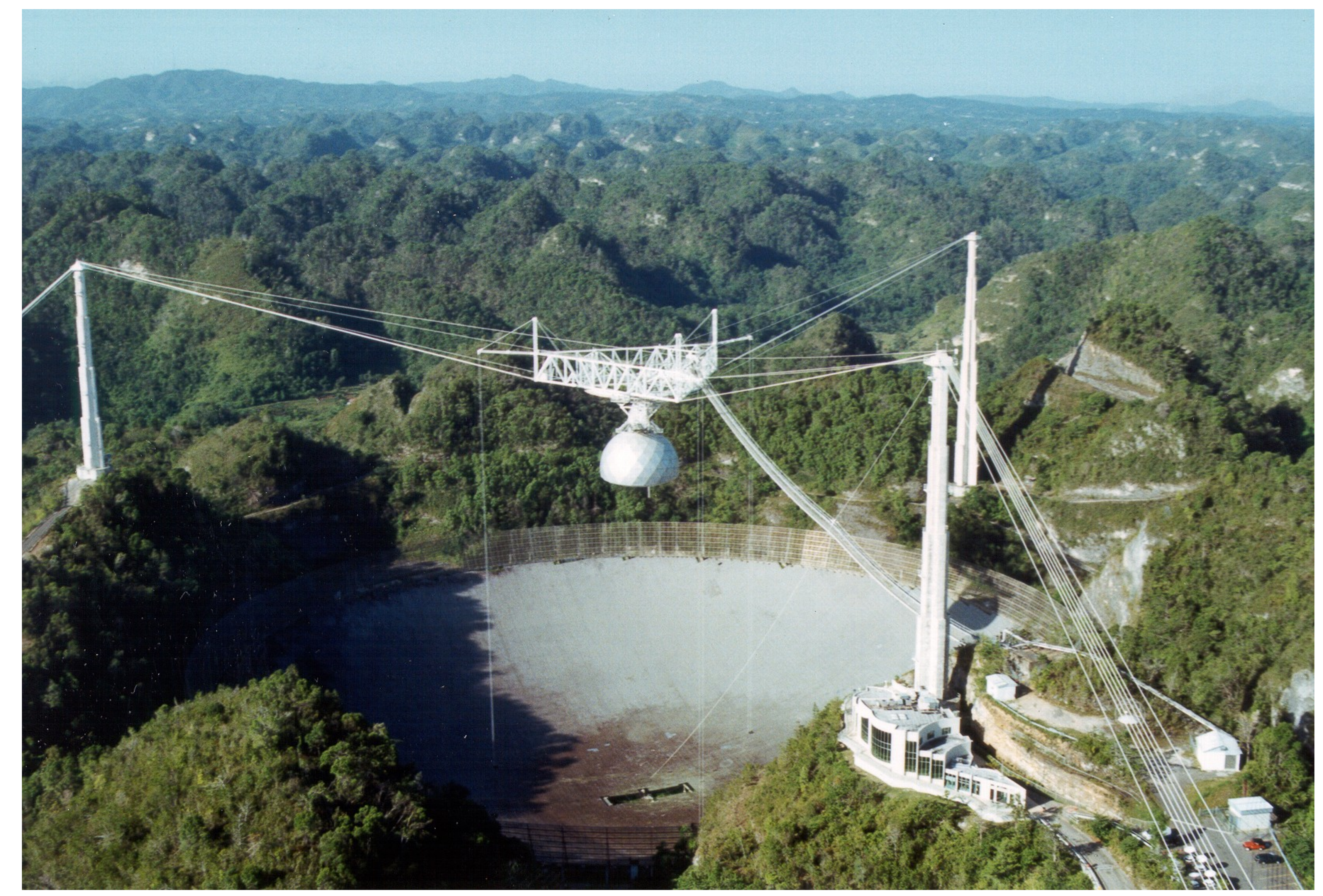
Partner

Observations

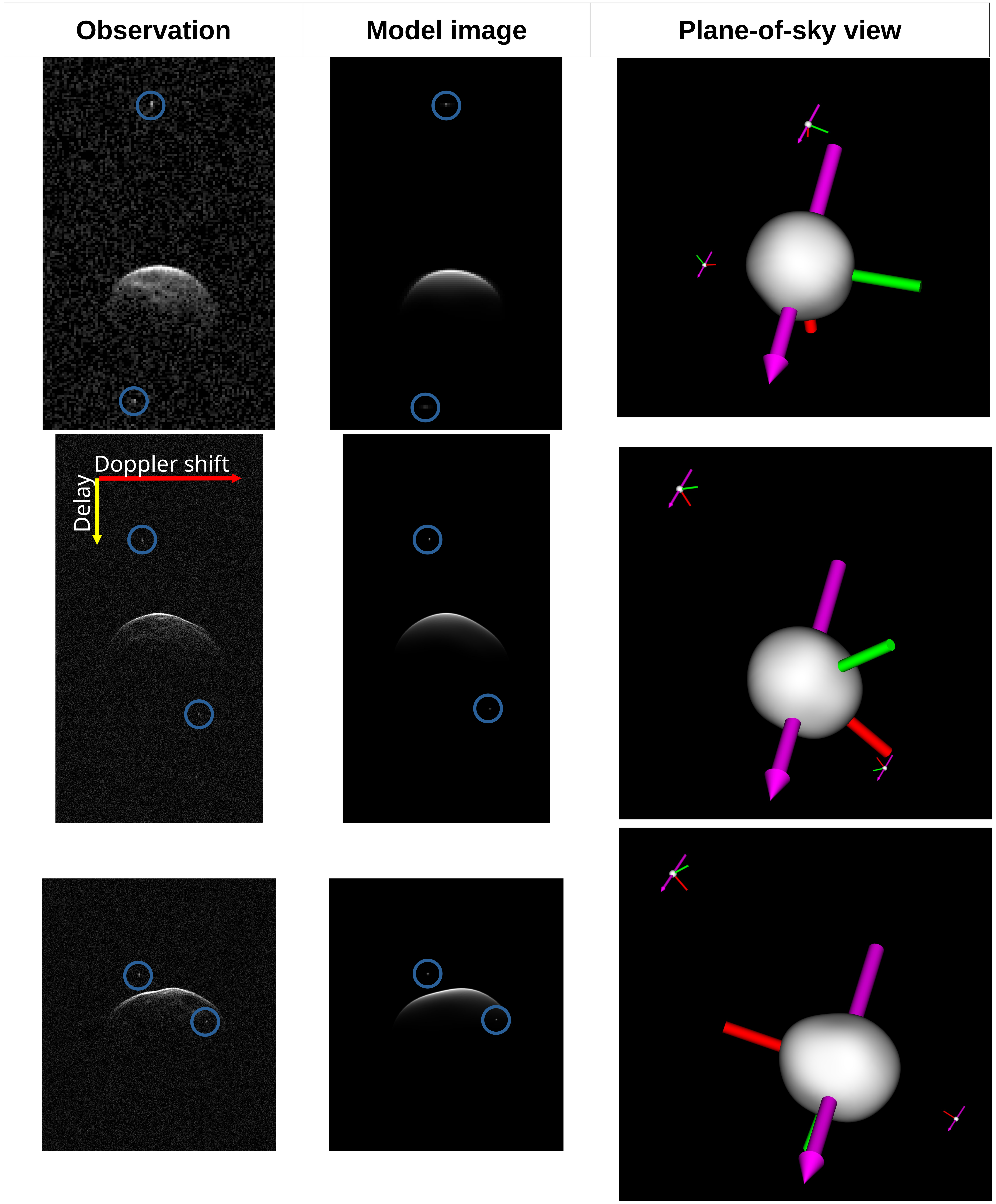
3122 Florence, a potentially hazardous near-Earth asteroid, made a very close approach in 2017. It passed just 18 lunar distances from Earth on September 1. It was observed with radar from the Goldstone Deep Space Communications Complex (8560 MHz, 3.5 cm) on 14 days between August 29 and September 13, with range resolution as fine as 75 m. It also was observed from Arecibo Observatory (2380 MHz, 13 cm) on 4 consecutive days, September 2 through 5, with range resolution as fine as 15 m.

The radar observations revealed that Florence is a triple system, with two satellites orbiting a much larger primary body. Florence is the largest of the five known near-Earth asteroid triples.





Given Florence's size and closest-approach distance, it was one of the best asteroid radar targets of the past decade. In particular, the Arecibo observations on the day of closest approach yielded a continuous-wave spectrum with a signal-to-noise ratio about 270 in just eight minutes of observations, and dozens of delay-Doppler images in which the primary is well resolved, with a clear signal in regions spanning hundreds of delay rows and hundreds of frequency channels. The radar observations covered a wide range of viewing geometries - about 90 degrees of sky motion.



Preliminary results

These images show three frames of radar data with the simulated views of our current best models. The left column shows the actual data. The middle column shows simulated delay-Doppler observations based on the model. The right column shows the corresponding plane-of-sky view of the models. In all delay-Doppler images shown on this poster, Doppler-shifted frequency is plotted along the horizontal axis, increasing to the right. Delay (range) is plotted along the vertical axis, increasing downward.

The original data had different delay resolutions, but all images have been stretched (along both axes) and cropped so that they are displayed at the same spatial scale. However, range is perpendicular to the plane of the sky. This stretching means that the original delay-Doppler pixels can appear rectangular here.

In the plane-of-sky frames, the magenta arrow shows the rotation axis, and the red and green shafts show the long and intermediate principal axes, respectively. (The short axis is aligned with the rotation axis.)

For the first stages of shape and orbit fitting, we are using SHAPE (Magri et al. 2007, *Icarus* 186) with only the Arecibo radar data. We are representing the primary as a sixth-order spherical harmonic and the satellites as spheres. We held the primary's rotation period constant at 2.358 hours and its rotation axis (pole) constant at ecliptic (164°, -86°), the values found from lightcurve inversion by Franco et al. 2018 (*Minor Planet Bulletin* 45-2).

The primary's average (volume-equivalent) diameter is 4.3 km.

The best-fit orbital pole direction for the outer satellite is ecliptic (77°, -79°). This is 12° from the primary's pole direction, but we have not yet investigated the pole directions carefully enough to reach a firm conclusion about whether either satellite is orbiting in the primary's equatorial plane, as is usually the case.

The inner satellite's pole direction is more uncertain. The best-fit pole direction was near (90°, -40°), but this seems too far from the other components' poles. Allowing nonzero eccentricity for the inner satellite yields much better fits. A circular orbit is sufficient for the outer satellite.

The best-fit orbital elements from our preliminary fits are given in the table below. Note that the inner satellite's orbital period, 7.3 hours, is the shortest known for any near-Earth asteroid binary or triple system (Brozović et al. 2024, *Planetary Science Journal* 5:123).

	Inner satellite	**Outer satellite**
Mean diameter	200 m	300 m
Orbital period	7.3 hr	21.7 hr
Semimajor axis	5.0 km	10.1 km
Orbital eccentricity	0.07	0 (assumed)

Acknowledgments: Arecibo's planetary radar program was fully supported by NASA's Near-Earth Object Observations Program in the Planetary Defense Coordination Office through grant 80NSSC19K0523 awarded to University of Central Florida (UCF). UCF managed the facility for the National Science Foundation under a cooperative agreement with Yang Enterprises Inc. and Universidad Ana G. Méndez. This grant also funds the current work at UCF. This research made use of the Stokes high-performance computing cluster at UCF's Advanced Research Computing Center.