Looking for Lurkers: Objects Co-orbital with Earth as SETI Observables

James Benford

*Microwave Sciences, 1041 Los Arabis Lane, Lafayette, CA 94549 USA*

jimbenford@gmail.com

**Abstract**

A recently discovered group of nearby co-orbital objects is an attractive location for extraterrestrial intelligence (ETI) to locate a probe to observe Earth while not being easily seen. These near-Earth objects provide an ideal way to watch our world from a secure natural object. That provides resources an ETI might need: materials, a firm anchor, concealment. These have been little studied by astronomy and not at all by SETI or planetary radar observations. I describe these objects found thus far and propose both passive and active observations of them as possible sites for ET probes.

1. **Introduction**

Perhaps one or more such alien civilization was drawn in recently, by radio signals emanating from our world. Or maybe it has resided in our solar system for centuries, millennia or longer. Alien astronomy at our present technical level may have detected our biosphere many millennia ago. Long-lived robotic lurkers could have been sent to observe Earth long ago. If properly powered, and capable of self-repair (von Neumann probes), they could report science and intelligence back to their origin over very long time scales. Long-lived alien societies may do this to gather science for the larger communicating societies in our galaxy.

I will call such a probe a ‘Lurker’, a hidden observing probe which may respond to an intentional signal and may not, depending on unknown alien motivations. (Here Lurkers are assumed to be robotic.)

Observing ‘nearer-Earth objects’ would explore the possibility that there are nearby ‘exotic’ probes that we could discover or excite.

1. **Lurker History**

Bracewell first advanced the *sentinel hypothesis*: that if advanced alien civilizations exist they might place AI monitoring devices on or near the worlds of other evolving species to track their progress. Such a robotic sentinel might establish contact with a developing race once that race had reached a certain technological threshold, such as large-scale radio communication or interplanetary flight [1].

Looking for such *Bracewell probes* offers a number of advantages over traditional SETI, which is listening to the stars. A probe located nearby could bide its time
while our civilization developed technology that could find it, and, once contacted, could undertake a conversation in real time. Meanwhile, it could have been routinely reporting back on our biosphere and civilization for long eras.

In 1974 Lunan hypothesized that a Bracewell probe was responsible for long-delayed echoes of early radio transmissions which were observed in the 1920s [2]. These delays were later found to be better explained as propagation phenomena in the earth magnetosphere. Such magnetospheric ducting is the best understood mechanism for long delayed echoes [3]. Papagiannis suggested searching for Lurkers in the asteroid belt [4].

In David Brin’s science-fiction novel *Existence*, Lurkers of several types and generations are residing in Earth orbit and the asteroids, where they have been for millions of years [5]. He also authored an “An Open Letter to Alien Lurkers” [6]. John Gertz made a case for probes instead of beacons for interstellar communicating and reviewed where they may be in our Solar System [7].

2. Co-orbital Objects

A promising location to search for Lurkers lies among the co-orbital objects, which approach Earth very closely annually at distances much shorter than anything except the moon. They have the same orbital period as Earth. These objects could be natural, such as asteroids which have wandered into this type of orbit for a period of centuries to millennia. Or the objects could be artificial in part or in their entirety. Artificial constructs could be noticed by spectroscopy in the visible or near infrared.

Some objects have unusual horseshoe orbits that are co-orbital with Earth. Sometimes these horseshoe objects temporarily become quasi-satellites for a few centuries, before returning to their earlier status (Figure 1). Both Earth and Venus have quasi-satellites, as well as most of the outer planets. Venus may have Trojans [8].
Fig. 1 Horseshoe orbit of 2010 SO16. E is location of Earth, S is the Sun, where the reference frame co-rotates with the Earth's orbit.

A *quasi-satellite* is an object in a 1:1 orbital resonance with a planet. This means the object stays close to that planet over many orbital periods. A quasi-satellite's period around the Sun is the same as the planet, but has a greater eccentricity. When viewed from the perspective of the planet, the quasi-satellite will appear to travel in an oblong retrograde loop around the planet (Figure 2).

They are not true satellites; they are outside the Hill sphere. (An astronomical body's Hill sphere is the region in which it dominates the attraction of satellites, meaning the Hill sphere approximates the gravitational sphere of influence on a small body by a more massive body.)
Fig. 2 Quasi-satellite appears to have an oblong orbit as seen from the planet.

Earth’s quasi-satellites have been discovered in the last decade; it’s likely that quite a few more will be found. They are in ‘horseshoe’ and ‘tadpole’ and ‘quasi-satellite’ orbits (Figure 3). Their orbits are stable for centuries or much longer. They are not Earth-crossing asteroids (Apollo asteroids), which follow far larger orbits and spend most of their time far from Earth.

Figure 3 Three types of co-orbital orbits.

Examples of co-orbitals:
• ‘Second moon of Earth’ Cruithne (3753), estimated size 5 km, closest approach to Earth 0.080 AU = 12 Mkm. [9]. Origin unknown, as it experienced close encounter with Mars 2500 years ago.

• ‘Earth Trojan’ (2010 TK7) at 0.3-0.5 km, oscillating about Sun-Earth Lagrangian point L4, so 0.81 to 1.19 AU from Sun, 21 degrees from elliptic in ‘tadpole’ orbit, closest approach 0.13 AU = 20 Mkm, 50 times Moon distance [10].

• ‘Earth’s Constant Companion’ 2016 HO3 (469219) is 40-100 m in diameter. It is currently the smallest, closest, and most stable (known) quasi-satellite of Earth. discovered in 2016. Minimum distance is 0.0348 AU = 5.2 Mkm [11].

• Other quasi-satellites are: (164207), (227810) 2006 FV35, 2013 Lx28, 2014 OL339, 2010 SO16 and (469219).

Figures 4-6 show aspects of their orbits. Figure 7 shows the orbits of several of these objects relative to Earth. Table 1 gives some of the key parameters of several of them. Other quasi-satellites are: (164207), (227810) 2006 FV35, 2013 Lx28, 2014 OL339, 2010 SO16 and (469219).
Fig. 5 Earth Trojan orbit [2010 TK$_2$].

Fig. 6 Orbit of 2016 HO$_3$. 
Figure 7 shows the orbits of several of these objects relative to Earth. Table 1 gives some of the key parameters of several of them.

Fig. 7 Orbits of several of these objects relative to Earth in geometric equatorial coordinates. From reference 10.
Table 1 Parameters of several co-orbital objects

| Name                          | Orbit Type | Size     | Closest Approach |
|-------------------------------|------------|----------|------------------|
| Cruithne 1986 TO              | Horseshoe  | 5 km     | 12 Mkm           |
| 'Earth Trojan' 2010TK9         | Tadpole    | 0.5 km   | 1.5 Mkm          |
| 'Earth's Constant Companion' 2016 HO3 | Tadpole    | 0.1 km   | 5.2 Mkm          |
| 2006 FV35                     | Horseshoe  | 0.14-0.32 km | 15 Mkm        |
| 2014 OL339                    | Tadpole    | 0.17 km  | 2.7 Mkm          |
| 2013 LX28                     | Horseshoe  | 0.13-0.3 km | 56 Mkm        |

3. SETI Searches of Co-orbital objects

Several approaches to study these objects, starting with passive observations:

1) Plan a multiyear program of observations by radio and optical telescopes and planetary radars around the world. Central to the project would be optical telescopes, such as the Lick Observatory and other platforms participating in the Breakthrough Listen project, to discern their size, shape, rotation periods, and optical properties, such as spectra. We would need to discern their optical spectra out to at least J-band (to 1.2 µ). A Bracewell probe could also give specular reflection of sunlight from its artificial surfaces [12].

2) Conduct passive SETI observations of these nearer-Earth objects.

3) Use active planetary radar to investigate the properties of these objects. These objects have not been pinged or imaged by any planetary radar as yet. Recent developments in planetary radars have shown they can detect the presence and trajectories of spacecraft in lunar orbit, even though their size is a few meters [13]. Whether these radars are sensitive or powerful enough to get a return signal from any of the presently known co-orbital objects requires analysis. In any case, they can "ping" the objects, meaning that a signal reaches there but the return signal may be too weak to detect at Earth. If there is an ET probe there, it might sense that it had been noticed by us. We could imprint a message on these signals.

4) Conduct active simultaneous planetary radar ‘painting’ and SETI listening of these objects. This would be ‘Active SETI’, which could solicit a response from a hypothetical probe. This does not incur the objections to sending interstellar messages, messaging to ETI (METI), because any such alien lurkers would already know we are here. Of course, this is at very short range compared to the interstellar ambitions of METI enthusiasts. We presume that Lurkers already know that we have
radar, but might not respond to a single simple radar painting such as we have done to many asteroids. If we want to send a message, as Paul Davies suggested for the Lagrange points in 2010, how would a signal be designed to elicit such a response? [14, 4]. This is the basic question of METI. Figuring out this near-term possible use of METI can drive discussion and research ideas in this field because it’s a concrete problem: what message would draw them out of their passive state to interact with us? One straightforward message to send would be a photograph of the object we are sending the message to. Taking the highest resolution pictures of it as it rotates would simply say “We see you.”

5) Launch robotic probes and manned missions to conduct inspections, take samples. Make First Contact? For example, 2016 HO3 at close approach had a relative velocity of 3-5 km/sec, so is within present capability. 2006 FV35 requires ~12 km/sec to rendezvous [15].

Perhaps probes are waiting on these objects, listening to us and waiting for us to find them. They may remain silent and simply report back to wherever they communicate to.

4. Not favored For Lurking Near Earth

There are several regions that a Lurker might locate. Here I describe several that are less promising than the co-orbitals.

- **Earth orbit**: Orbits near Earth are not stable over the long term; in geostationary equatorial orbit the satellite drifts out of this orbit because of perturbations such as the solar wind, radiation pressure, variations in the Earth’s gravitational field, and the gravitational effect of the Moon and Sun. This will happen within decades, unless thrusters are used to maintain the orbit: ‘station-keeping’. Geosynchronous orbits eventually get out of the plane, when fall to Earth in ~ 10 years. It would be very observable and I suspect they wouldn’t want to be seen too soon.

- **Lagrangian points**: The Earth-Moon L4 and L5 Lagrangian points contain only interplanetary dust in what are called Kordylewski clouds. At least one asteroid, 2010 TK7, detected in October 2010, oscillates about the Sun–Earth L4 Lagrangian point (~60 degrees ahead of Earth. See section 2.)

- **Moon**: The moon of course is the nearest object. From orbiters we have photographs of almost all the moon at resolutions of ~1 meter, and teams of people looking at them carefully. Nothing has been seen except our own artifacts we sent there. So then one would have to presume that they've built in a very disguised way. (As in 2001, where the Monolith was “deliberately buried”, to ensure that only a civilization capable of spaceflight would be able to discover it.) Moreover, if a probe is going to respond to us, it would surely have done so by now, by noticing the many transmissions that been made to
the moon for communications with our orbiters and landers.

- **Earth-crossing asteroids** (Apollo asteroids), which follow far larger orbits and spend most of their time far from Earth.

- **Asteroids**: Some of the swarm of asteroids in the Belt might be used by Lurkers, but have many drawbacks as a location: Of course, asteroids are much further away. And at several AU, the solar flux is reduced by a factor of 4-11. Therefore solar panels would have to be a very large. Nuclear powered systems would be preferred. (This is another reason to lurk near Earth: higher solar flux.) The asteroids are very cold for the same reason. That means that mechanical systems and electrical systems, as well as lubricants and everything associated with chemistry would be far more difficult to keep working over long times. However, there are potential reasons to lurk there: (i) availability of metal and volatile-rich materials, (ii) safety from orbital perturbations over much longer time scales ... tens or hundreds of millions rather than mere tens of thousands of years, (iii) opportunity to evaluate a new spacefaring culture in safety from discovery for longer periods.

5. Discussion

General Observations:

- The basic fact is we do not know alien logic, alien instinct, alien intention or anything else about them.
- The civilization that sent the probe may be very long-lived, meaning that individuals may live much longer than we do or that they are in fact AI's. If properly powered, and capable of self-repair (von Neumann probes), they could report science and intelligence back to their origin over very long timescales. Therefore, looking locally near Earth not only explores a new space, but also Deep Time [16].
- An overall reason to look closer to Earth is that we haven't seen anything in the rest of the solar system. And we haven't seen anything communicating from the nearby stars out to about 100 light years.
- To study these nearby objects changes the means of inspection from listening to the stars to astronomical diagnostics such as imaging and spectroscopy. This approach involves techniques well developed for the study of asteroids and planets. That means using other technologies and other institutions to pursue this search.
- This possibility allows a local test of messaging (METI) prospects. We can construct messages and try them against nearby objects, thus circumventing arguments that we might be noticed by or encourage hostile forces in the stars. The SETI and METI landscape is thus transformed into a local experiment. Many of the arguments against interstellar METI (e.g. drawing attention to ourselves) seem less compelling when it comes to attempted messaging of potential Lurker sites that are so close by, since such nearby Lurker will already know of us.
• Civilizations would not need to be very close to the solar system to send a probe here in the last few centuries. Here are some numbers: Suppose a probe can be launched at 1/10th speed light, which is certainly something we have figured out how to do conceptually by either beam-driven sails (photon beams, neutral particle beams) or nuclear fusion rockets. Traveling over 300 years, such probes could reach us from 100 light years out. About 3000 main sequence stars lie within 100 light years, so plenty of stars that might have civilization.
• For societies with time horizons beyond a century-long payoff, lower speeds like 0.01 c demand a millennium to take up residence and study Earth. Worlds that take even longer perspectives can use lower speeds and so lower their initial costs. Note that this implies that by searching locally, we extend our quest over both long distances in space and great spans in time, generalizing the entire SETI approach. Even alien societies that have ceased their interstellar interests or are even extinct can still tell us something, through their ancient probes.

What have we to lose by checking out these objects? Certainly resources such as time on telescopes, radio and optical. And funds. But we would be studying newly found objects, which could well be interesting astronomy. Nobody has really looked at these co-orbitals, other than orbital calculations and faint images. We know almost nothing about them.

6. SETI Reconsidered

In my view SETI has suffered from being seen as somewhat nonscientific. That's because it doesn't offer itself as a study with falsifiable propositions, which is the very definition of science, as Popper said. I advance a falsifiable proposition:

"There exist in near-Earth space extraterrestrial probes which are observing Earth and it may be possible for us to find and contact them."

This proposition can be disproved. It might be verified. We can observe them, ping them with radar, transmit messages to them, send robotic probes to them and visit them with human spacecraft missions.

Acknowledgements

Thanks to Dominic Benford, Gregory Benford, David Brin, Keith Cooper, Paul Davies, John Gertz, Paul Gilster, Al Jackson, Joe Lazio, Andrew Siemion and Marty Slade for comments.
References

1. R. N. Bracewell, "Communications from Superior Galactic Communities," Nature, 186, pg. 670, 1960. Reprinted in A.G. Cameron (ed.), Interstellar Communication, W. A. Benjamin, Inc., New York, pg. 243, 1963.]
2. D. Lunan, Man in the Stars, London Souvenir Press 1974. Published in the US as Interstellar Contact, Henry Regnery Chicago, 1975.
3. R. J. Vidmar and F. W. Crawford, "Long-delayed radio echoes: Mechanisms and observations," Journal of Geophysical Research, 90, pg. 1532, 1985.
4. M. D. Papagiannis, “Are We Alone, or Could They be in the Asteroid Belt?”, Quarterly Journal of the Royal Astronomical Society, 19, pg. 277, 1978.
5. D. Brin, “Existence”, Tor Books, New York, 2012.
6. D. Brin, “An Open Letter to Alien Lurkers”, Invitation to ETI, http://www.ieti.org/articles.brin.htm. (Posted March 1999, last Accessed 9 March 2019).
7. J. Gertz, “ET Probes: Looking Here as Well as There”, JBIS 69, pg. 88, 2016.
8. P. Pokorný and M. Kuchner, “Co-orbital Asteroids as the Source of Venus’s Zodiacal Dust Ring”, Apj Lett., 843, L16, 2019.
9. P. A. Wiegert, K. A. Innanen and S. Mikkola, “An asteroidal companion to the Earth”, Nature, 387, pg. 685,1997.
10. A. Mainzer, J. Bauer, T. Grav and 32 coauthors, “Preliminary Results from NEOWISE”, Apj, 731, 53, 2011.
11. C. de la Fuente Marcos and R. de la Fuente Marcos, "Asteroid (469219) 2016 HO3, the smallest and closest Earth quasi-satellite", Monthly Notices of the RAS, 462, 2016.
12. B. C. Lacki, “A Shiny New Method For SETI: Specular Reflections From Interplanetary Artifacts”, arXiv: astro-ph/1905.05839v1, 14 March 2019.
13. Brozovic et al., “Radar Observations of Spacecraft in Lunar Orbit”, ISTS-2017
14. P. Davies, The Eerie Silence, pg. 107, Houghton Mifflin Harcourt, 2010.
15. G. Stacey and M. Conners, “Delta-v requirements for earth co-orbital rendezvous missions”, Planetary and Space Science, pg. 822, 2009.
16. G. Benford, Deep Time: How Humanity Communicates Across Millennia, Avon Books, 1999.