Asteroidal Satellites

Establishing their existence

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Historical context

- 1977-1982. 5 claims to satellites. Most were visual observations. Initial disbelief. Searches with large aperture (2+m) telescopes + Hubble found nothing - no confirmation.
- For next 40 years, any suggested occultation discoveries disbelieved
- Changes started in 2021 with the occultation discovery of (45337) Arecibo. That was initially treated with great skepticism, but was confirmed with a subsequent detection. The Gaia data was analysed, and a basic orbit was determined.
- Since then, another 5 discoveries (two still to be formally announced)
- The historical skepticism is (hopefully) waning.

Effect of history

- The historical context means we cannot afford to make a claim to a satellite without adequate justification. A false satellite claim would simply bring back past attitudes of occultation discoveries being unreliable
- Consequence is a rigorous review process

The simple test for the discovery of an asteroidal satellite

- …. there isn't one
- The methodology is to exclude every other plausible explanation
- Possible explanations that need to be considered vary from one event to the next
- Future events may require considerations not thought of in this presentation

Consideration #1
Double star

- The primary consideration for all possible discoveries
- If the Light curve drops are not to the same level (consistent with noise and possible Fresnel diffraction issues), the explanation is a double star

Double star (ii)

- A double star with equal components will give a light drop for each component of 0.75 mag
- To exclude this, need to establish the mag drop is >0.75. Allowing for noise etc, a drop of 1.0 or more is desirable.
- *If your recording does not go down to at least 1.0 mags fainter than the target star, you will be unable to claim a satellite discovery from your recording.*

Double star (iii)

- Best way of establishing mag drop requirements. Include in the avi measurement comparison stars of known brightness that are more than 1 mag fainter than the target, with the light curve plot showing the target dropping below the comparison stars

Double star (iv)

- If star is faint, and disappears during the occultation, need to establish the limiting magnitude is 1.0 mags or more fainter than the star
- *Cannot reliably do this with light curves*
- Carefully inspect the recording to find the faintest stars that are consistently visible
- Need to make sure the stars have a similar ‘color’ to the target star. That is, the difference between the V magnitudes , and the difference between the R magnitudes (or B magnitudes) are similar.

Double star (v)

- If predicted mag drop is less than ~2, brightness of the asteroid needs to be taken into account
- In practical terms, asteroid satellites cannot be discovered in low mag drop events.

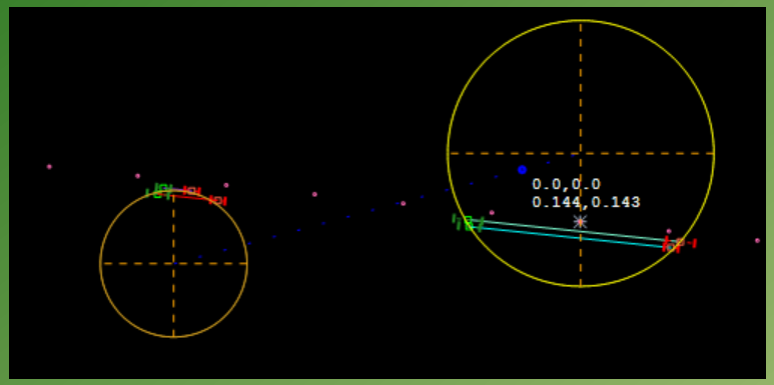
Grazing occultation

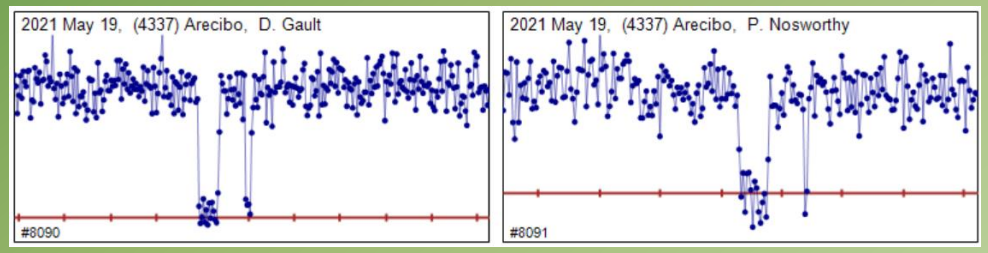
- Is the spacing of the two chords broadly compatible with the NEOWISE/Akari AcuA/IRAS diameters of the asteroid, allowing for plausible elongation of the body
- Is the required ellipticity of such a body compatible with known light curve brightness variations of the asteroid. Is there is a DAMIT shape model; if so, does it indicate the required ellipticity. Does the raw NEOWISE data indicate the required ellipticity

Single events by spaced apart observers

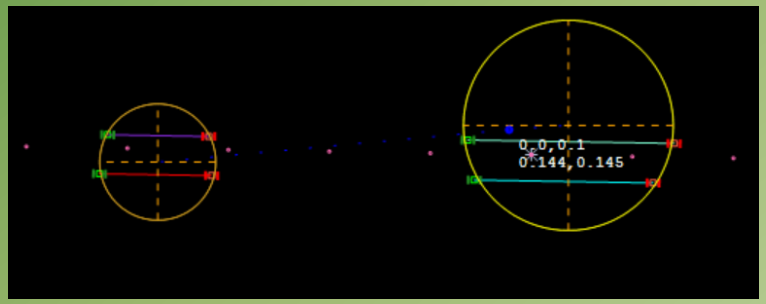
- What is the spacing between the two chords?
- For an explanation of single body causing the event, is the size of that body broadly compatible with the NEOWISE/Akari AcuA/IRAS diameters of the asteroid
- Is the required ellipticity of such a body compatible with known light curve brightness variations of the asteroid. Is there is a DAMIT shape model; if so, does it indicate the required ellipticity. Does the raw NEOWISE data indicate the required ellipticity

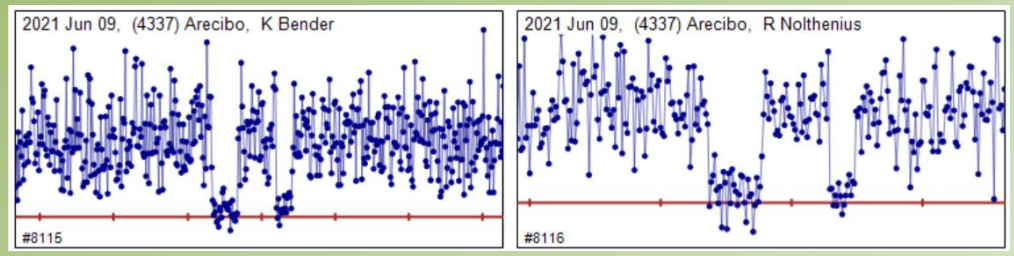
(4337) Arecibo





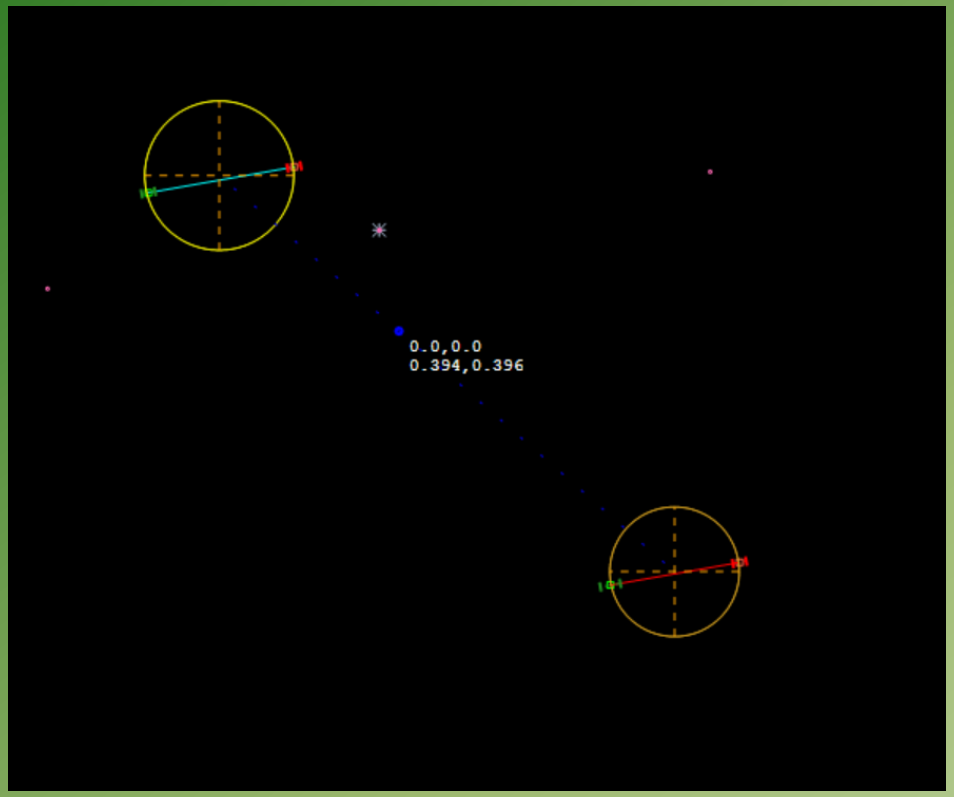
The relative positions of the short and long chords on the two bodies excludes a graze. Light curve drops the same, and much greater than 0.75. An extremely elongate asteroid (for a graze) is incompatible with known light curve variations



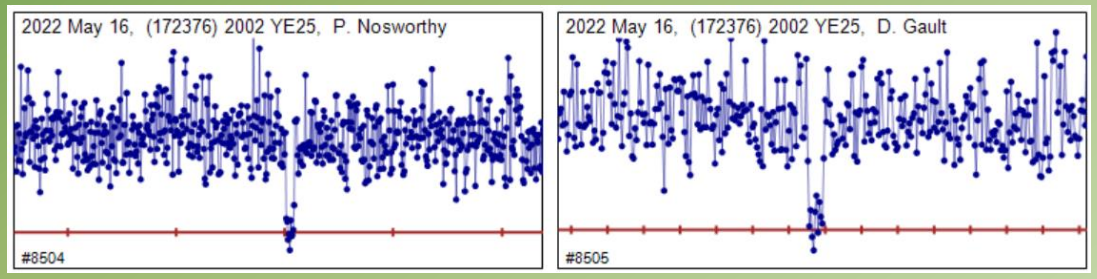


The wide spacing between the chords on each body excludes a graze

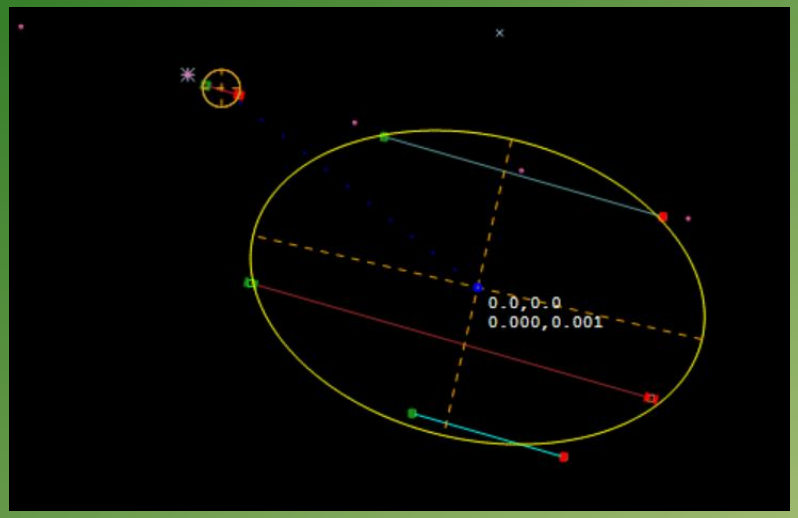
172376 2002 YE25

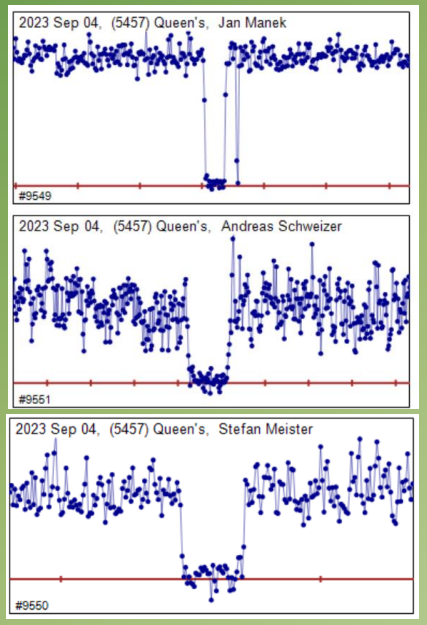


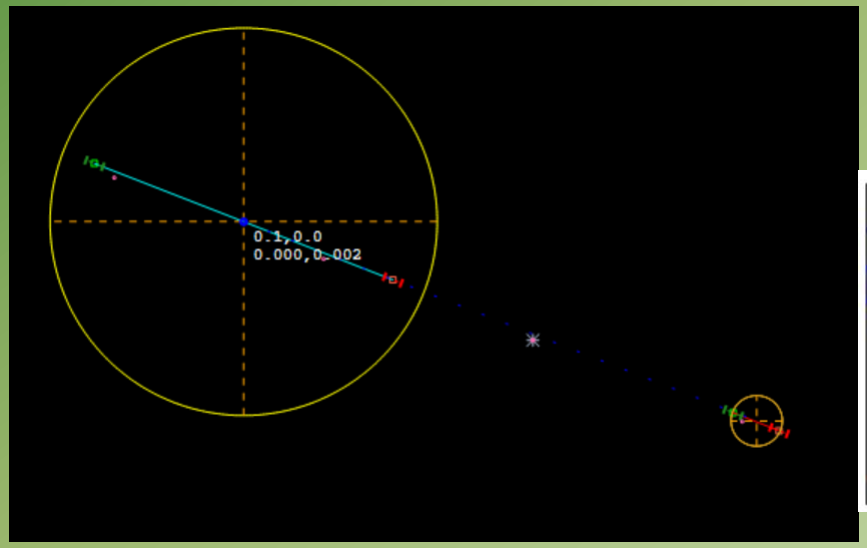
- Same light curve drop (to background) Drop >>0.75. Separation of the chords incompatible with diameter of asteroid and any plausible elongation.

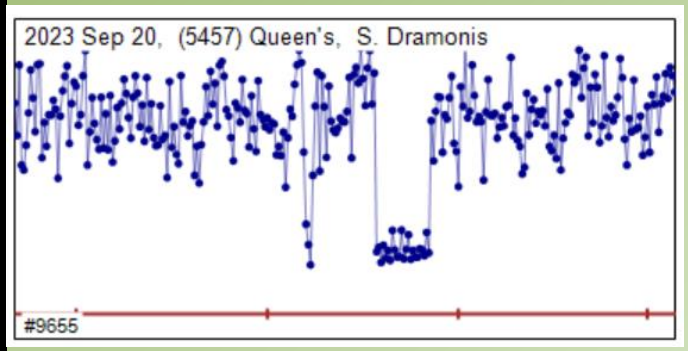


5457 Queen's





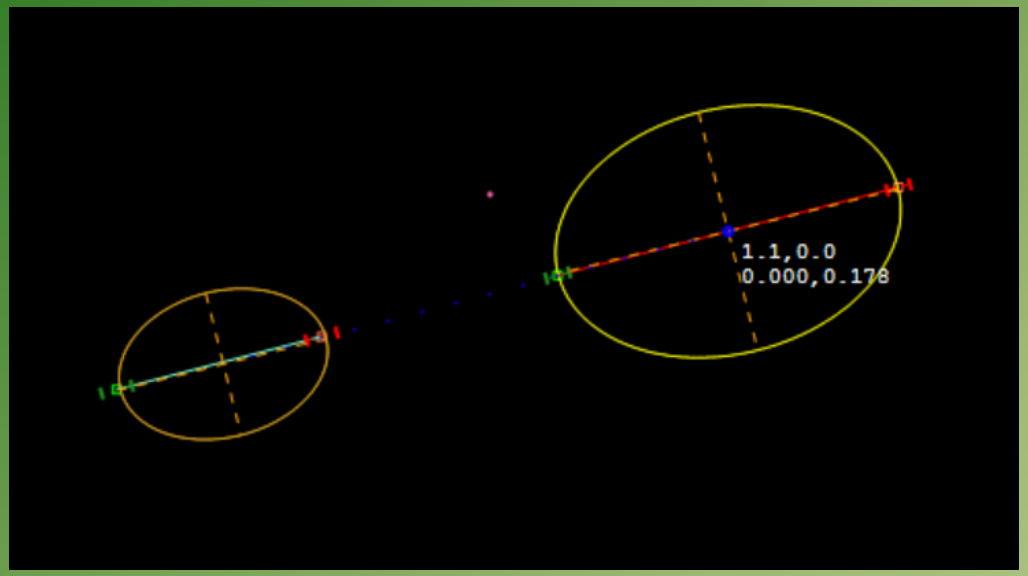




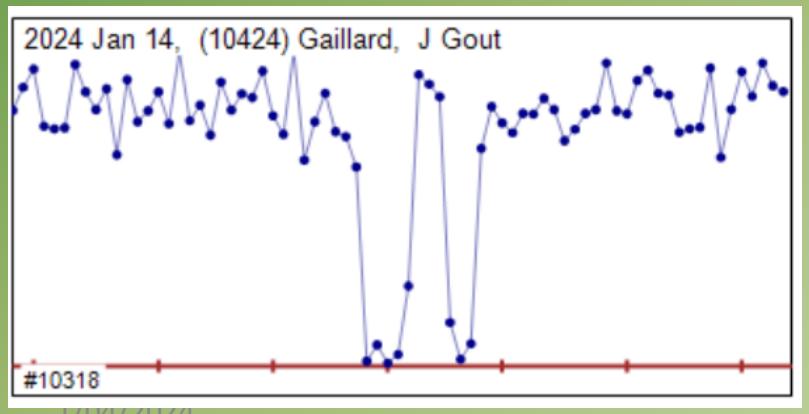
- Light drop the same, & >1.
- Neither are compatible with grazes

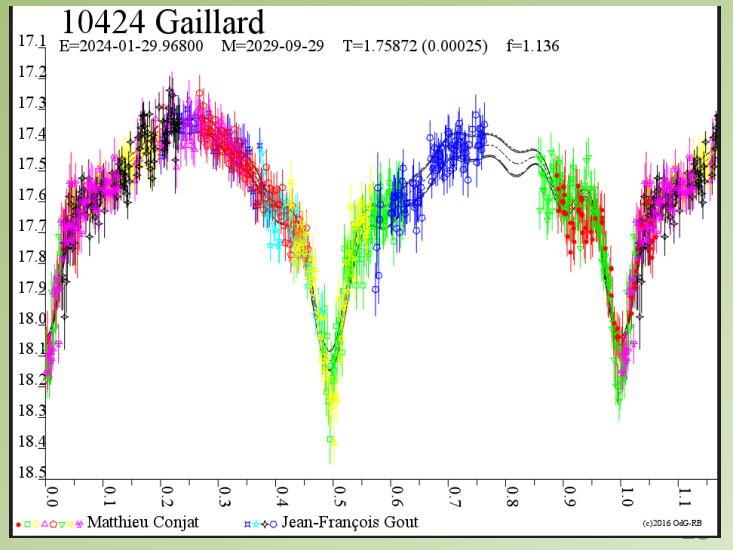
42.18 +/- 0.02 hr,

(10424) Gaillard

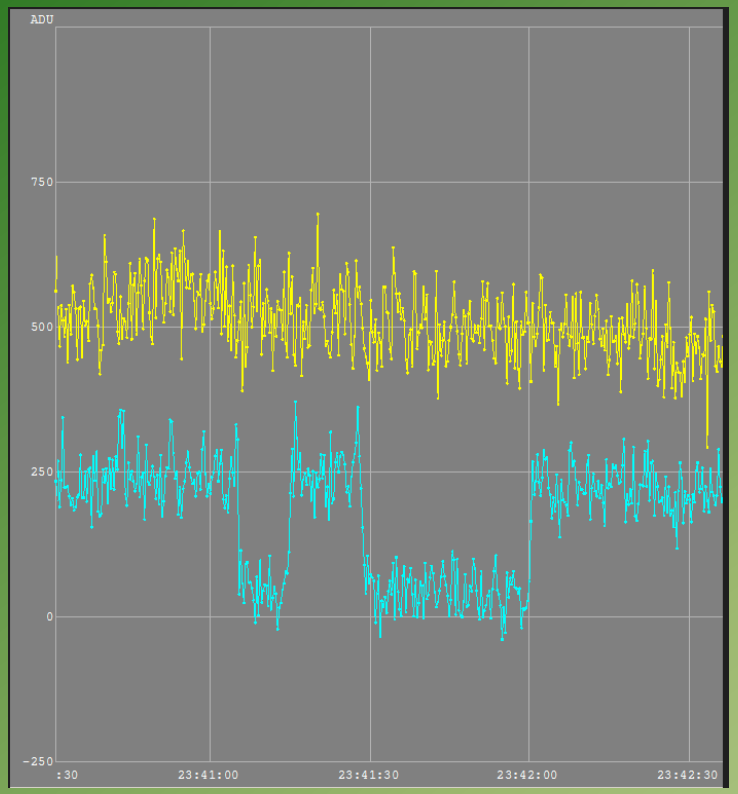


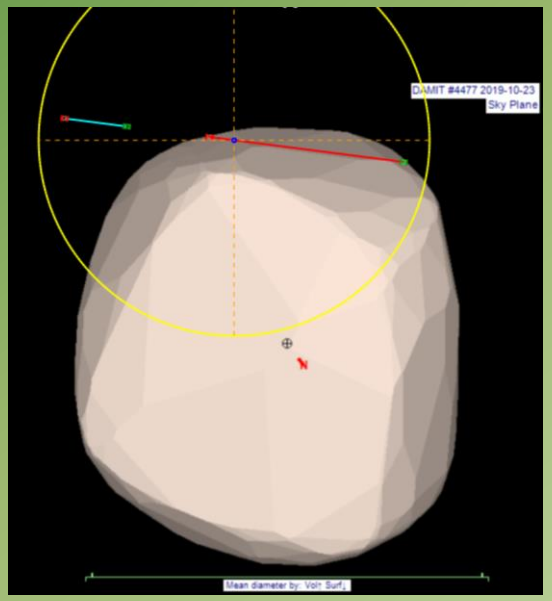
- Single observer discovery
- Separation too large for graze
- Subsequent dense light curve measurements confirmed binary, and established a period of 42.18 ±0.02 hrs, and ratio of the size of the bodies

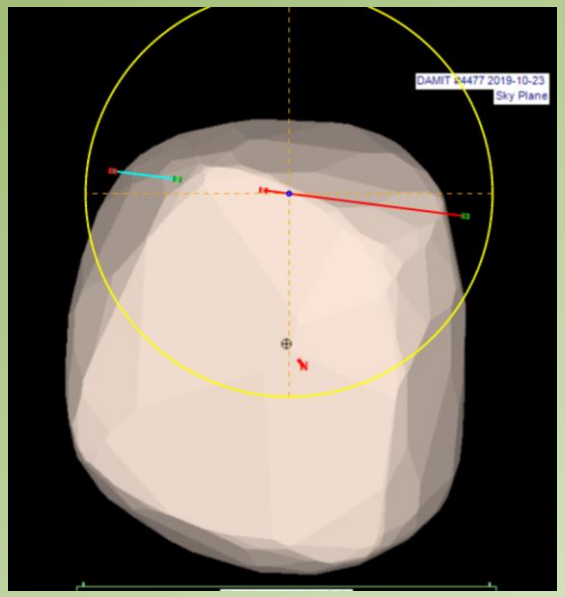




(1180) Rita







Low quality shape model. No dedicated light curves

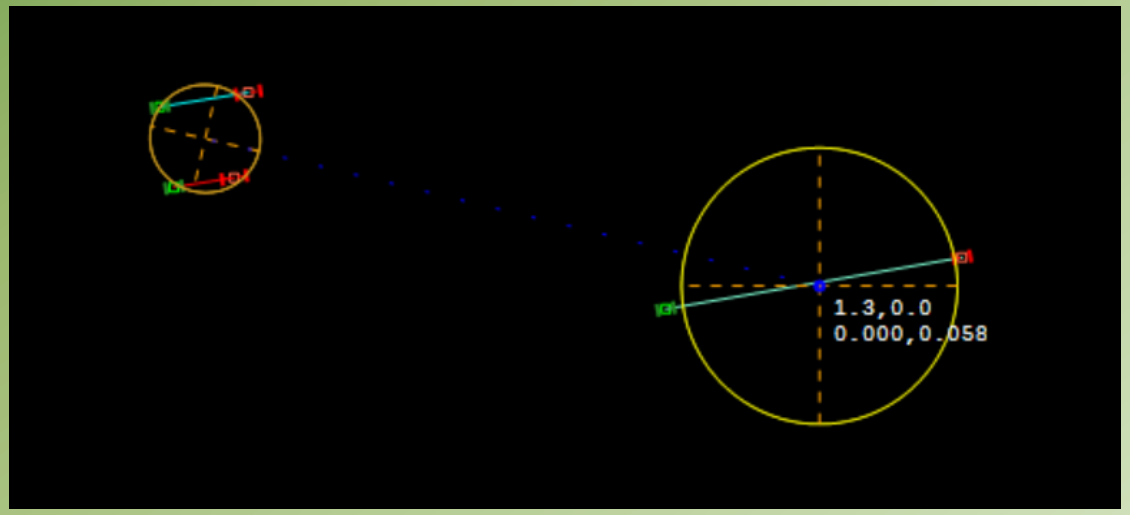
Super-critical factor. Orientation of axis directly toward observer. Which means orbit is face-on. Orbit will be circular. No plausible orbit

5232 Jordaens

- Analysis being finalized
- 3 observers. All with a single event. 1 chord across one body. 2 chords across the other body.
- All mag drops >1

(100624)1997 TR28

- Analysis finalized but not yet reported
- Transcontinental event – Europe + Japan
- Main issue – determining the limiting magnitude to exclude a double star explanation



Statistics of the discoveries

Asteroid	A	B	sepn	[A, B & sepn in km]
4337 Arecibo	24,	14	48	
5232 Jordaens	10,	10	47	
5457 Queens	25,	2	20	
10424 Gaillard	4,	3	7	
100624 1997 TR28	10,	4	24	
172376 2002 YE_25	4,	3	18	

- Separations at discovery less than about 4 diameters of the primary

Any questions?