How to measure the flux of large meteoroids?

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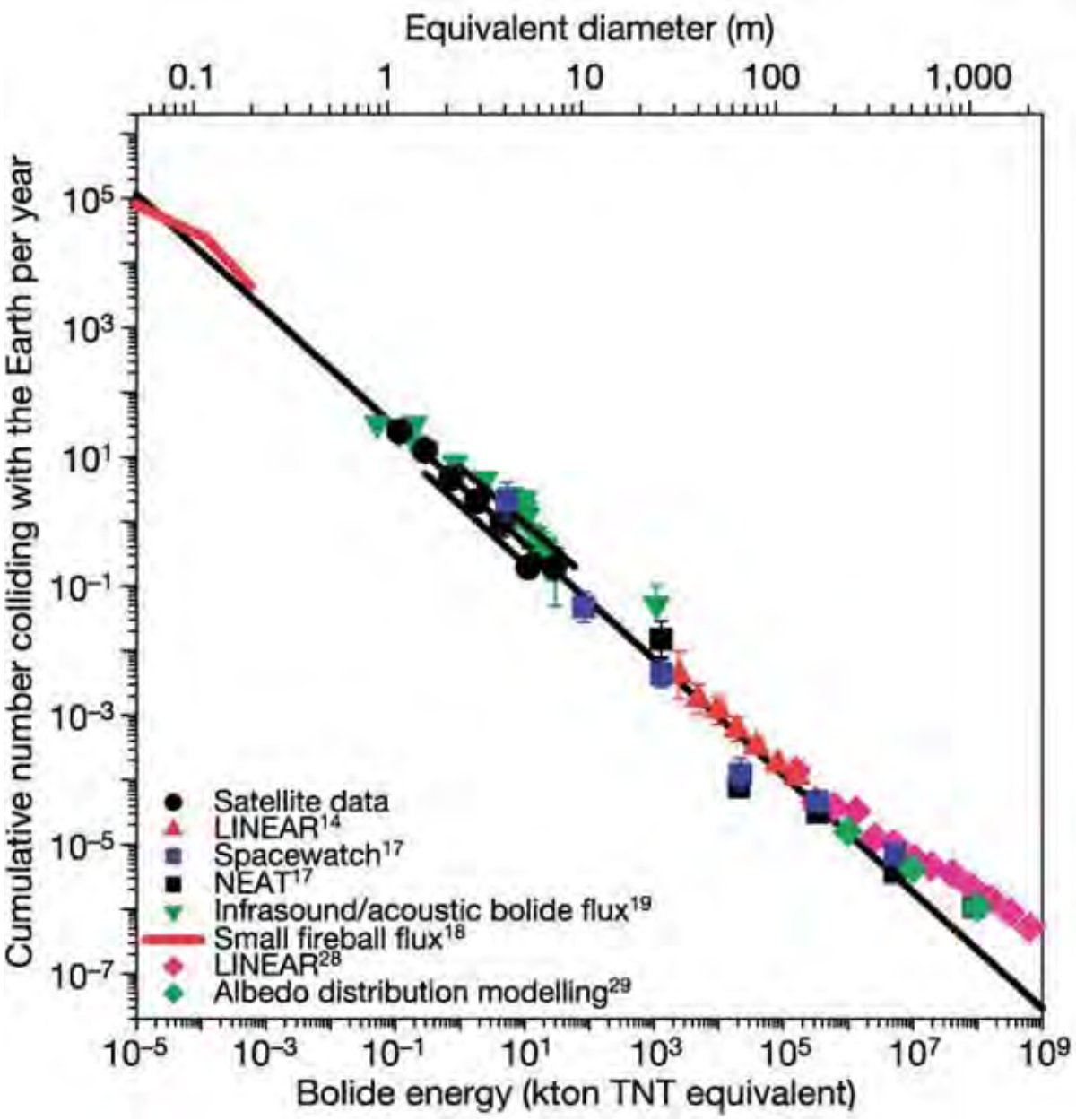
International Meteor Conference 2012

I don’t know.

But it’s a good question!

The frequency of small bodies colliding with Earth (Brown et al. 2002)



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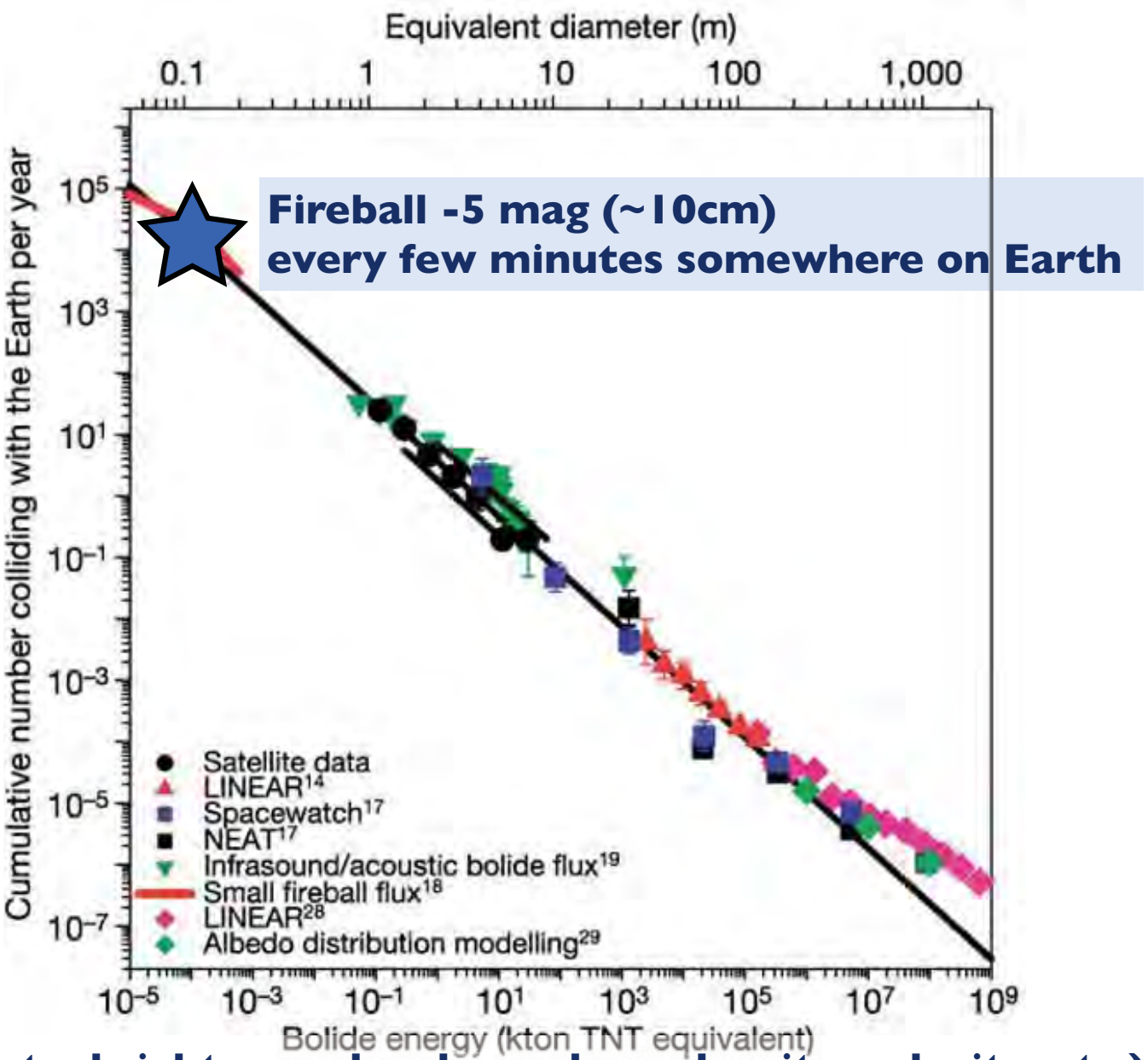

(Note: brightness also depends on density, velocity, etc.)

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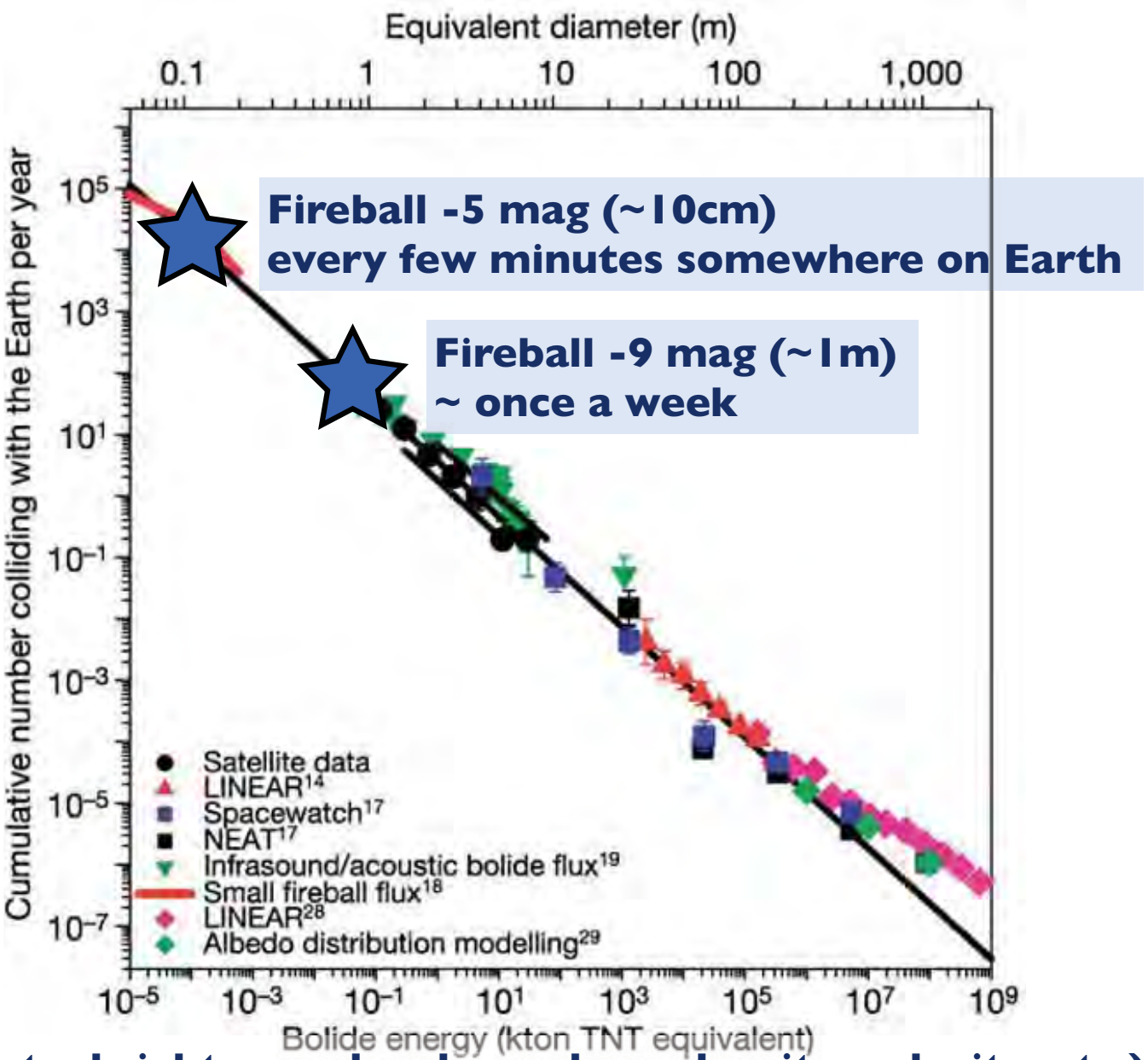

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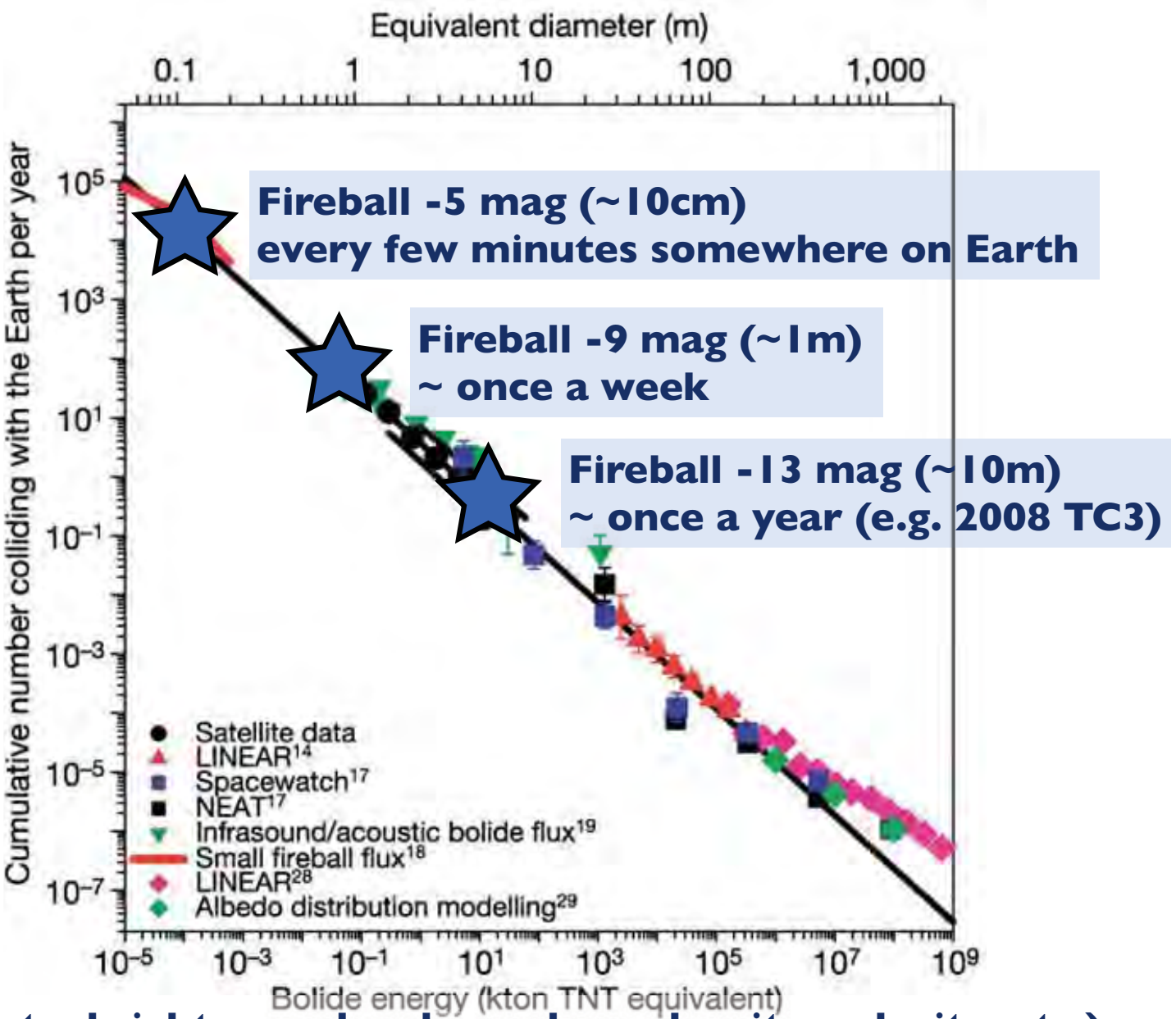

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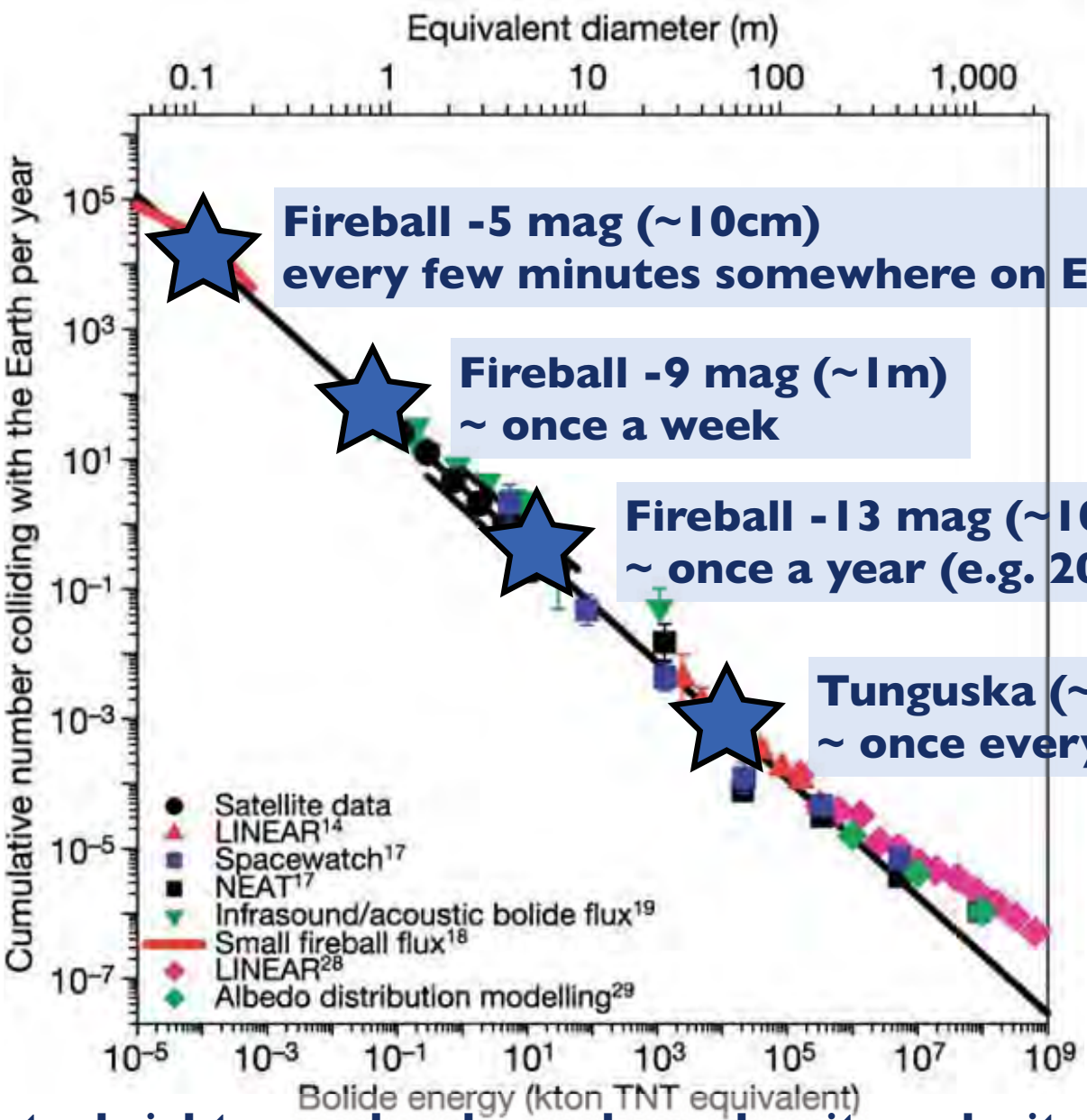

Fireball -5 mag (~10cm)
every few minutes somewhere on Earth

Fireball -9 mag (~1m)
~ once a week

Fireball -13 mag (~10m)
~ once a year (e.g. 2008 TC3)

Tunguska (~50m)
~ once every 1000 years?

(Note: brightness also depends on density, velocity, etc.)

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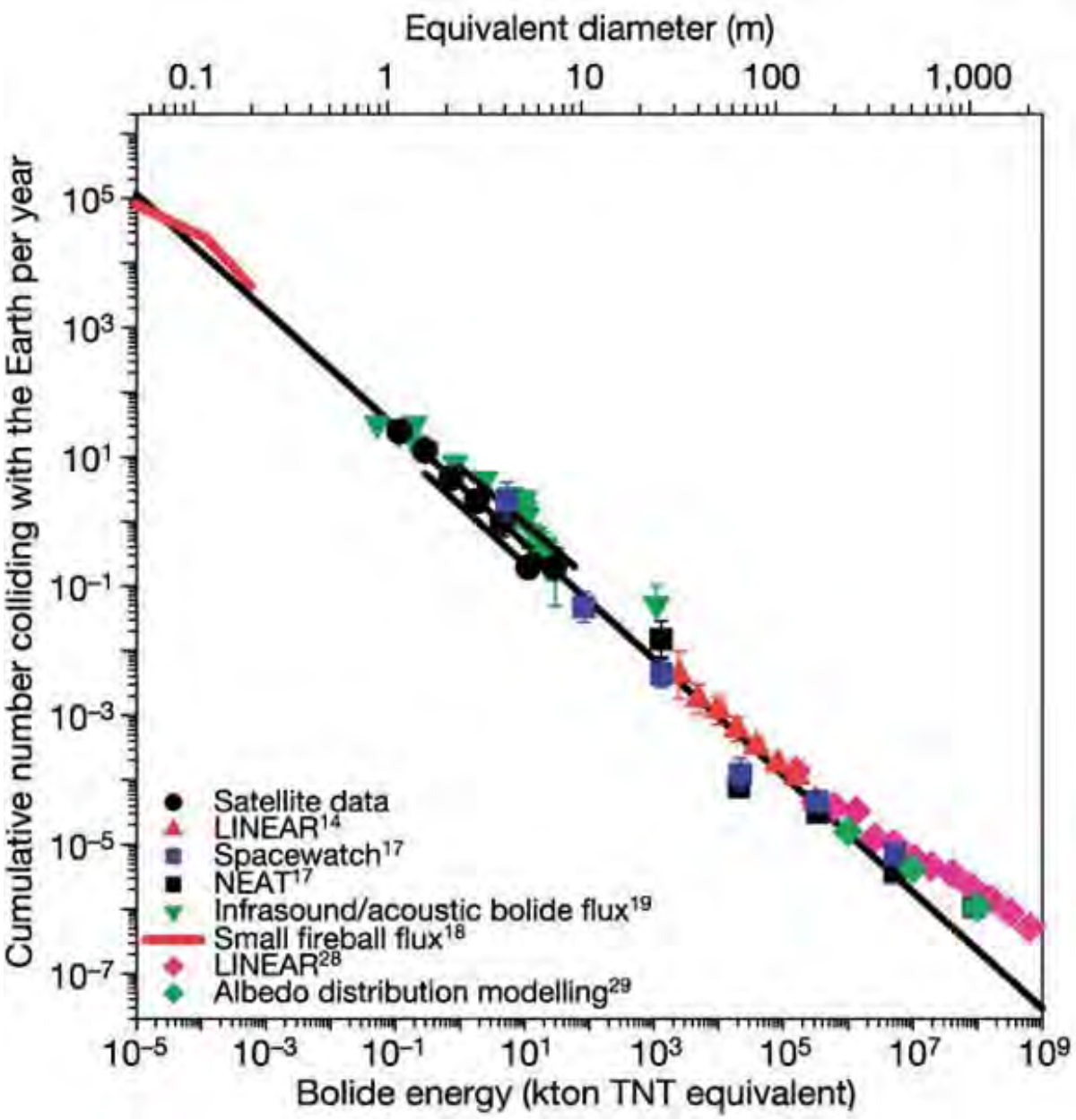

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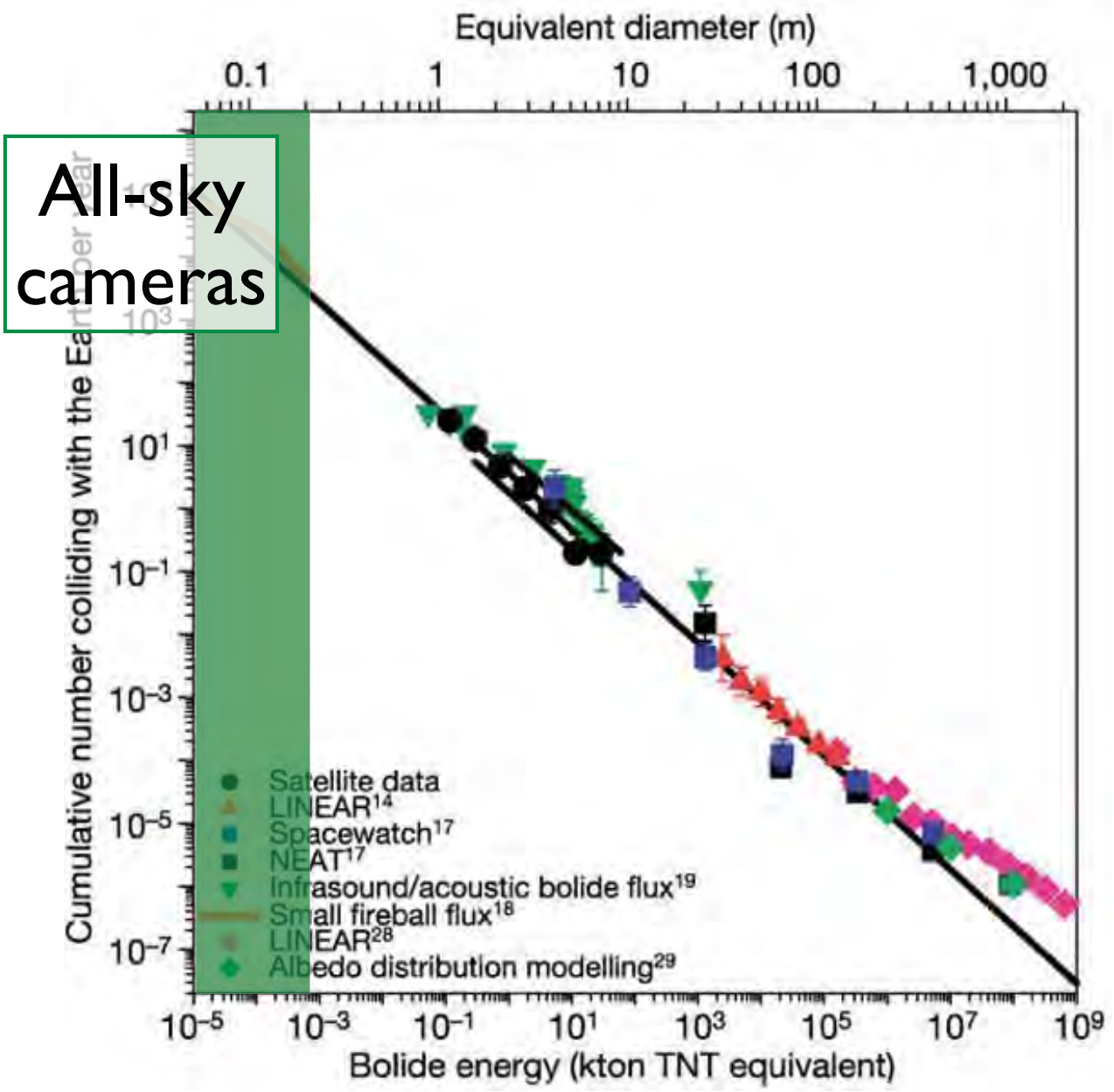

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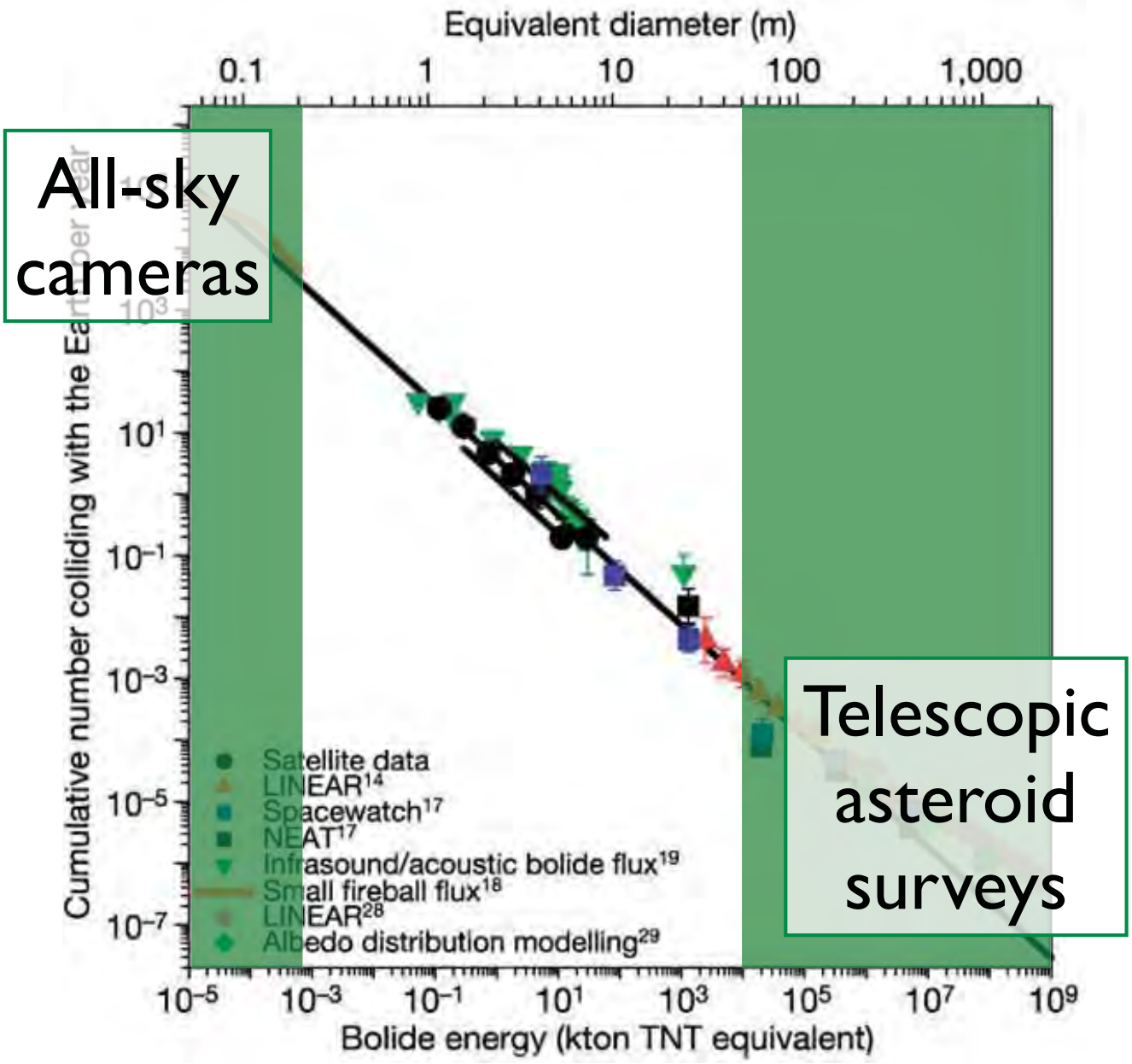

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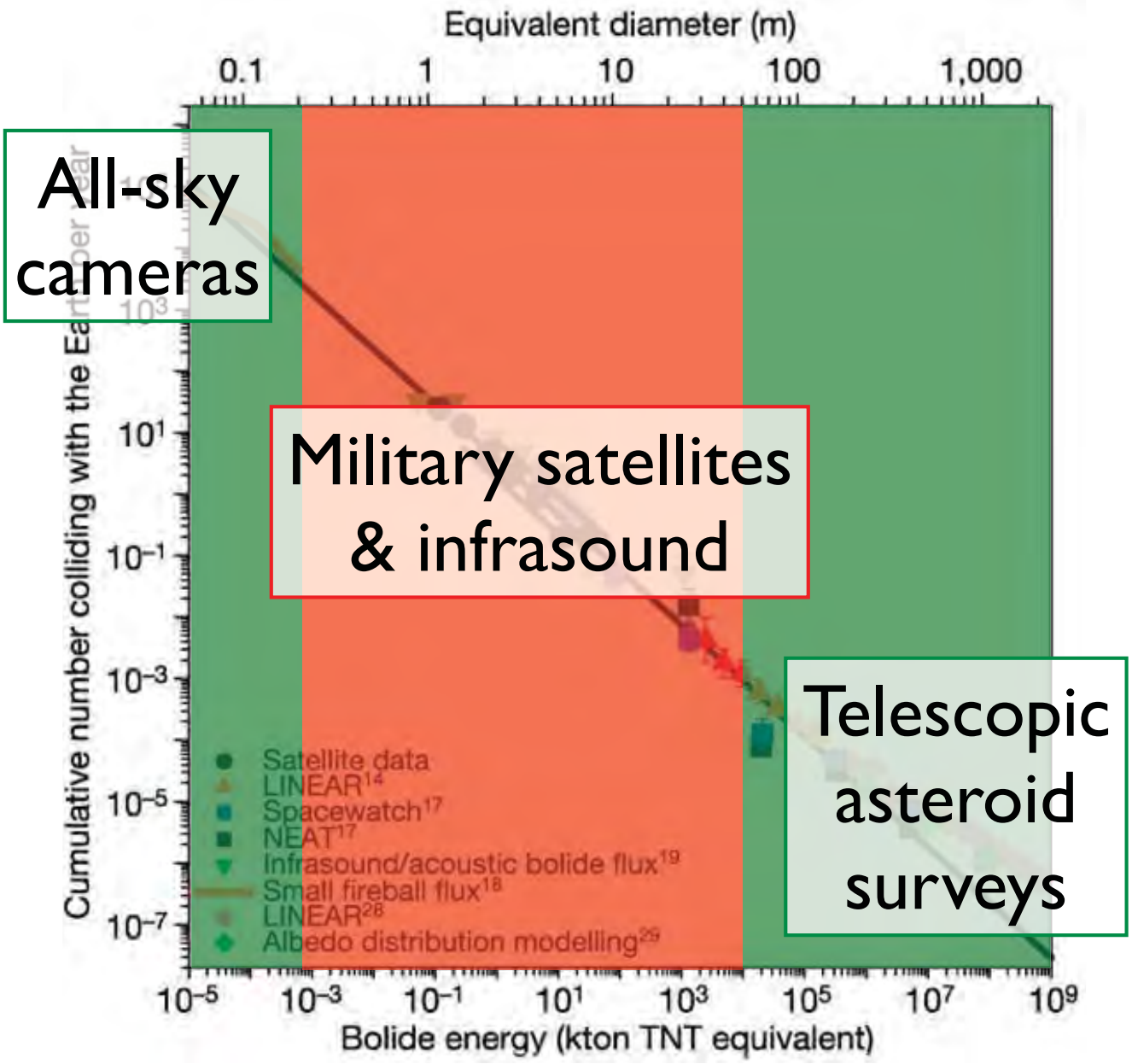


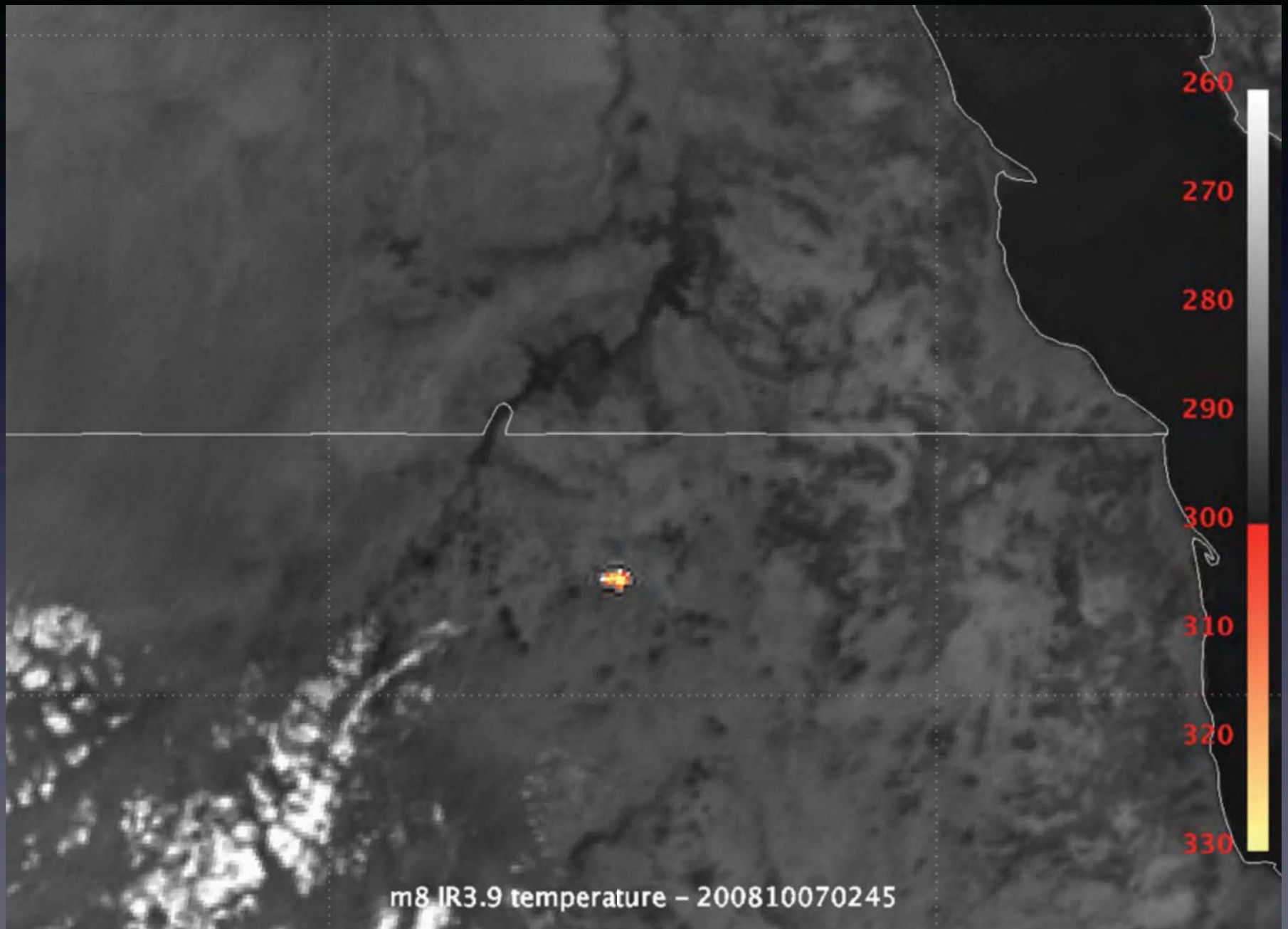
Data on large meteoroids

1. Military satellites
   - US Defense and Energy departments operate satellites to detect nuclear explosions;
   - detected ~300 bolide detonations between 1994 and 2002;
   - sensitive down to ~1 meter objects (as far as reported?)
2. Ground-based infrasonic/acoustic data
   - 19 events in Brown et al. (2002);
   - biased towards deeply penetrating (asteroidal) bodies.

Problem

- Data on meteoroids between 20cm and 10m is either sparse or restricted.
- All-sky cameras tend to miss this size range because
  - the objects are very infrequent;
  - brightness estimates are tricky due to saturation.

A pre-planned exception



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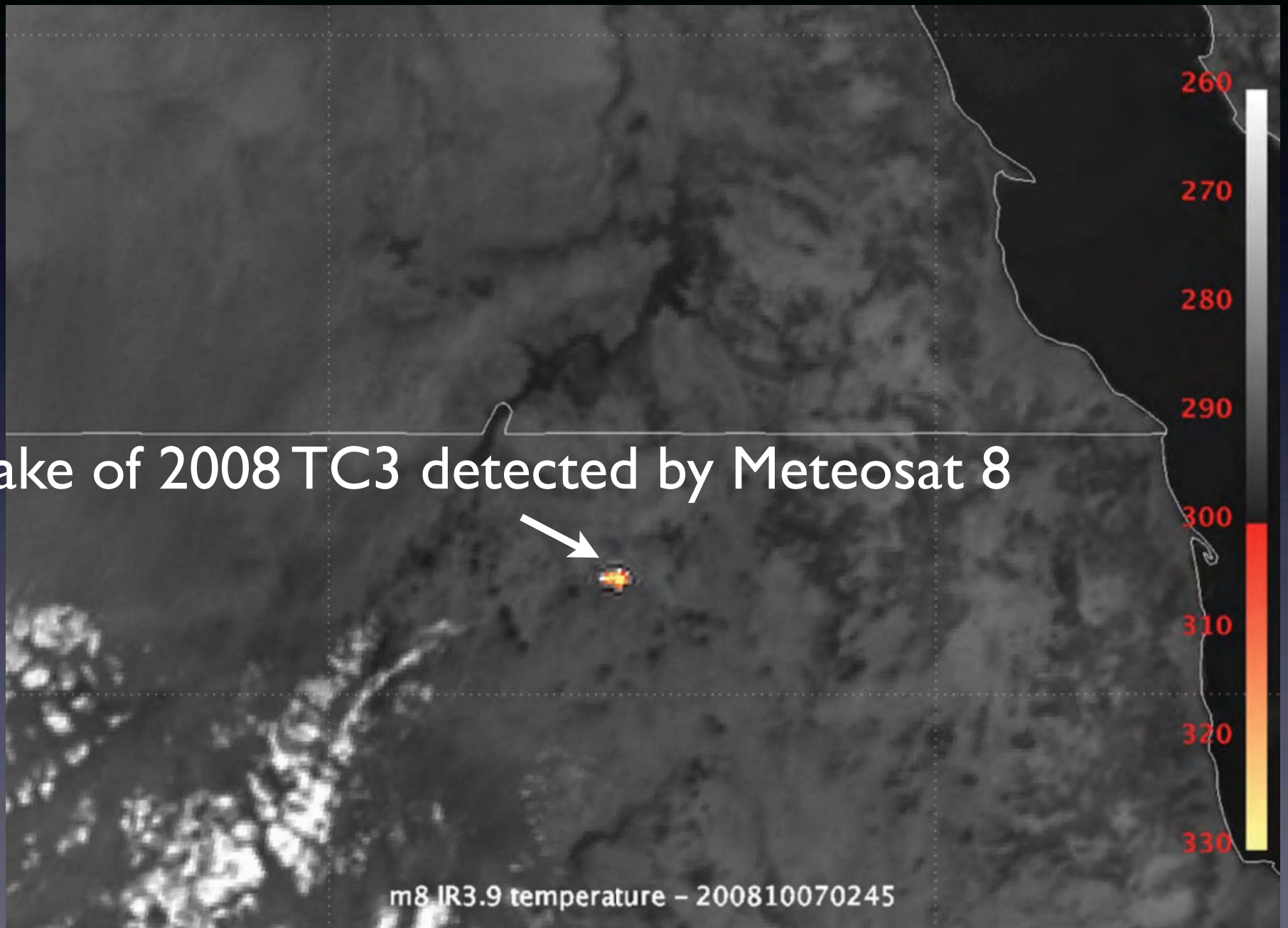

Yet we know that meteoroid streams may contain big fragments!

Comet 73P/Schwassman-Wachmann 3

Broke into dozens of sub-km fragments in 1995 and 2001 (e.g. Vaubaillon & Reach 2010)

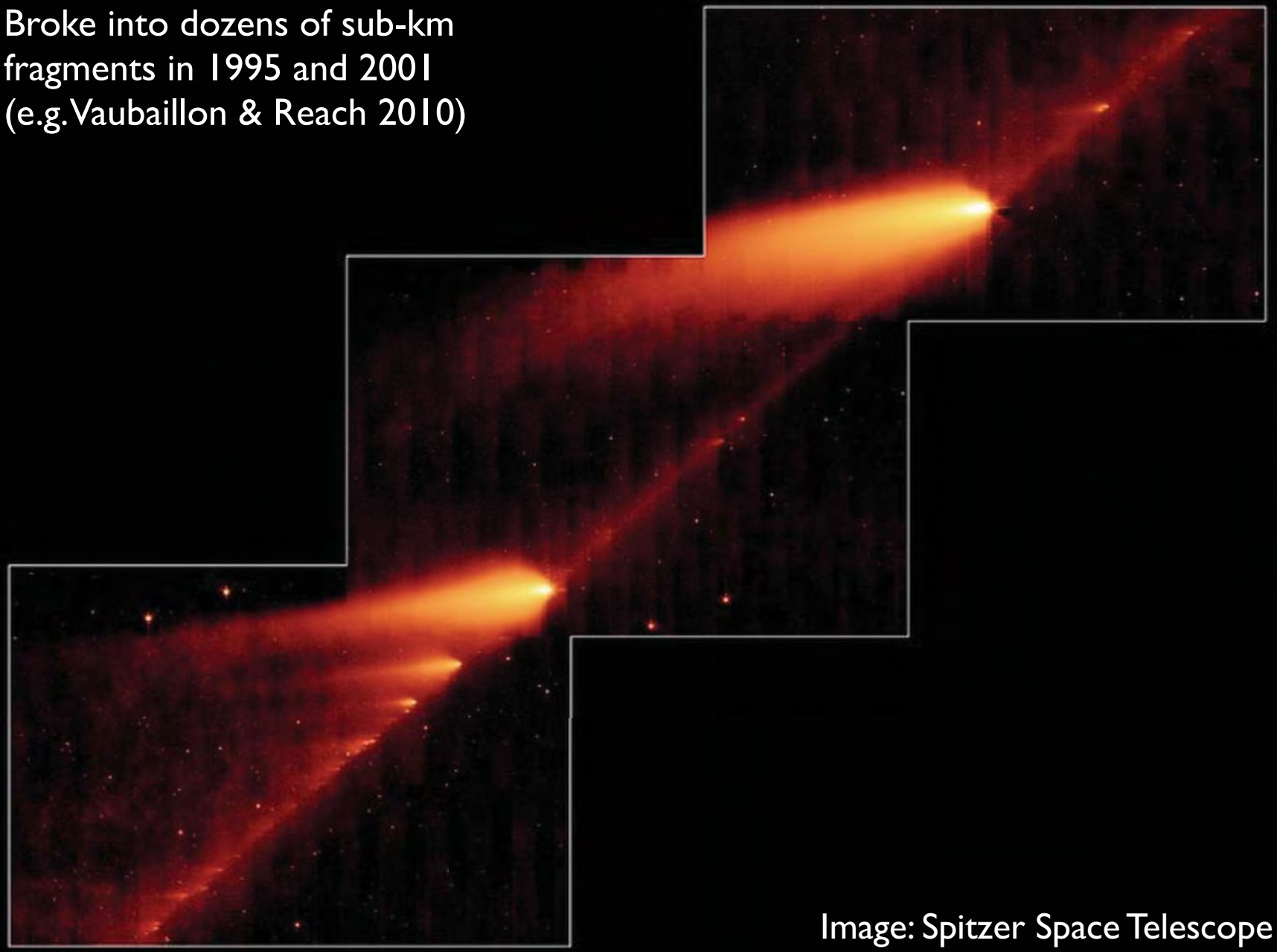

Image: Spitzer Space Telescope

Comet McNaught

Orientation of "striae" suggests fragmentation
(e.g. Sekanina et al.)

Image: Robert McNaught

Comet Hartley 2

Fly-by of EPOXI spacecraft revealed meteoroids sized 3 to 30 cm (A'Hearn et al. 2011)

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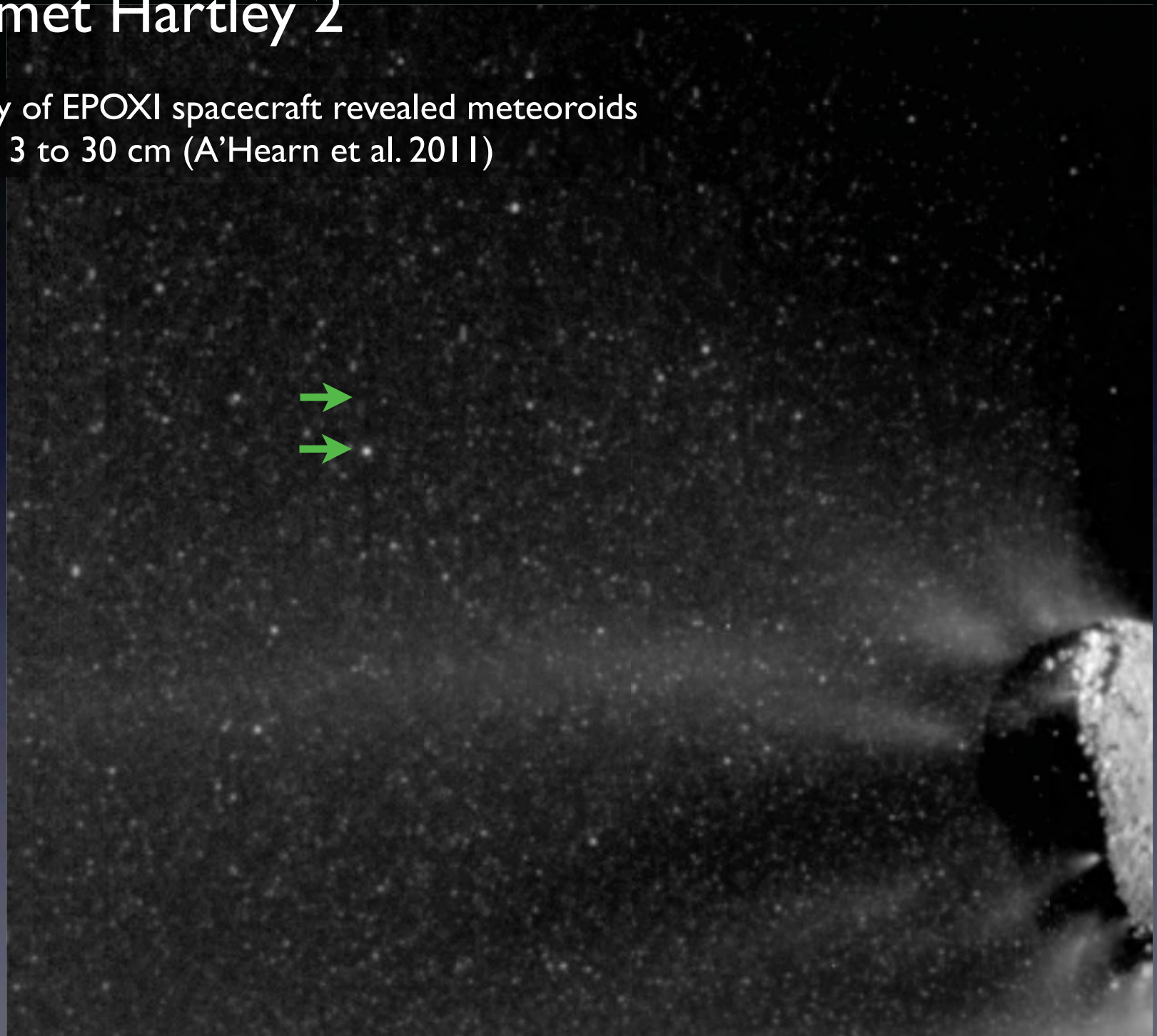

Tunguska event (1908)

Timing and direction of Tunguska object appears consistent with Taurid complex (e.g. Kresak 1978, Jopek 2008)

Two other major airbursts coincided with Perseids on 13 Aug 1930 and Geminids on 11 Dec 1935 (Napier & Asher 2009)

Taurids, Geminids and Arietids are associated with km-sized asteroids (e.g. Jenniskens et al. 2008)

Do our current meteoroid streams harbour large objects?

- **Pro:** decameter-sized bodies may have sublimation lifetimes lasting dozens of perihelion passages (Beech & Nikolova 2001)
- **Con:** they may disintegrate quickly due to thermal and tidal stresses, radiative spin-up, collisions (e.g. Davidsson 1999)

=> Need to measure their flux to determine just how frequent (or rare) they are!

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=> Need to measure their flux to determine just how frequent (or rare) they are!

=> Important because it puts constraints on the fragmentation process and the frequency of Tunguska events.

So, how to measure the frequency of large meteoroids?

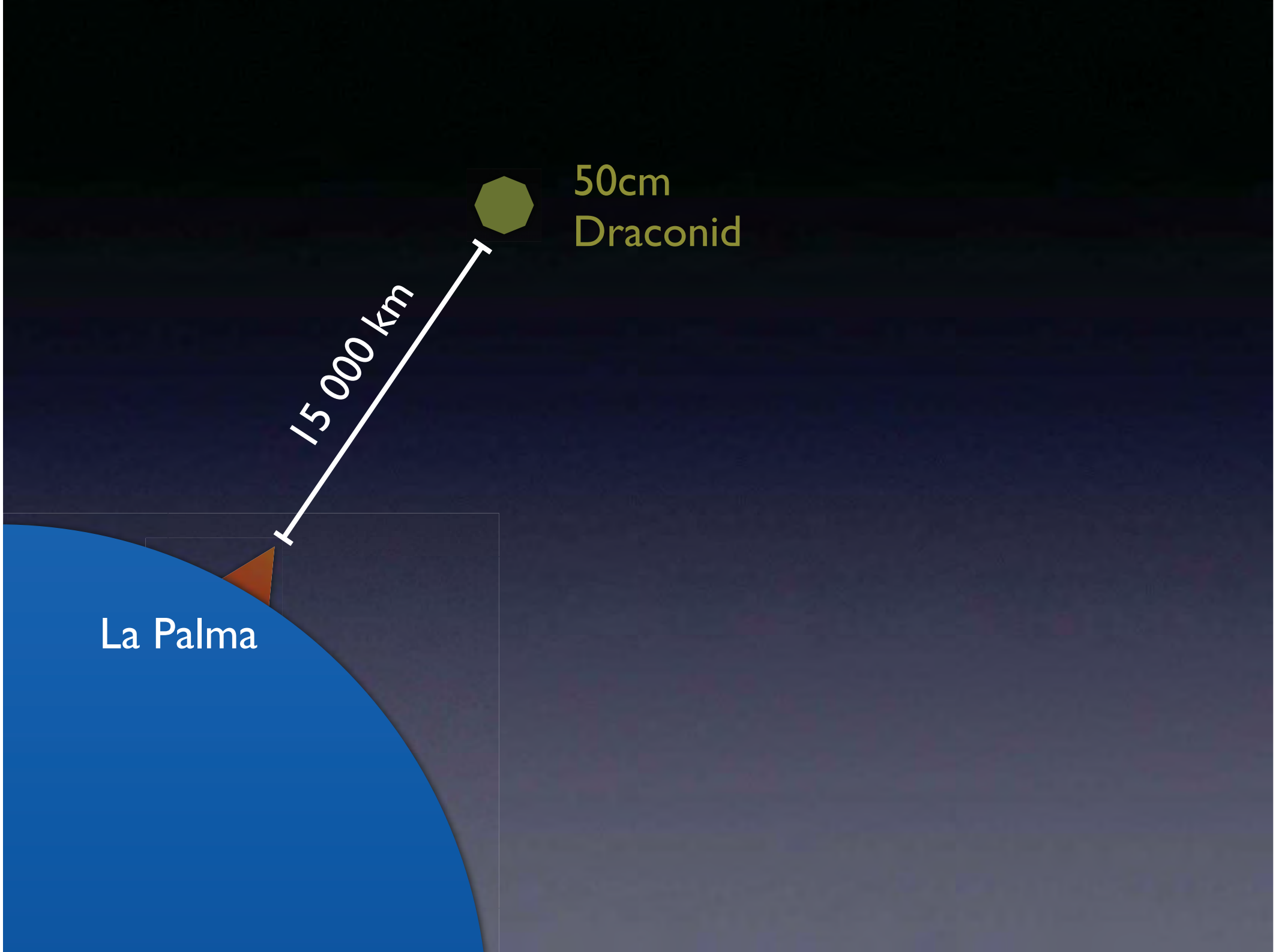
I still don’t know.

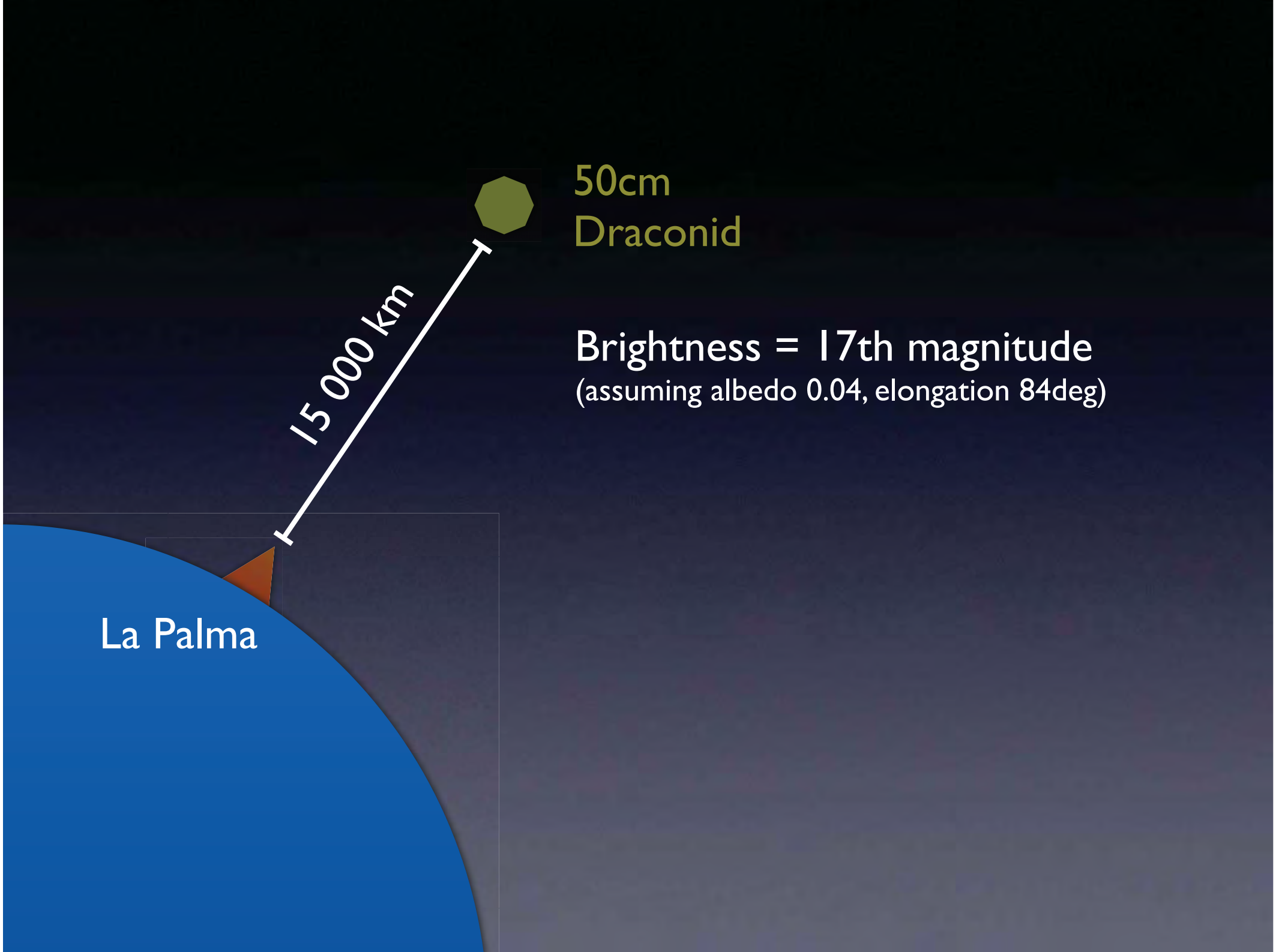
But here are two ideas...

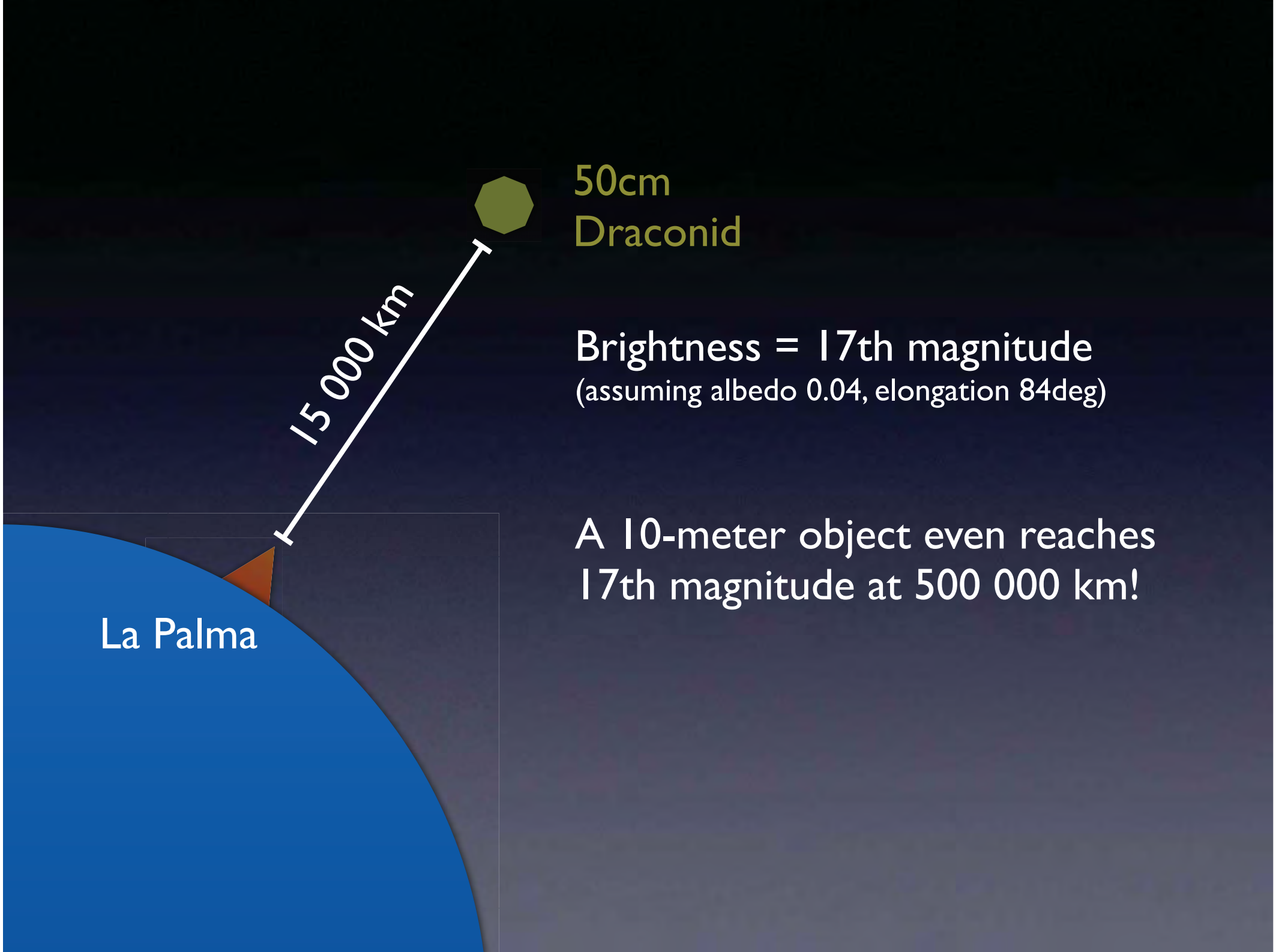
1. Point a telescope at a meteoroid stream
2. Exploit fireball sightings by humans

Pointing a telescope at a stream

- Barabanov et al. (1996) and Smirnov & Barabanov (1997) reported the detection of five decameter-sized objects during the Perseids, using a 1m-telescope.
- A repeat experiment by Beech et al. (2003) failed to detect any such objects.
- Draconids 2011 offered an excellent opportunity to repeat such experiment.

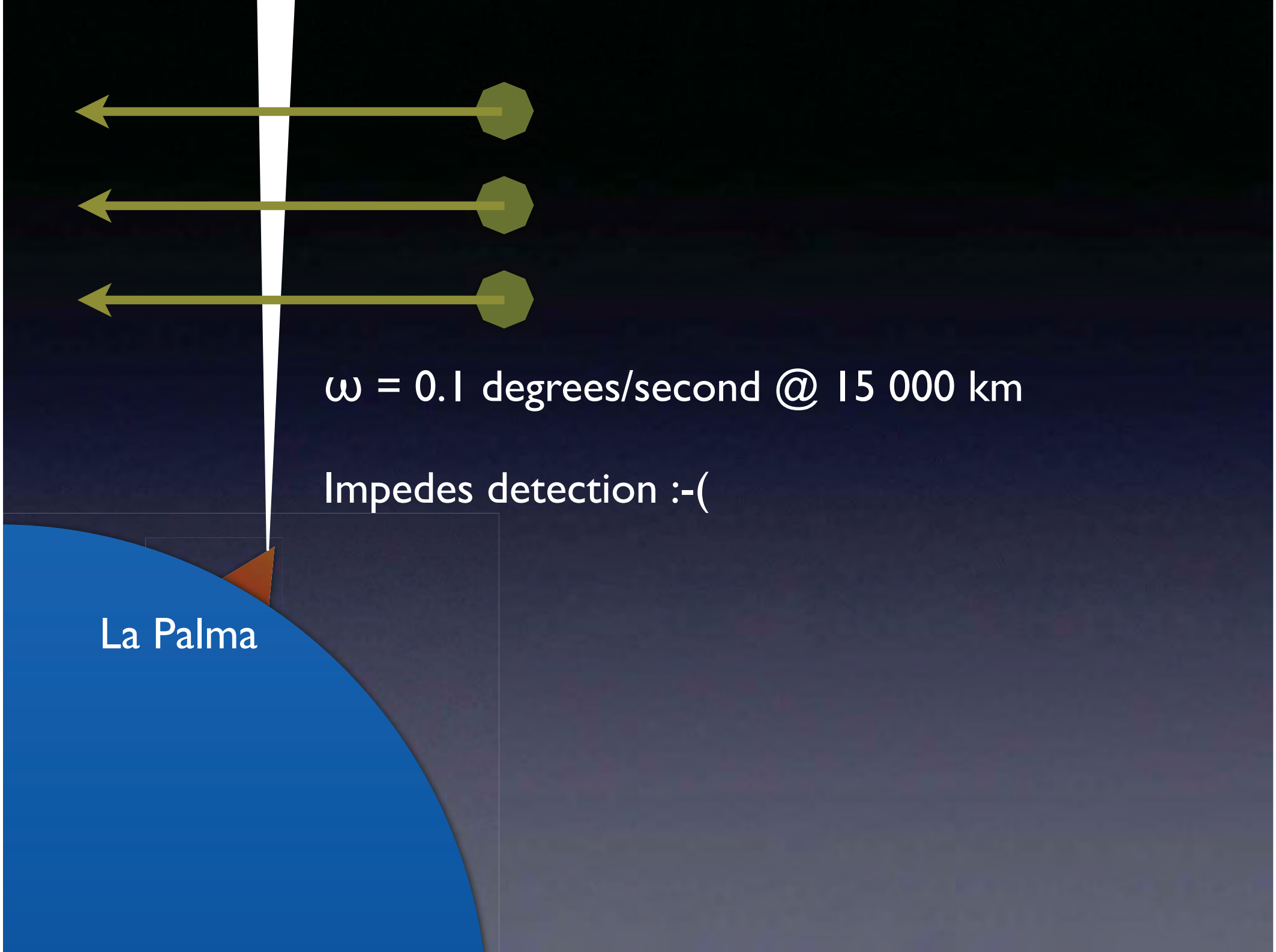

50cm
Draconid
15 000 km
La Palma


50cm
Draconid
15 000 km
Brightness = 17th magnitude
(assuming albedo 0.04, elongation 84deg)
La Palma



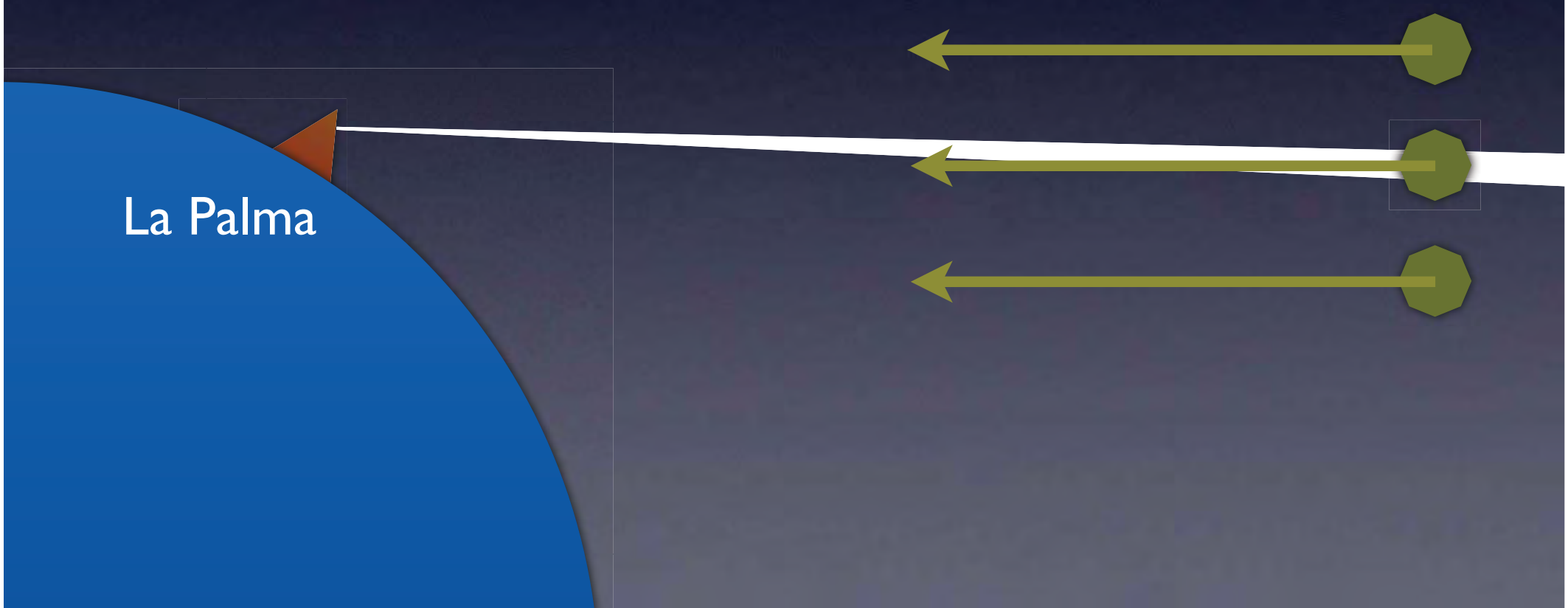
Brightness = 17th magnitude
(assuming albedo 0.04, elongation 84deg)

A 10-meter object even reaches
17th magnitude at 500 000 km!


ω = 0.1 degrees/second @ 15 000 km
Impedes detection :-(
La Palma

If you point within 0.5 degrees from the radiant...

ω < 2 arcseconds/second :-)

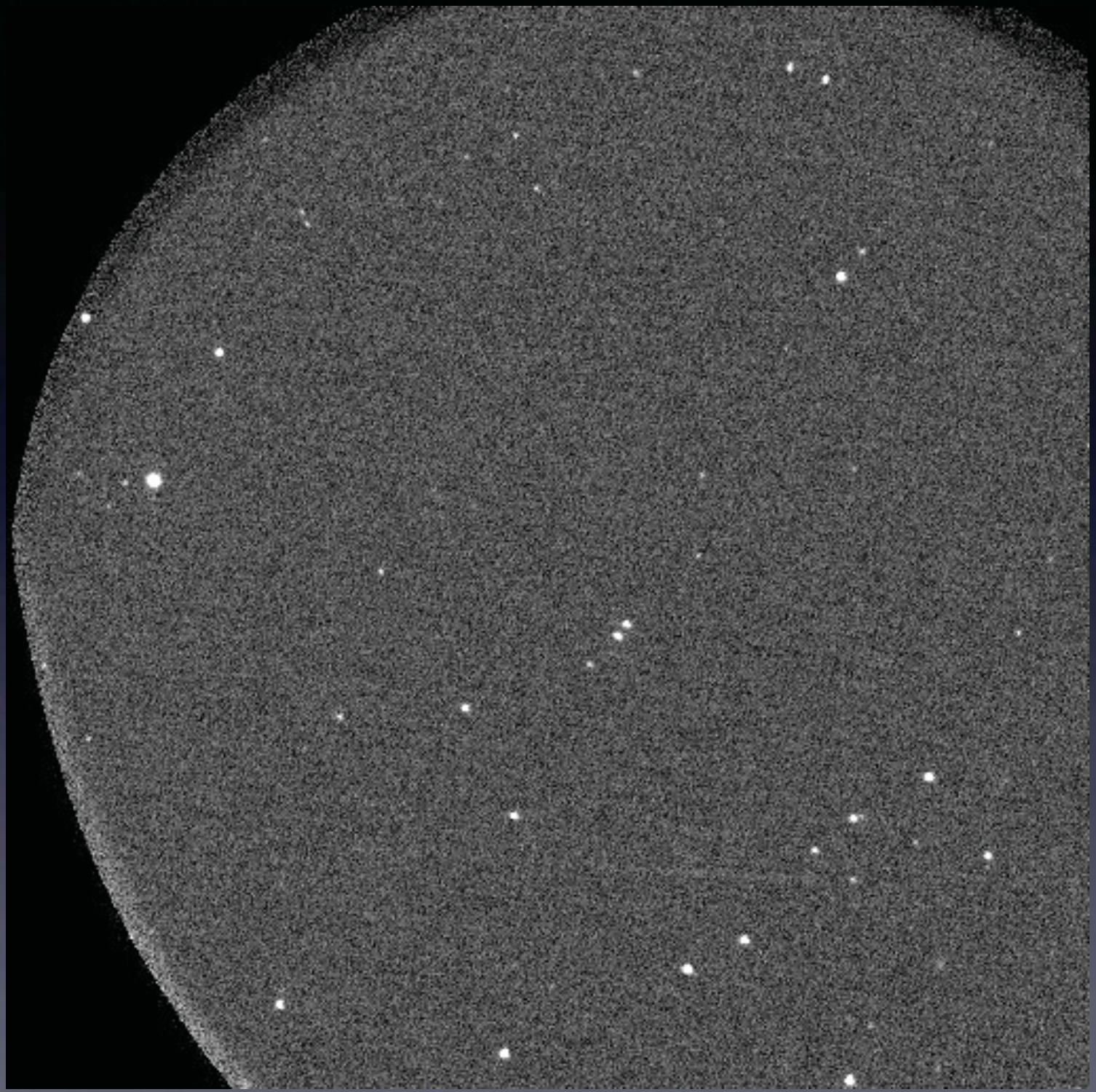


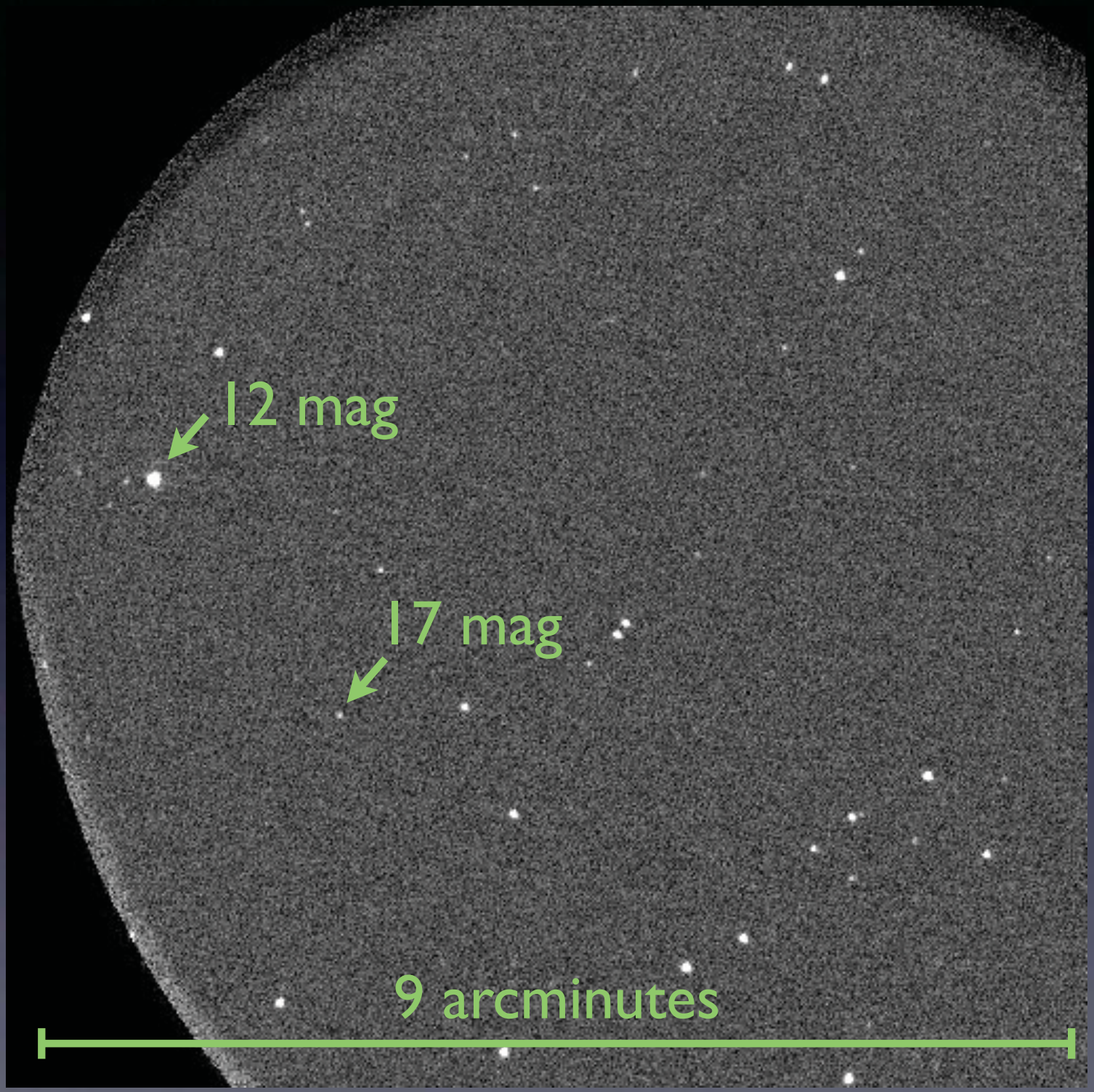

Liverpool Telescope (La Palma)
2.0 meter robotic Cassegrain

Andor DW435 ‘RISE’ camera
E2V frame-transfer CCD

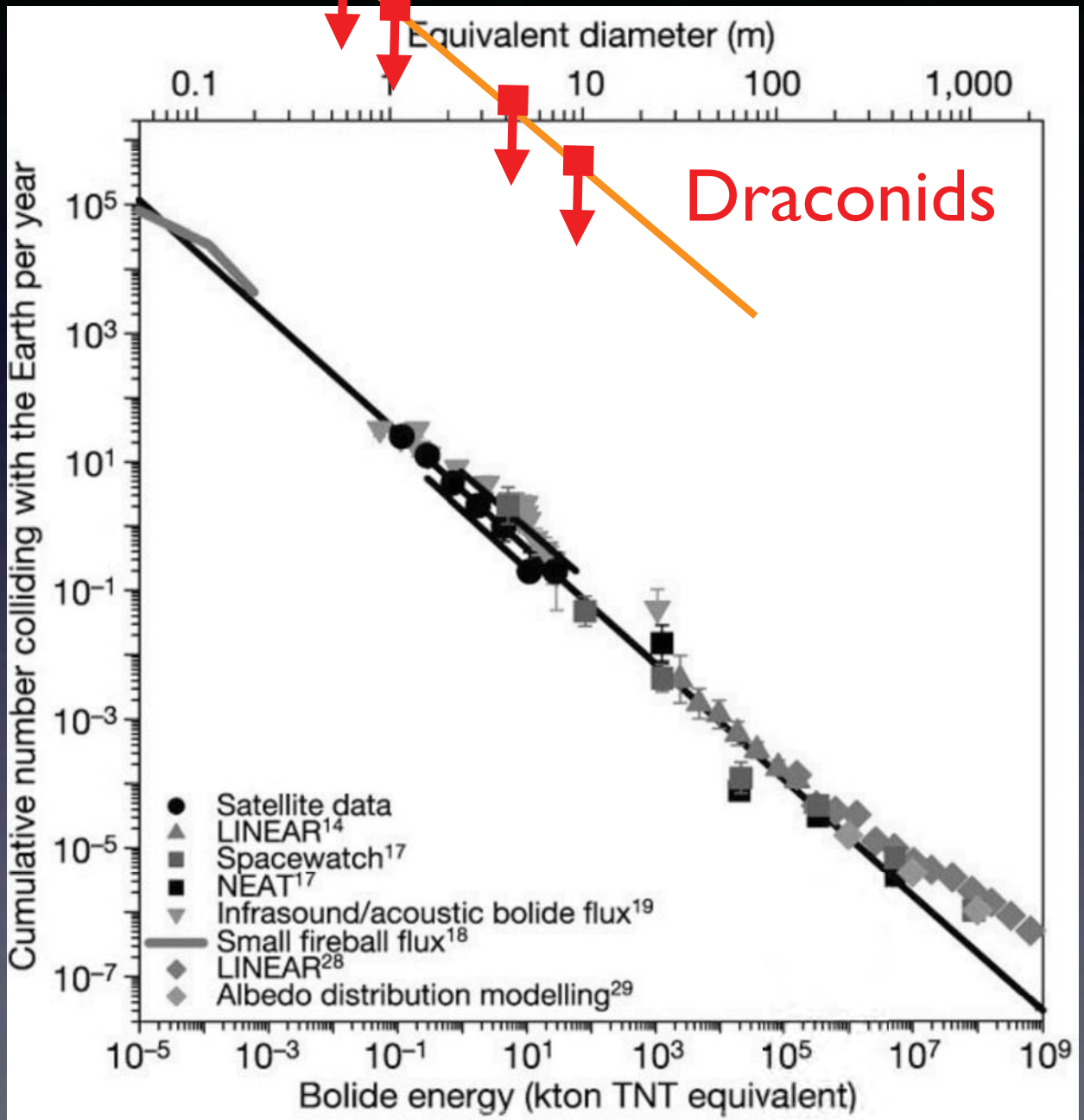
No readout overhead!

We used this camera to take 7500 x 0.8 second exposures during the Draconid outburst



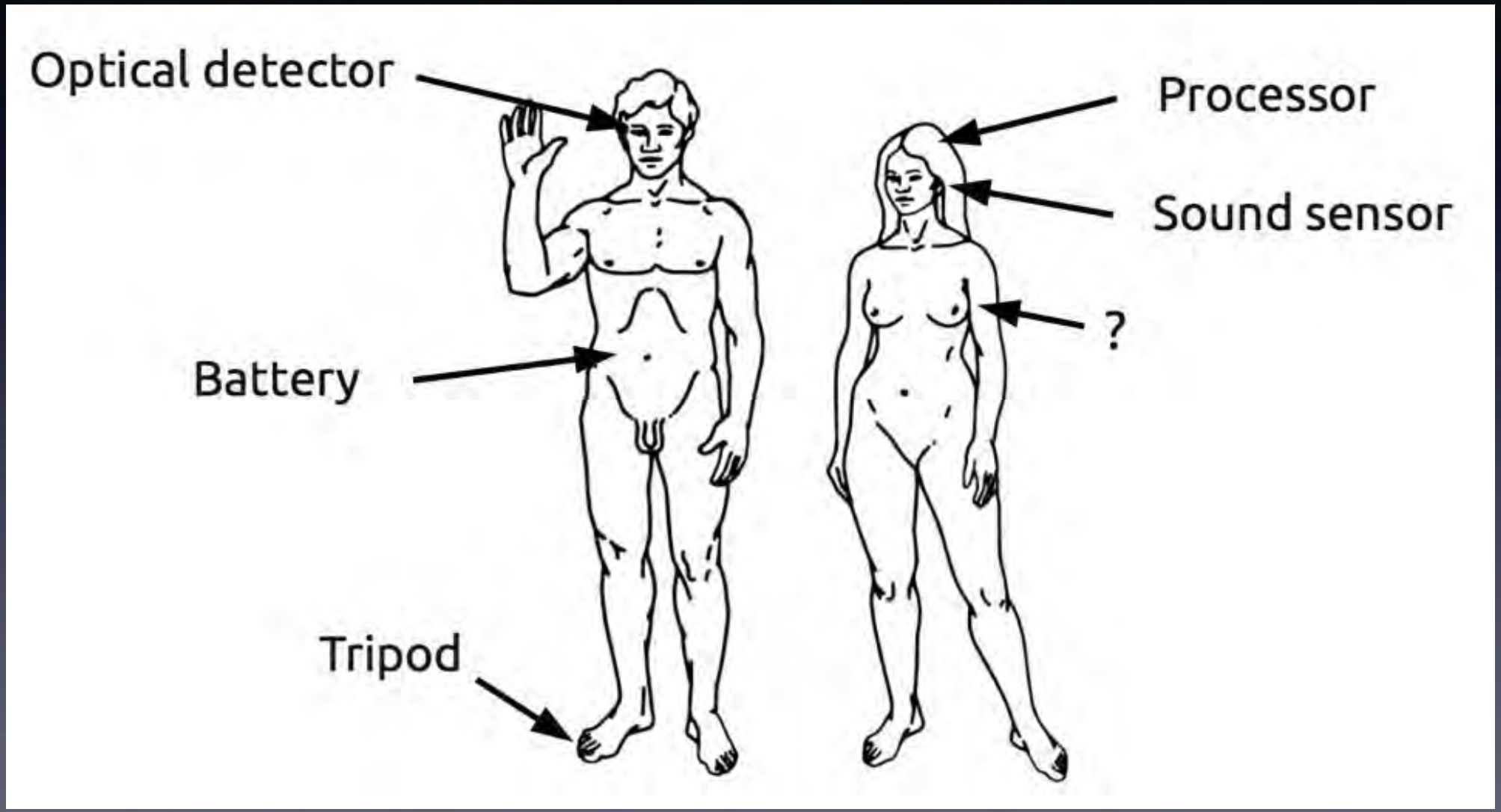

12 mag
17 mag
9 arcminutes

No convincing detections; hence upper limit on the flux:



Need to cover a larger area in space to obtain tighter constraints

World's largest sensor network



Human fireball sightings

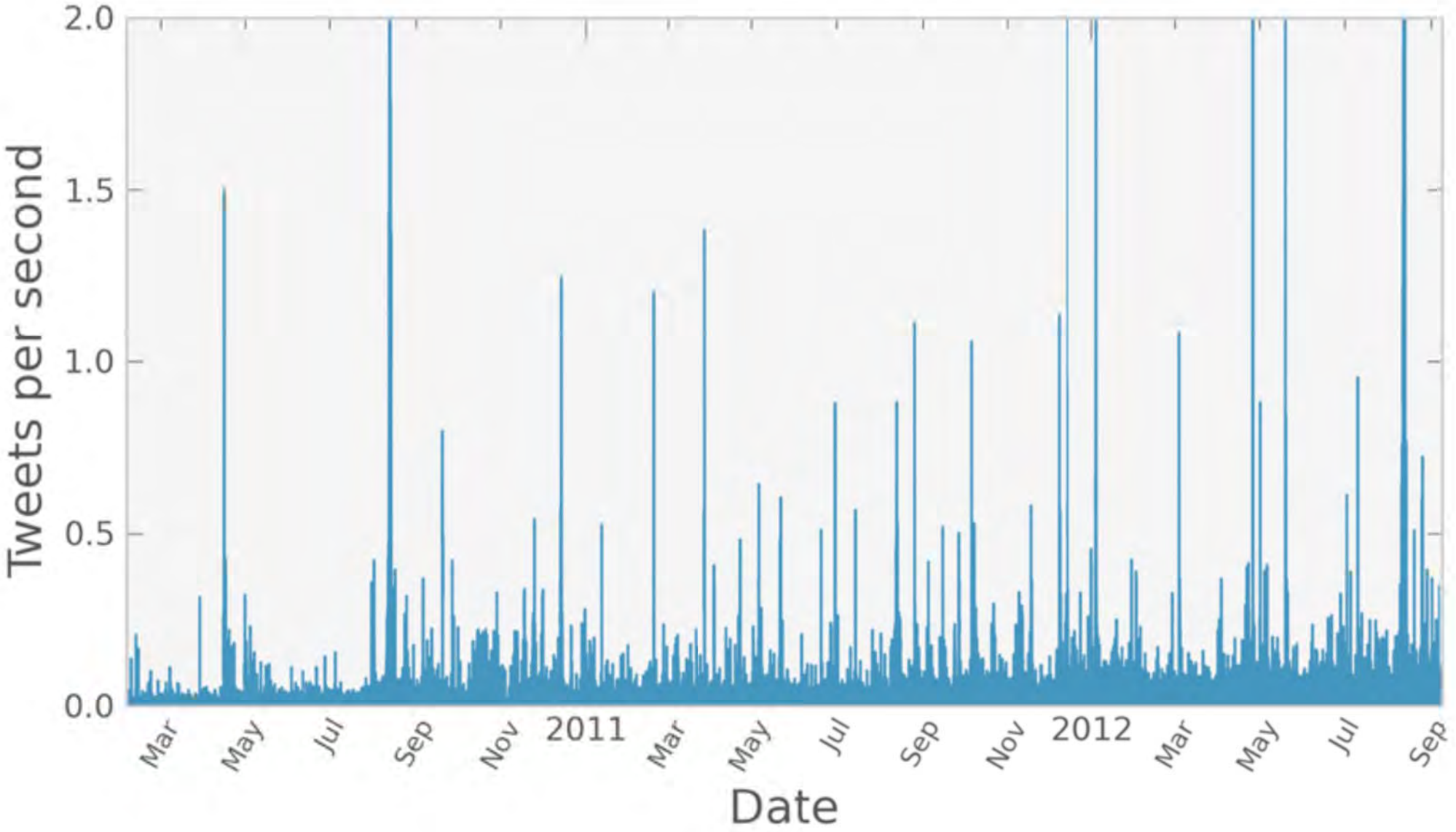
- Amount of atmosphere monitored by humans remains much larger than that by all-sky cameras
- Brightness range
  - CCD chips: 6 magnitudes
  - Humans: >20 magnitudes
- Databases of fireball sightings remain useful, but ...
  - No global database?
  - Tricky selection effects (e.g. different reports forms)

Hold on.

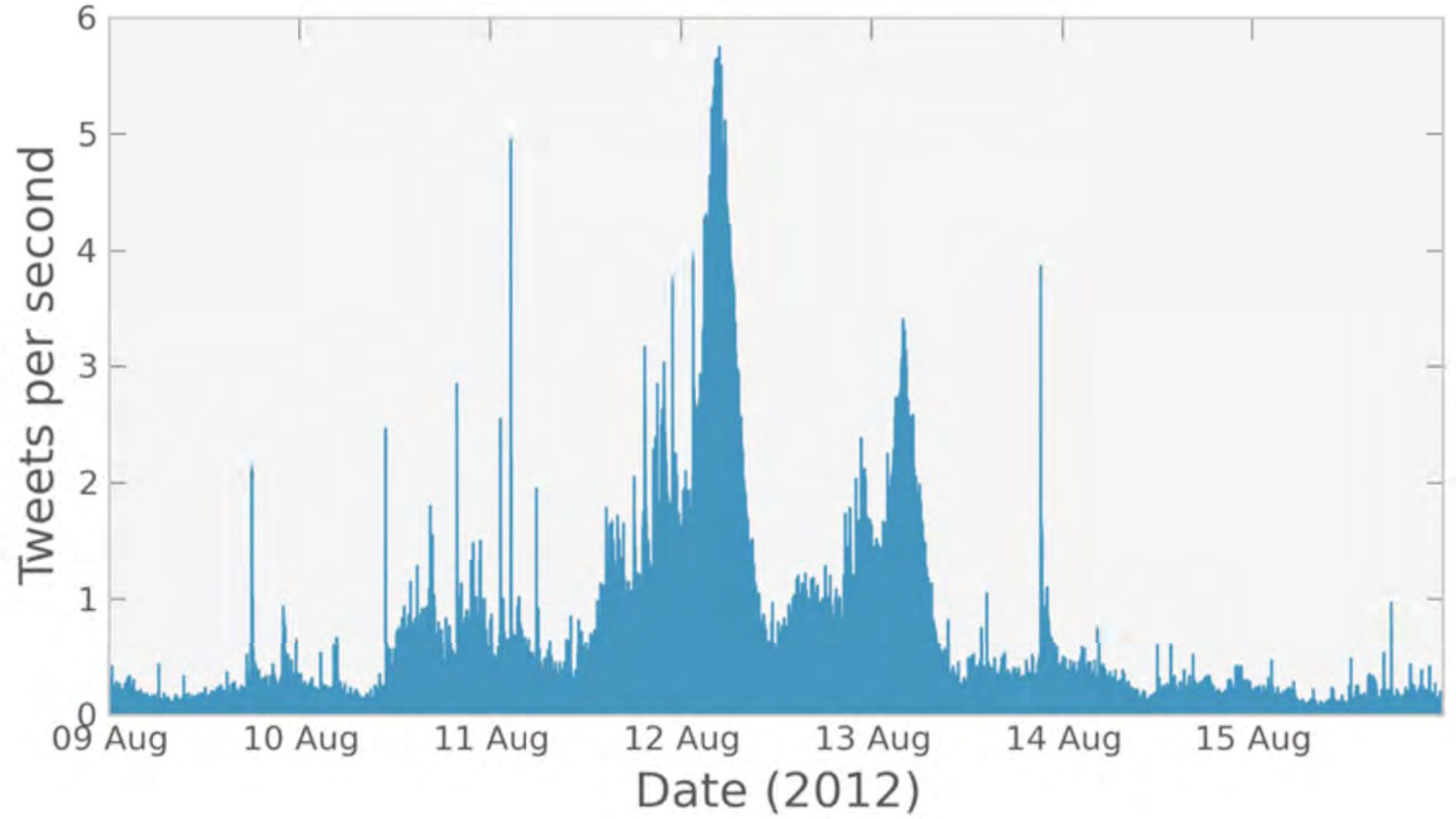
There is a global database.

- Designed to share text messages of 140 characters with the world.
- 500 million active users (!!);
  340 million messages per day

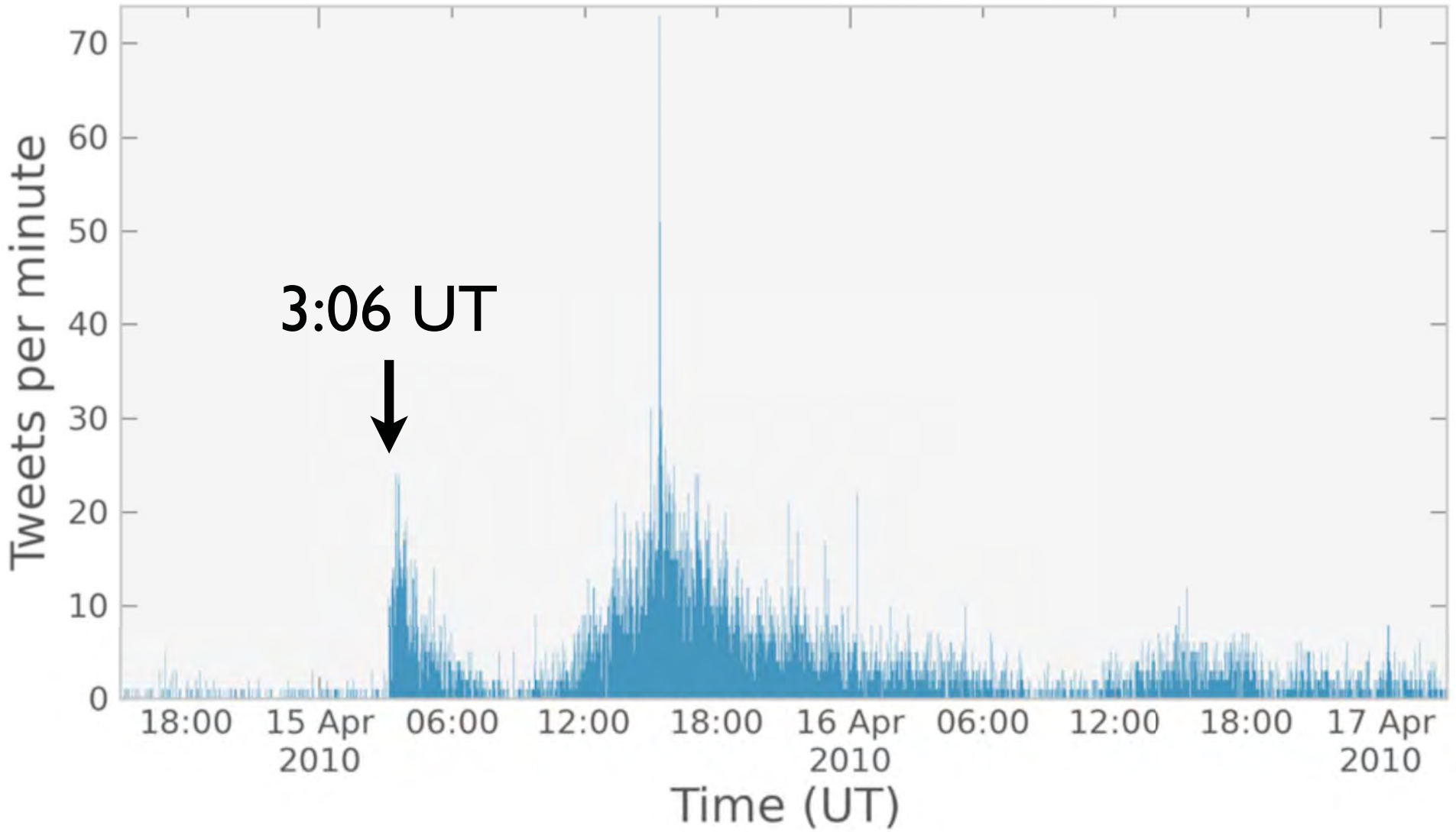
5.6 million messages since 2010 contained one of the words "*meteor(s), meteorite(s), meteoro(s), meteorito(s), fireball(s)*"



e.g. during the Perseids:



But also at unexpected times, e.g. 15 April 2010



15 April 2010

3:06:41	@sarahrattenborg	**HOLY BALLS. METEOR.**
3:07:06	@JazzieBabeee	**I just saw a meteor!**
3:07:21	@zeroethic	**I swear to Bob I just seen a fireball ...**
3:07:24	@OhJorden	**Just saw like, a plane explode ...**
3:07:25	@BJWEISFLOG	**just saw a huge meteor ...**
3:07:25	@AdamPeters	**WHO JUST SAW THAT HUGE METEOR ...**

Followed by 600 similar messages within the hour.

METEORITE

Massive fireball reported across Midwestern sky

April 15, 2010 | By the CNN Wire Staff

Authorities in several Midwestern states were flooded Wednesday night with reports of a gigantic fireball lighting up the sky, the National Weather Service said.

The fireball was visible for about 15 minutes beginning about 10 p.m., said the National Weather Service in Sullivan, Wisconsin, just west of Milwaukee.

"The fireball was seen over the northern sky, moving from west to east," said the NWS in the Quad Cities area, which includes parts of Iowa and Illinois.

Data Mining Twitter

- Possible project: measure the fireball frequency using natural language processing.
- Assume the number of messages is a function of brightness?
  - Message counts can be normalized using the frequency of unrelated messages.
- Some geospatial information is attached to each message.

Conclusion

- Measuring the flux of large meteoroids is tricky
- Until we get access to satellite data,
  we'll have to be creative!


2011 Oct 8 19:58:13 UT