

Mega-Constellations and Astronomy

Patrick Seitzer
Dept of Astronomy
University of Michigan

American Astronomical Society
Committee on Light Pollution, Radio Interference, and Space Debris

pseitzer@umich.edu

SpaceX Starlink Launch: 2019 May 24



*Marco Langbroek
Leiden, Netherlands*

Astronomical Concern - Optical

- 18,000+ satellites in catalog.
- Two constellations in build phase:
 - SpaceX – 60 satellites launched: $V \sim 5^{\text{th}}$ mag
 - OneWeb – 6 satellites launched: $V \sim 8^{\text{th}}$ mag.
- ~200 satellites now visible to unaided eye in dark site.
 - ***This number could increase to 15,000 or more!***
 - ***Several hundred satellites visible at any one time.***
 - ***Changes night sky.***
 - ***Have not considered glints or flares like 1st generation Iridium ($V = -8$).***

2019-July-16 UT

Blanco 4.0-m DECAM

Cerro Tololo, Chile

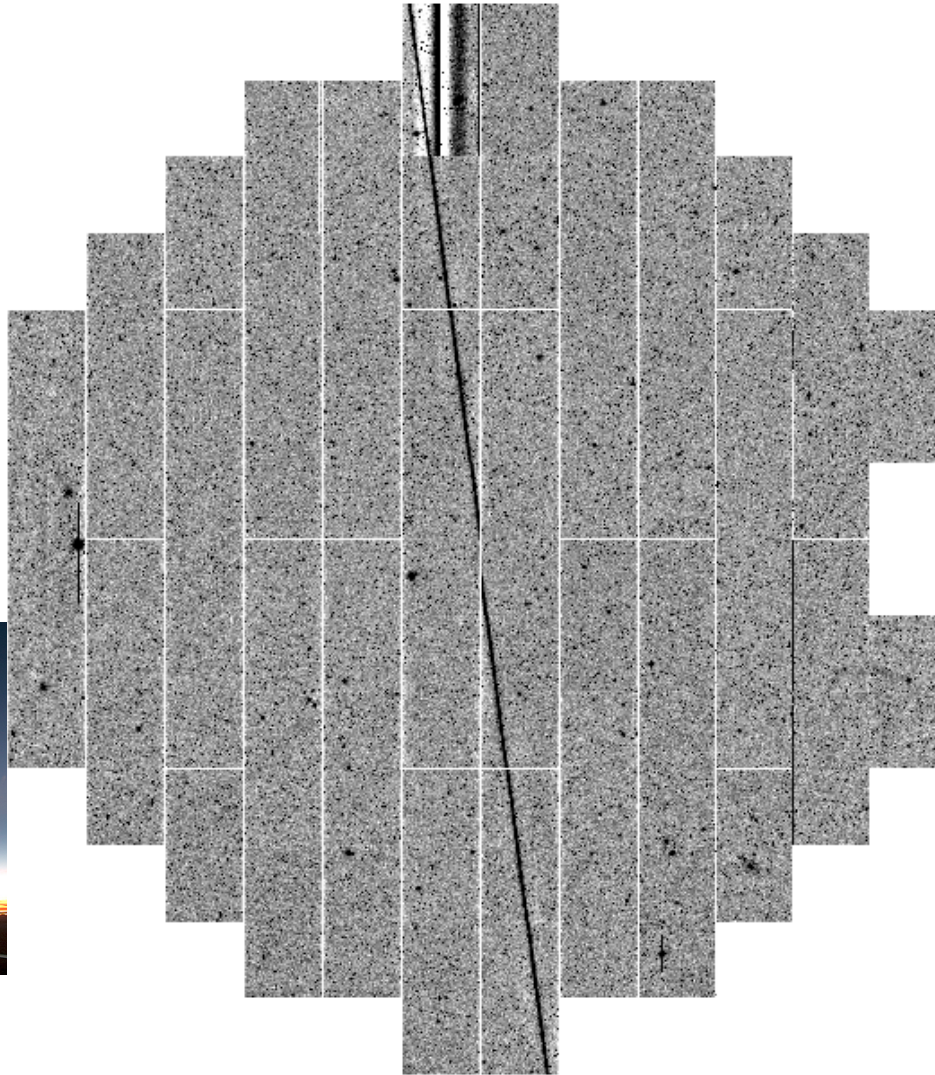
2.2 deg FOV

60 sec exposure
r' filter

Atlas Centaur 2 R/B

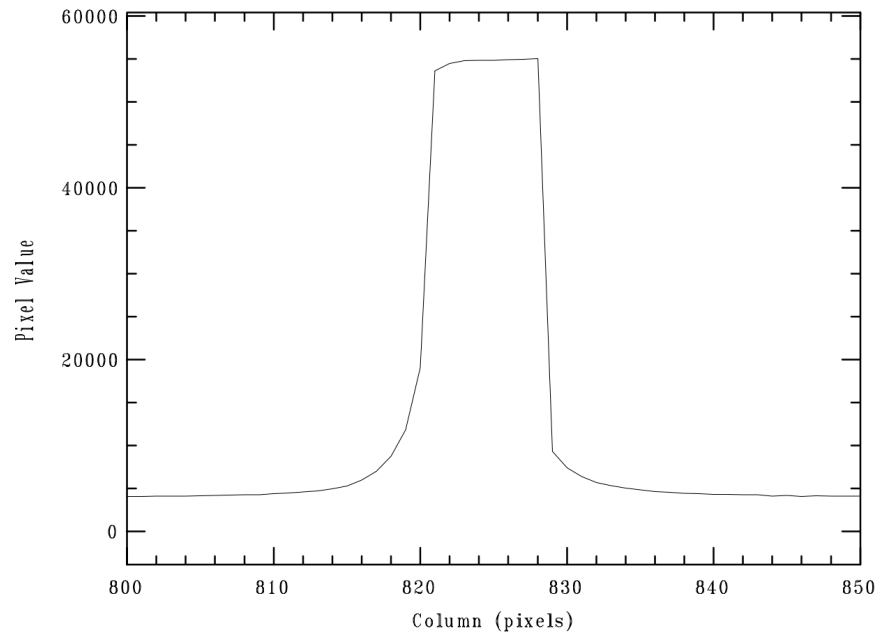
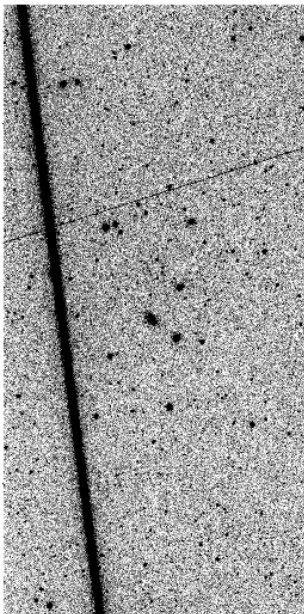
1963-047A 00694

$V \sim 4^{\text{th}} - 10^{\text{th}}$



2019-10-19

Streak saturates Detector



Modelling

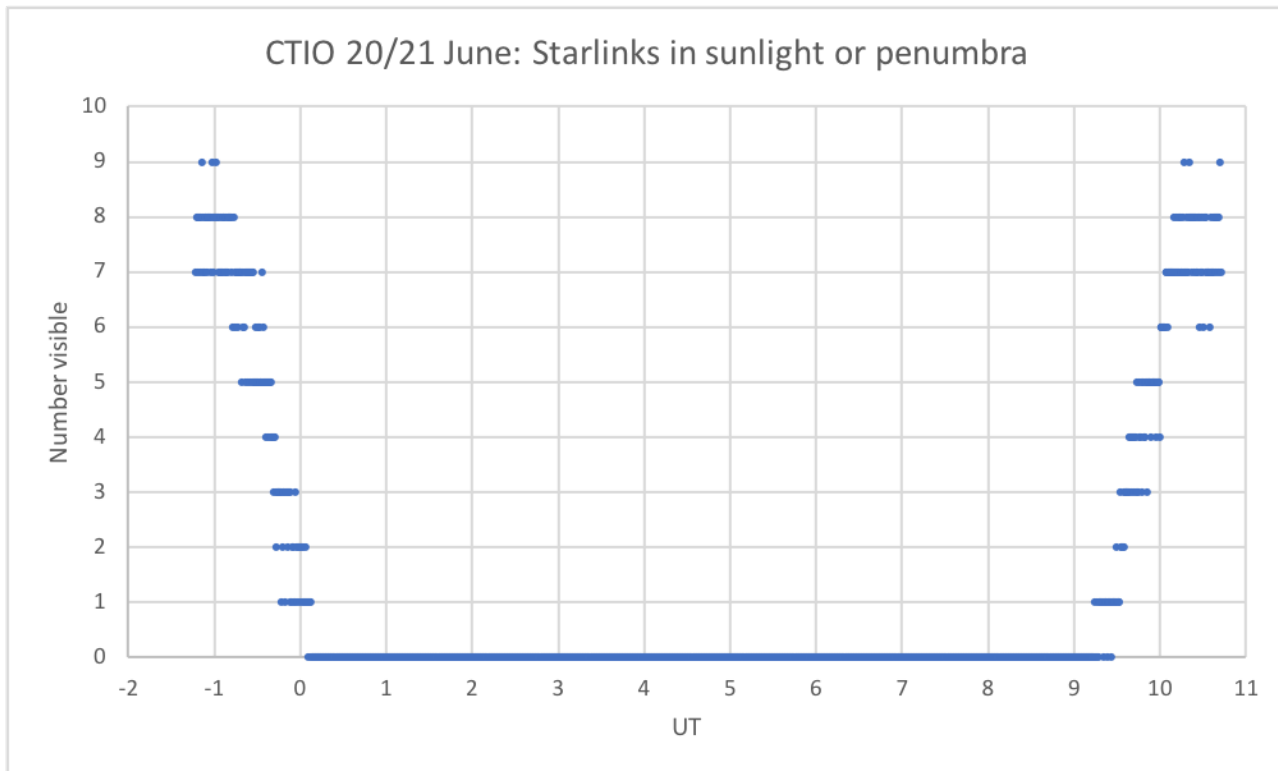
- How visible will these satellites be to astronomers?
- Initial Starlink constellation as approved by FCC:
 - 1584 satellites at 550 km altitude: 24 planes with 66 satellites per plane.
- Definitions of twilight:
 - Sun between 12 and 18 degrees below horizon: useful for calibration.
 - Sun 18 degrees or more below horizon: darkest time, observe faintest objects.

Geometric Visibility

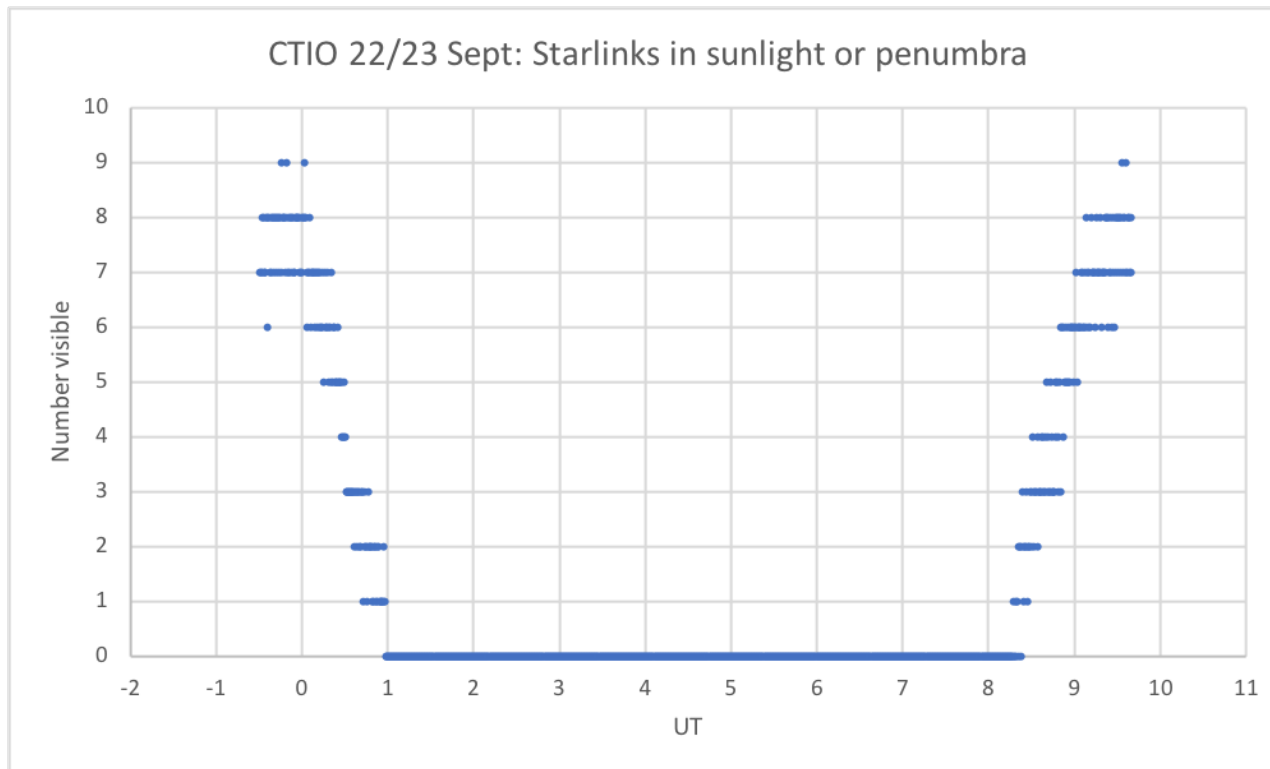
- Geometric Visibility: observer has a line of sight to satellite.
- No modelling of brightness. Starlinks currently $V \sim 5^{\text{th}}$ mag.
- Assumed full constellation of 1584 in final orbits by June 20, 2019.
- Constraints:
 - Sun 12 deg or more below observer's horizon (nautical twilight).
 - Satellite elevation ≥ 30 degrees. Airmass = 2.0, typical astronomical limit.
 - Satellite is in full sunlight or penumbra.
- Visibility computed for Univ of Michigan Curtis-Schmidt at Cerro Tololo Inter-American Observatory (CTIO) in Chile [LSST just south of this site].
 - Long = -70.80627 latitude = -30.16908 altitude 2216 meters (WGS84).

Results

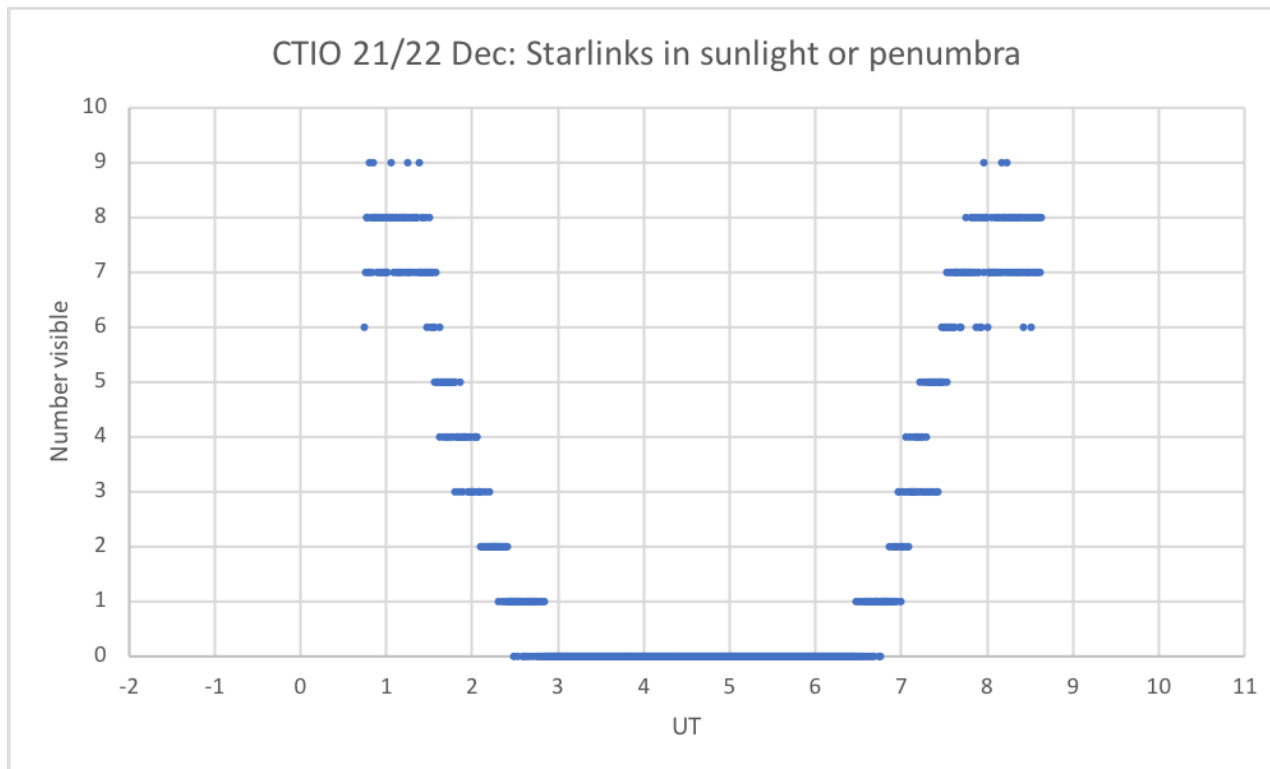
- Three nights for initial analysis of visibility of all 1584 satellites:
 - June 20/21 2019: longest night of the year in Chile.
 - Sept 22/23 2019: equinox.
 - Dec 21/22 2019: shortest night of the year in Chile.
- Plots run from evening nautical twilight (Sun -12 deg) to morning nautical twilight.
- Temporal bin width of 0.01 hours (36 secs) far less than plot resolution. Solid lines are not solid lines, just closely spaced markers.



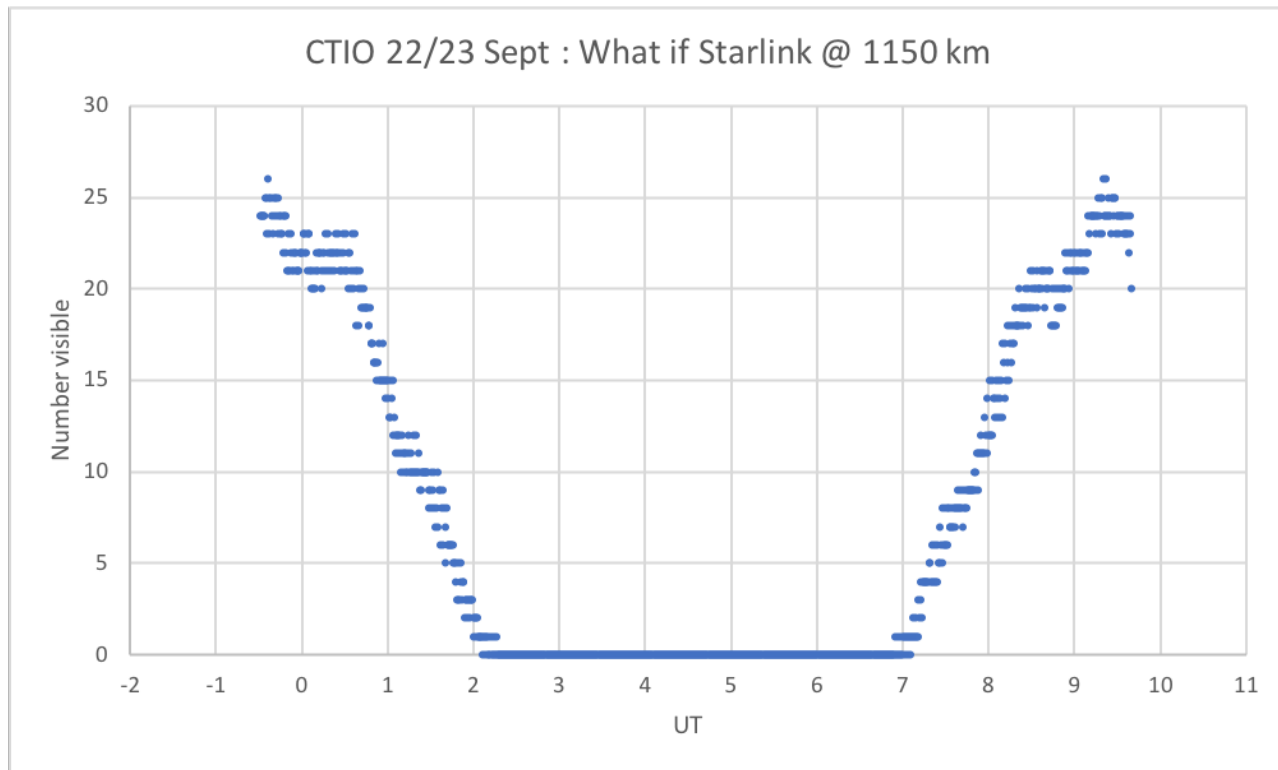
Astronomical twilight: 23:16 – 10:13



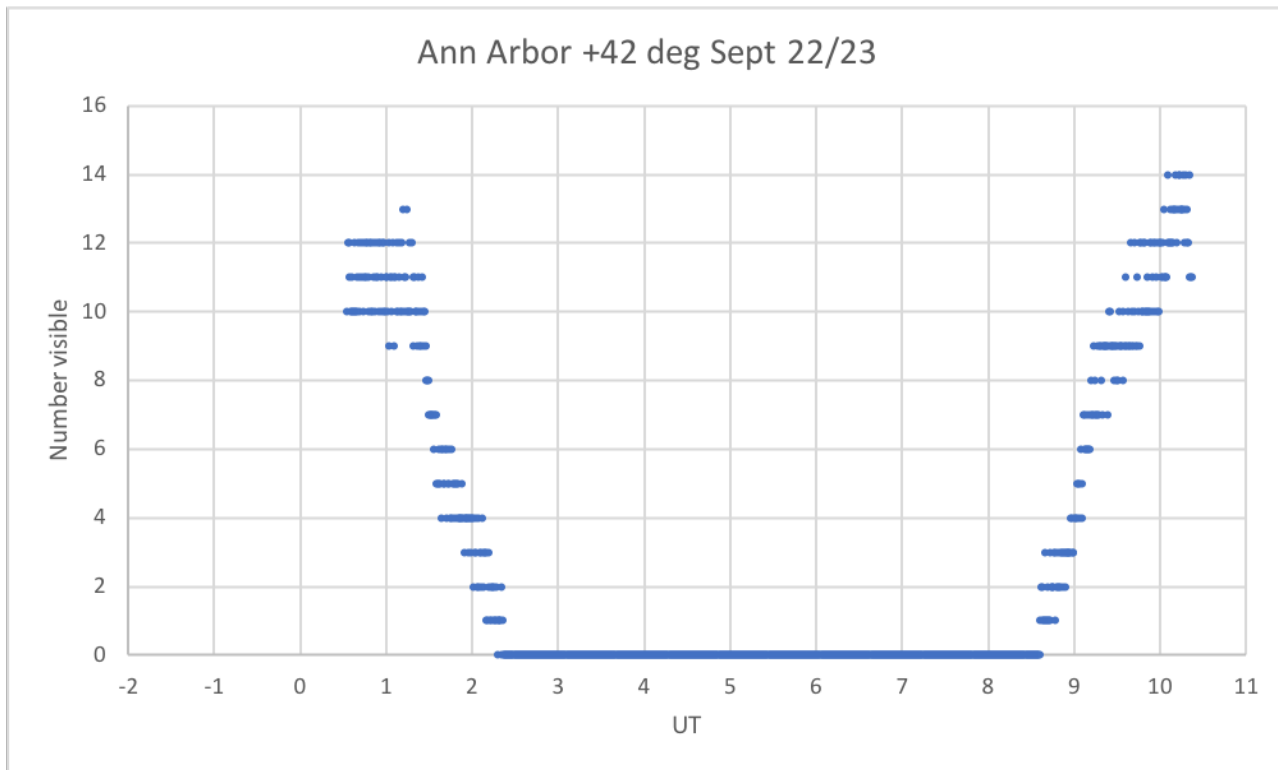
Astronomical twilight: 23:59 – 09:12



Astronomical twilight: 01:20 – 08:01



Astronomical twilight: 23:59 – 09:12



Conclusions

- As expected for Low Earth Orbit (LEO) satellites, Starlinks at 550km are visible only at start and end of night.
- Concern: during entire year, there are significant numbers of bright ($V \sim 5^{\text{th}}$ magnitude) Starlinks after start of astronomical twilight in evening and before end of astronomical twilight in morning.
- No significant differences between 72/22 and 24/66 configurations.
- If initial Starlink constellation of 1584 satellites was the only one to be launched, astronomers could handle this.

- **BUT** – 1584 just the start!
 - SpaceX: 12,000? 42,000?
 - OneWeb: initially 600, grow to? (at 1200 km).
 - Amazon: filed for 3,236 at 590, 610, and 630 km.
- All SpaceX and Amazon satellites visible to eye? Depends on design and surface treatment.
- No current national or international regulations or guidelines for brightness of satellites.

Wishes and future

- Mega-constellation operators provide accurate and precise ephemerides to astronomers for scheduling telescope. Updated every 24 hours, **predict and avoid**. TLEs not good enough.
- Minimize brightness as seen from Earth in design and operation.
- Observers with telescopes capable of tracking LEO satellites – high frequency (1s or faster) brightness measurements of current Starlink and OneWeb satellites. Are there flares/glints?



Special Session: Threats to Astronomy from Satellites

pseitzer@umich.edu