Overcrowded Orbits: Understanding the Impacts on Ground-Based Astronomy

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Contents

1. What are the impacts of satellite megaconstellations on astronomy?

2. What is the astronomy community is doing about it?

3. How will the problem be solved in the long term?

European Southern Observatory

- Intergovernmental organization for astronomy
  - Founded in 1962 by five countries with the goal to build a large observatory in the southern hemisphere
- Mission
  - Develop and operate world-class observatories for astronomical research
  - Foster cooperation in astronomy
- ESO today:
  - All ESO Observatories are in Chile, headquarters in Garching
  - 16 member states, 700+ employees

The Extremely Large Telescope

Taken by surprise...

24 May 2019: SpaceX launches first test batch of 60 *Starlinks*

After SpaceX Starlink Launch, a Fear of Satellites That Outnumber All Visible Stars

Images of the Starlink constellation in orbit have rattled astronomers around the world.

THERLANDS MAY 24 MARCO LANGBROEK VIA REUTERS

The Death of Astronomy?

Probably not, but forthcoming commercial satellite constellations herald a new era for our night skies

By Caleb A. Scharf on May 27, 2019 2

Express.co.uk

Alien hunt is being RUINED by Elon Musk and SpaceX's 12,000 SATELLITES, astronomers claim

Elon Musk's SpaceX launched the first 60 Starlink satellites on May 23, and ... will not only obstruct their view of the night's sky, but also effects radio astronomy.

Jun 6, 2019

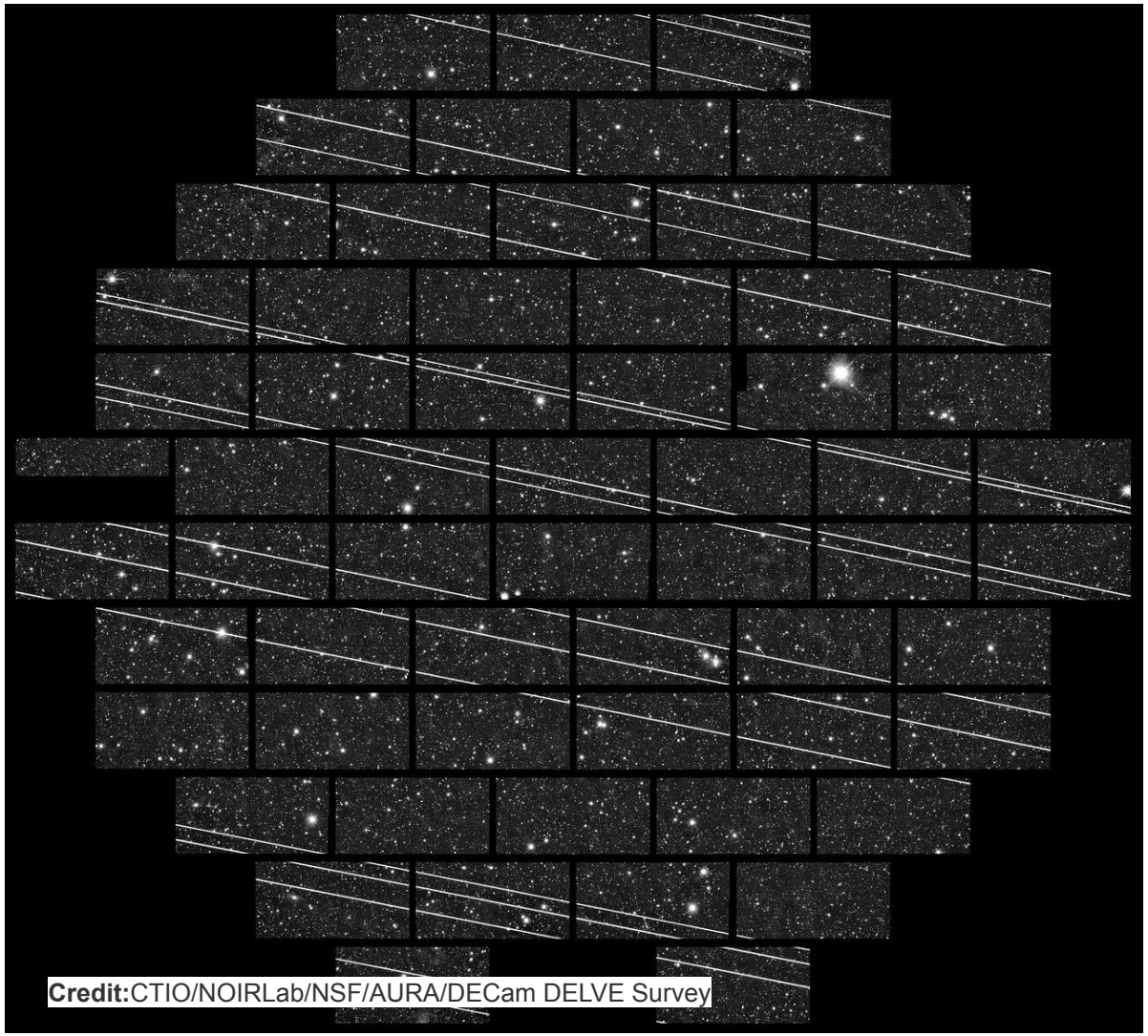
European Southern Observatory

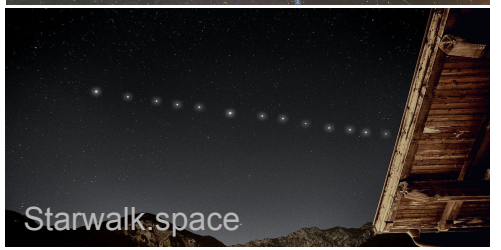
ann19029 — Announcement

On the increasing number of satellite constellations

7 June 2019

Optical astronomy and astrophotography impacts





Why should we care?

BBC Sign in | News | Sport | Reel | Worklife | Travel | Fu

NEWS

Home | US Election | Coronavirus | Video | World | UK | Business | Tech | Scie

Science & Environment

Is there life floating in the clouds of Venus?

By Jonathan Amos
BBC Science Correspondent

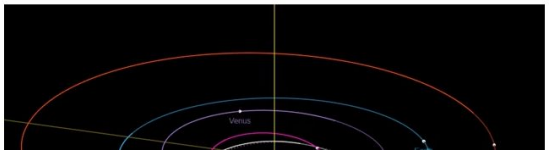
14 September 2020

Biggest asteroid to pass close (and undetected) this year

Posted by **Eddie Irizarry** *in* **SPACE** | June 11, 2020

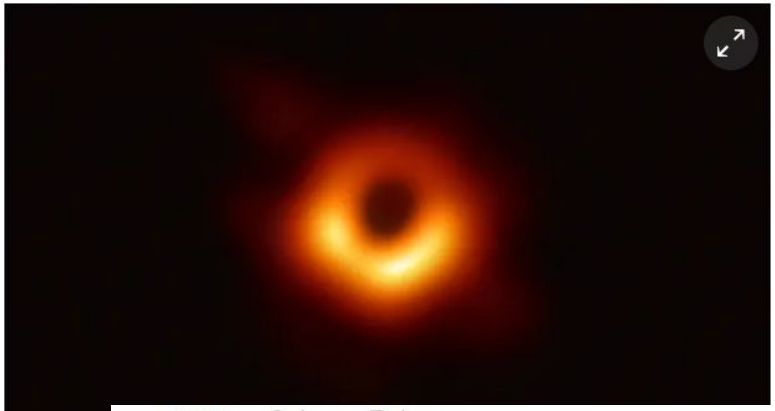
Asteroid 2020 LD passed within the moon's distance on June 5, but wasn't discovered until June 7. It's the 45th known and the largest asteroid to sweep within a lunar-distance of Earth so far in 2020.

Sharing is caring!



Black hole picture captured for first time in space breakthrough

Network of eight radio telescopes around the world records revolutionary image



▲ The image of

eso1737 — Science Release

ESO Observations Show First Interstellar Asteroid is Like Nothing Seen Before

VLT reveals dark, reddish and highly-elongated object

20 November 2017

For the first time ever astronomers have studied an asteroid that has entered the Solar System from interstellar

Satellite Megaconstellations

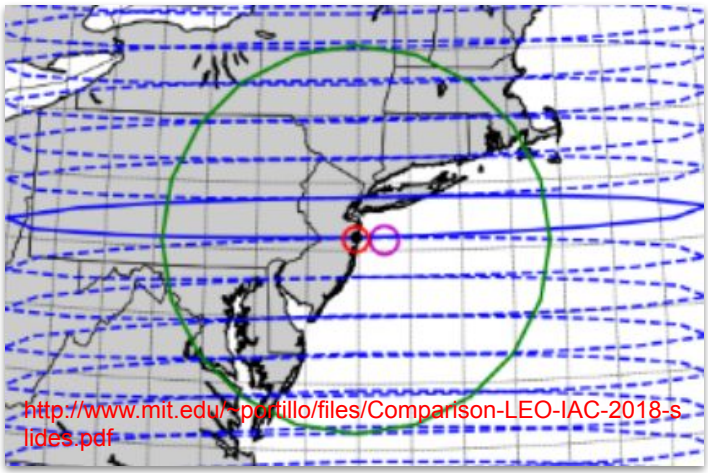
Satellite Constellation: a number of similar satellites, of a similar type and function, designed to be in similar, complementary, orbits for a shared purpose, under shared control [1].

- Navigation and geodesy (e.g. GPS, Galileo and GLONASS),
- Satellite telephony (e.g. Iridium)
- Earth Observation (e.g. DMC, PlanetLabs)
- Global satellite internet,
- Internet of Things to connect machines and systems together directly.

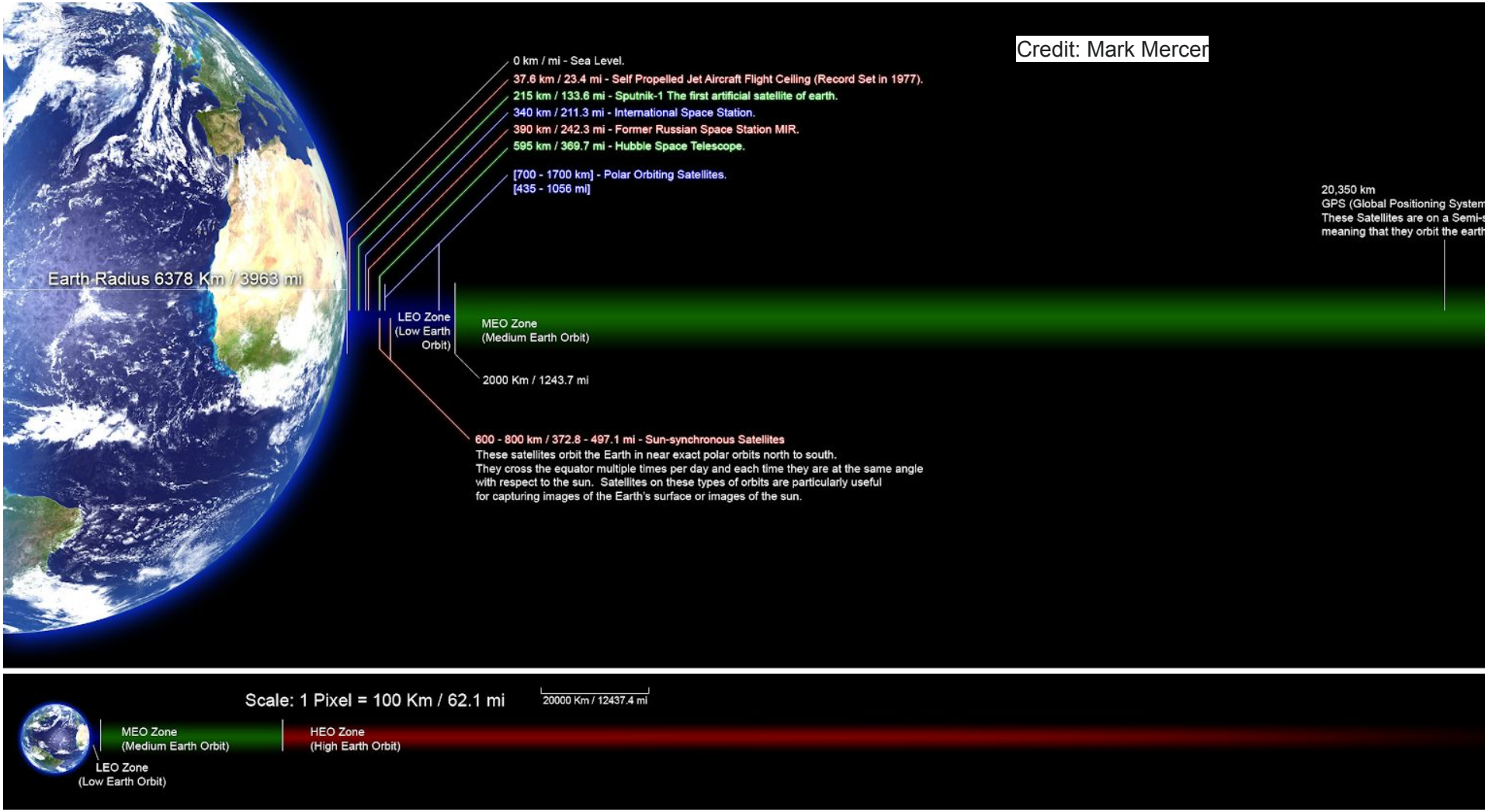
1.Wood, Lloyd, *Satellite constellation networks*, Internetworking and Computing over Satellite Networks. Springer, Boston, MA, 2003, p.13-34.

Important factor = signal latency - the time taken to signals to move from a ground station providing internet to the satellite and then on to a user.

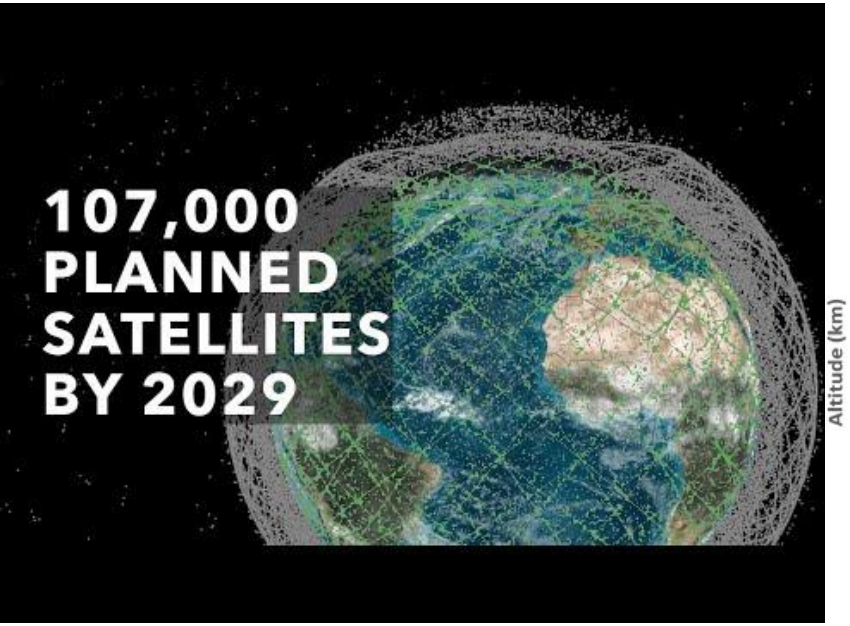
- Coverage on Earth
- Altitude of satellite
- Numbers of satellite units
- Power/ frequency / bandwidth etc.

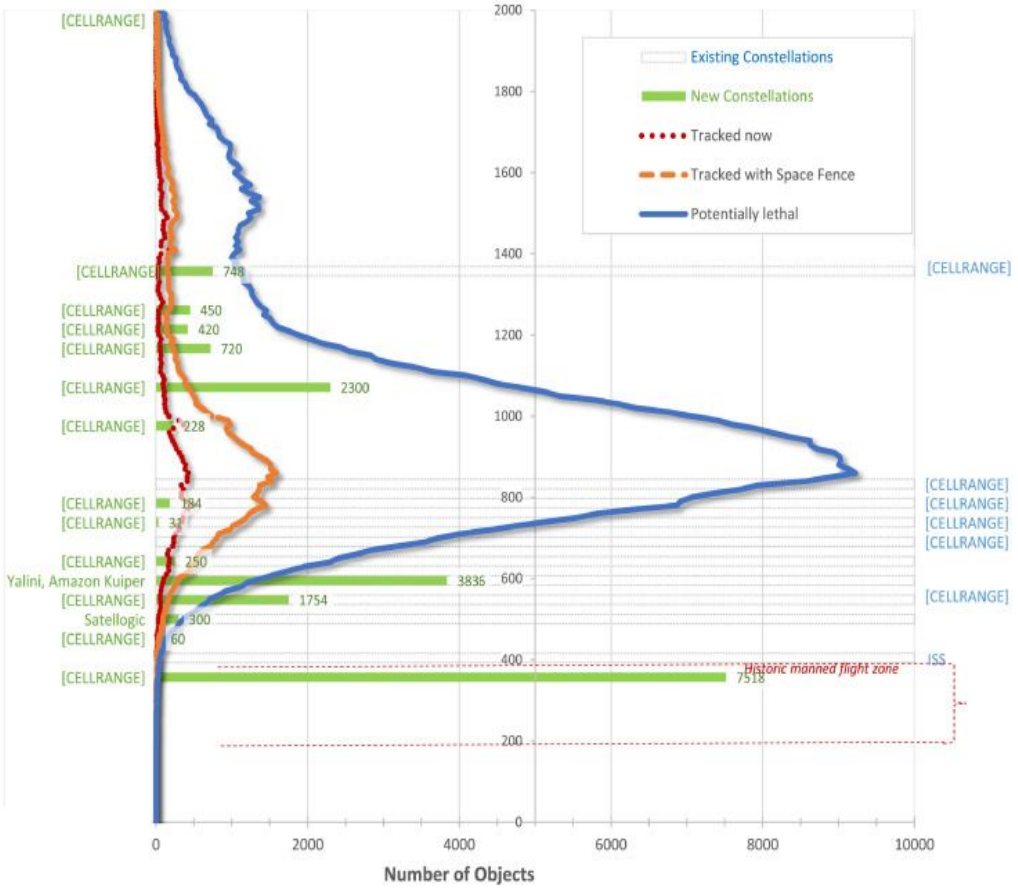


Low Earth Orbit



Growing Numbers of Satellites





Many problems other than impact on astronomy:

Space Traffic Management, Space Debris, Long Term Sustainability….

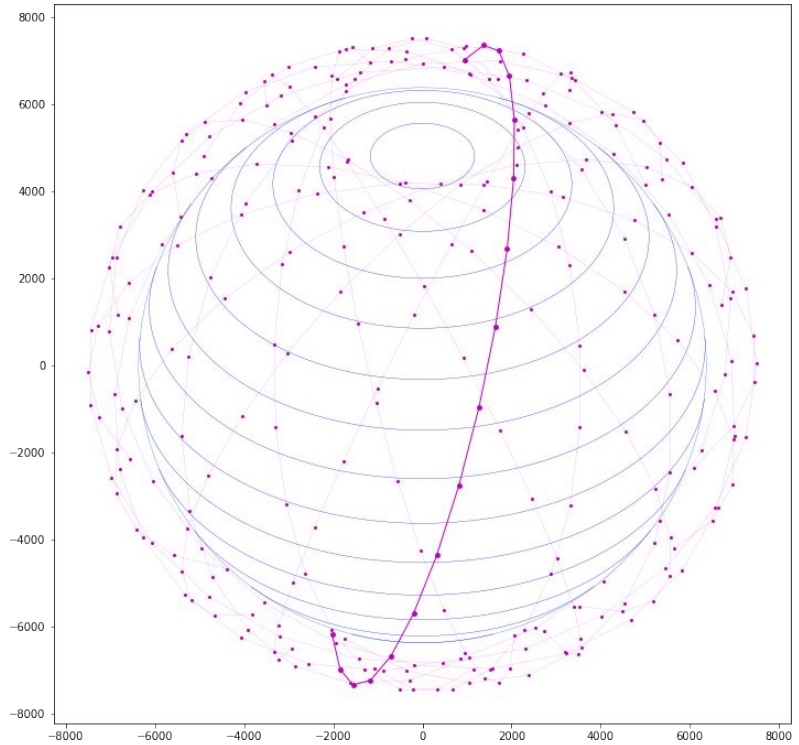
Muelhaupt, Theodore J., et al. "Space traffic management in the new space era." *Journal of Space Safety Engineering* 6.2 (2019): 80-87.

Simulating a constellation

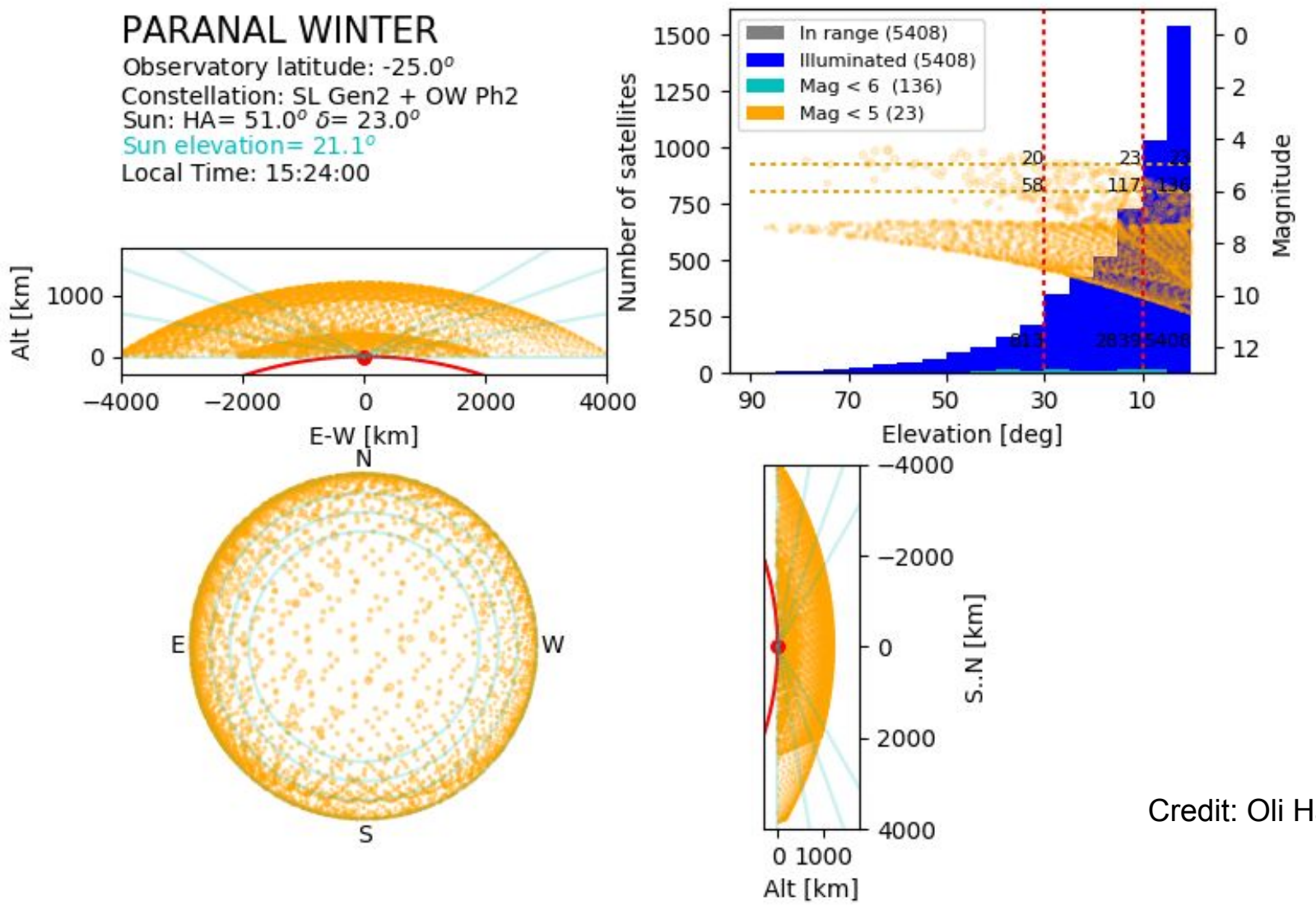
- How many satellites over the horizon at any given place on Earth?
- How many are illuminated by the sun?
- How bright are they?
- How many cross a telescope field of view?

Altitude [km]	Inclination [deg]	Planes	Satellites
328	30	84	7178
334	40	84	7178
345	53	84	7178
373	75	20	1998
499	53	40	4000
604	148	12	144
614	116	18	324
360	97	40	2000

Starlink Generation 2 (from May 2020 filing, JMcD Model III).

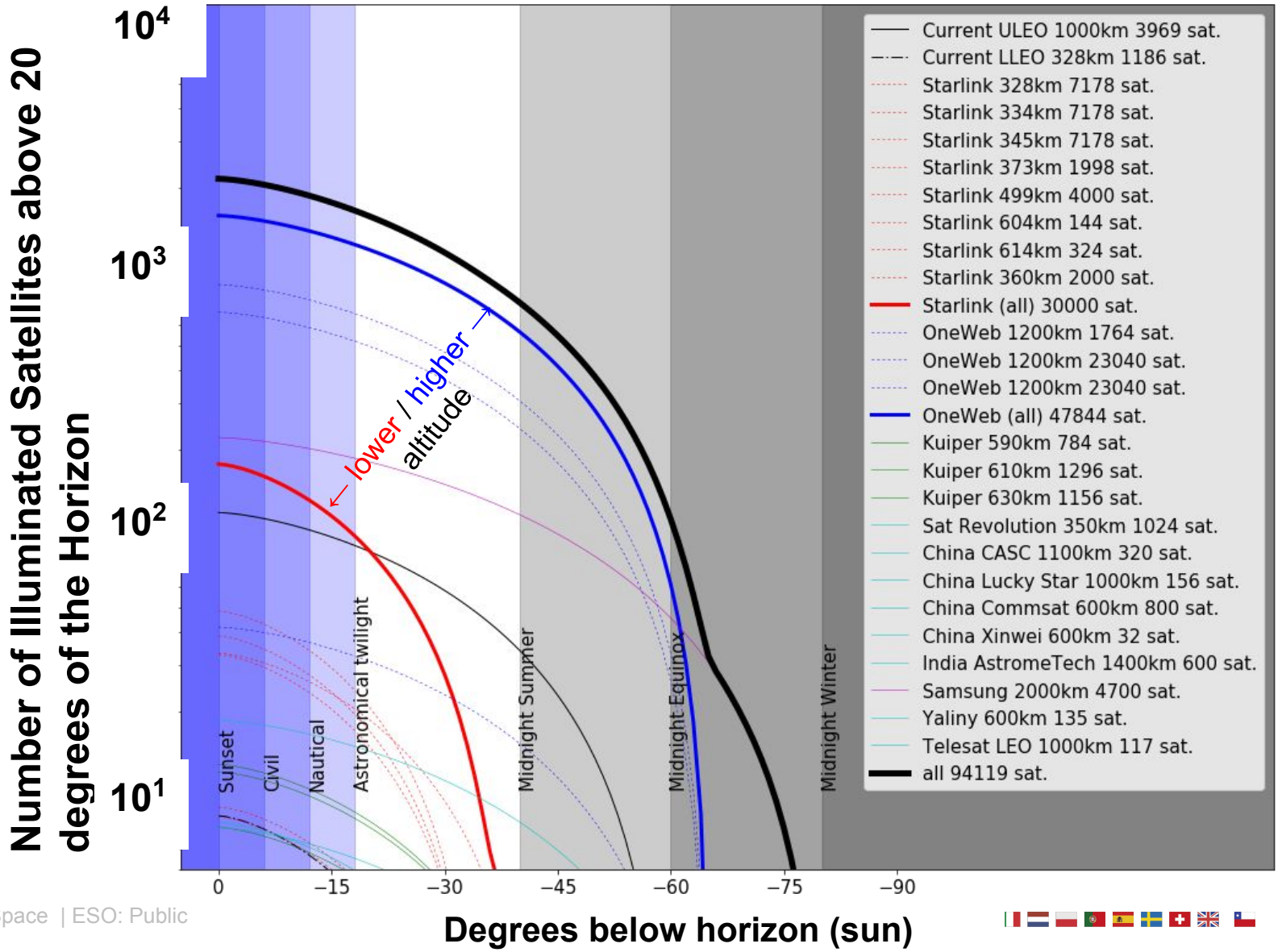


Simulating a constellation



Credit: Oli Hainaut

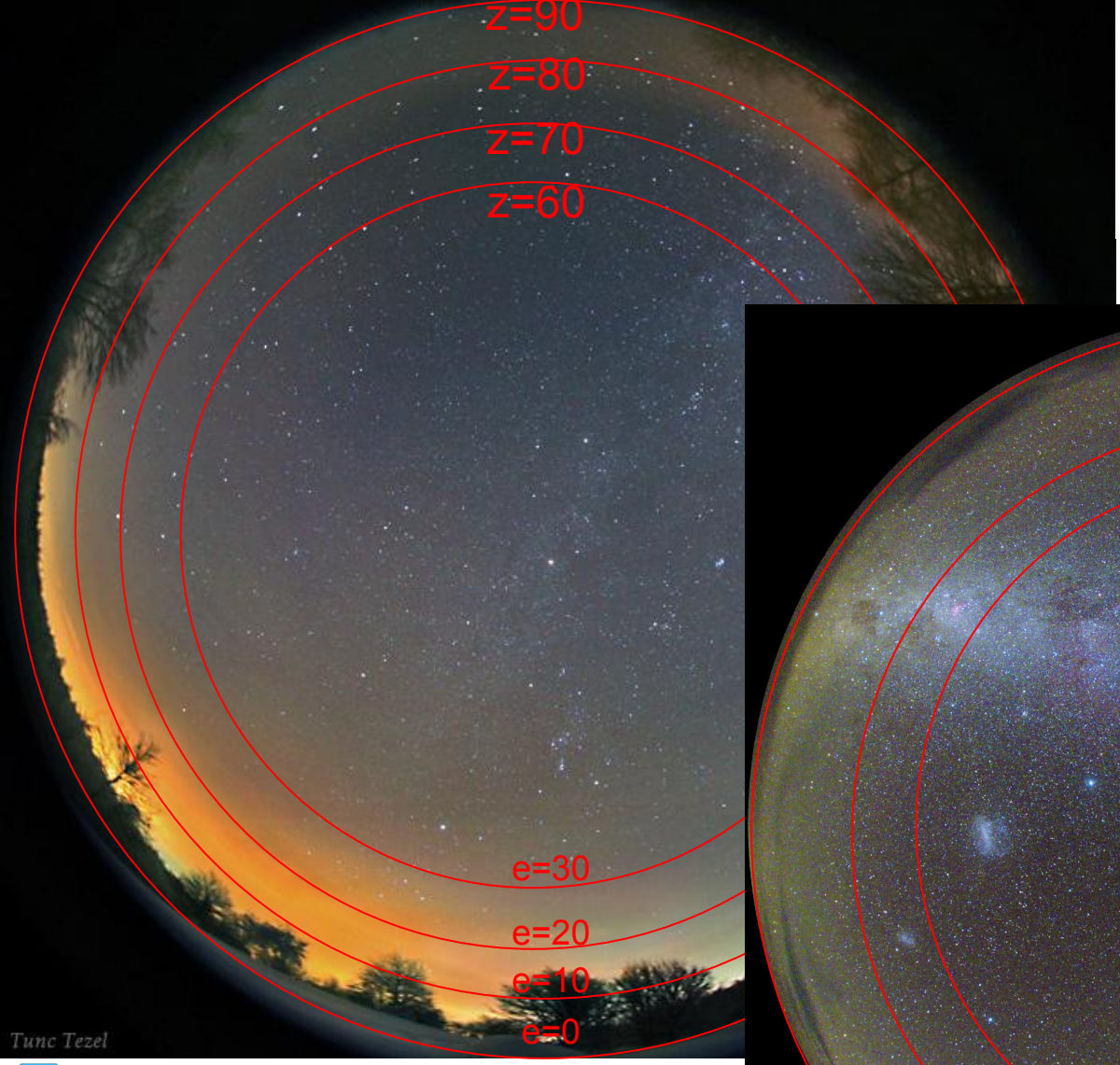
Current satellites & Future constellations



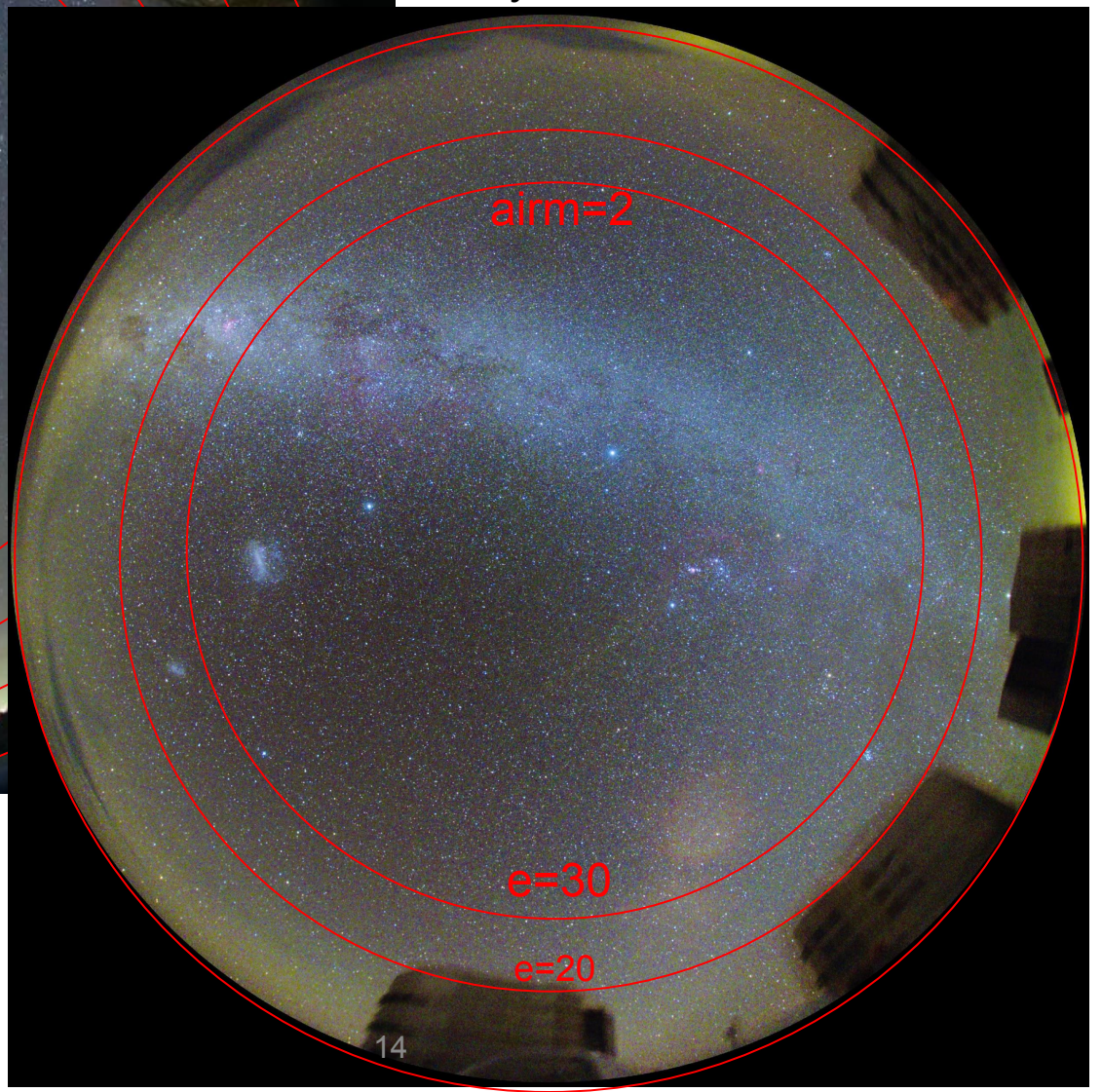
Pro: observations above

- 30º (Paranal: 96%)
- 20º (Surveys)

Amateurs: lowest 10º almost always lost



⬆️ Tunk Tezel TWAN.org
(it's a distant freeway junction)



ESO VLT Paranal ➡️

Astronomical Community Steps

- Initial studies, simulations, limited observations campaigns
- Understanding of mitigations
  - Scheduling tools
  - Science strategy
  - Shuttering, post-image analysis / trail removal
  - Darken satellites
  - Keep satellites low
  - Don’t launch them

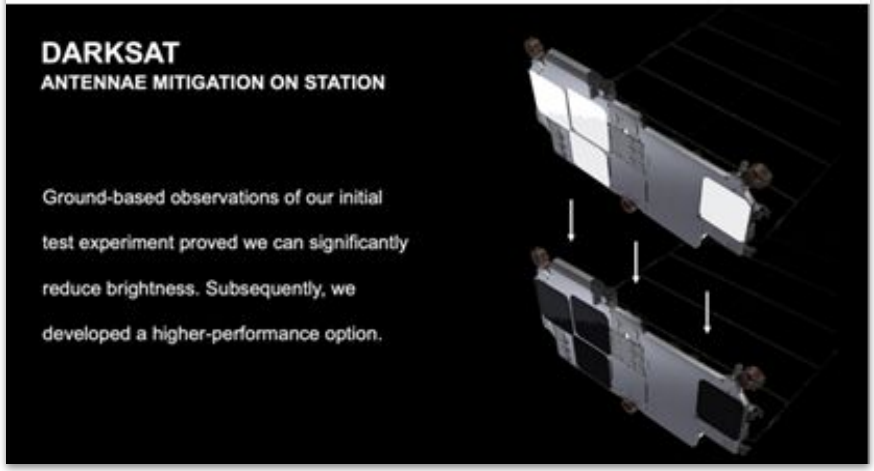
No combination of mitigations will avoid all impacts!

Astronomical Community Steps

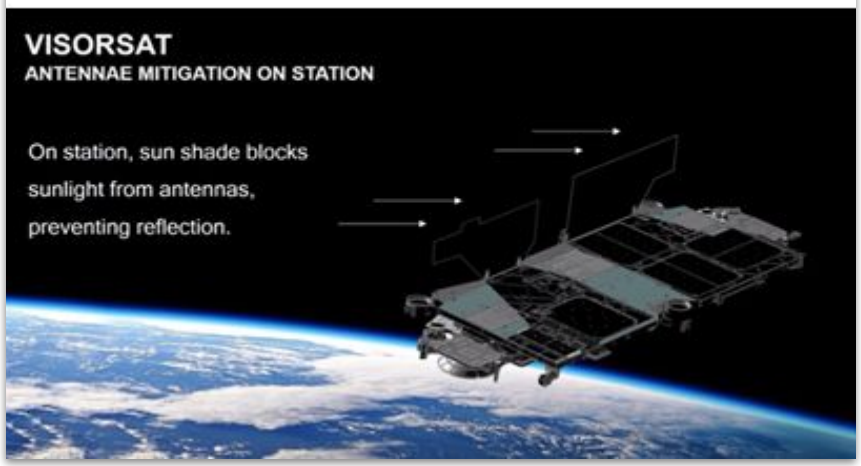
- NSF/AAS SATCON1 Workshop
- SATCON2 - Policy and Regulation
- UN/IAU Workshop on Dark Skies
- Many national working groups
- *Collaborative Work with Space Industry!*

SpaceX efforts to reduce visibility of Starlink

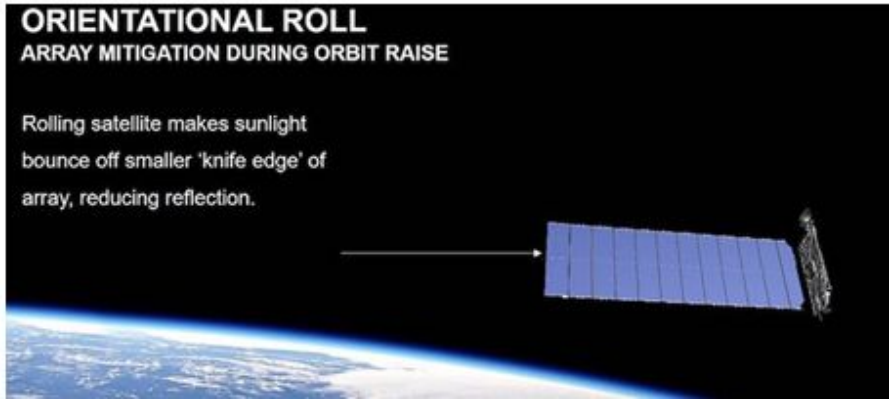
1. DARKSAT: black coating



2. VisorSat: Sun Shield



3. Attitude Control during orbit raise



"***I'm confident that we will not cause any impact whatsoever in astronomical discoveries, zero. That's my prediction. We'll take corrective action if it's above zero.***" – Elon Musk, CEO, SpaceX, quoted 3/10/20 BusinessInsider.com

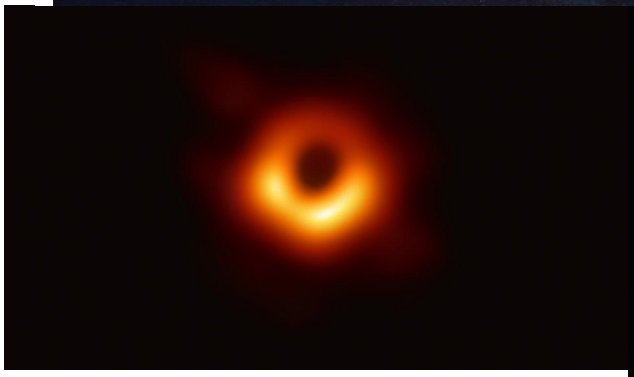
But...

Broader questions:

- Who has the “right” to the night sky?
- Who decides?
- How to balance access to sky for science with access for commercial or other purposes?

This Russian startup wants to put huge ads in space. Not everyone is on board with the idea.

Swarms of tiny, light-reflecting "cubesats" would come together to form luminous words or logos.



Work for future space professionals...

- Regulation
  - Space traffic, debris, space data
  - Radio and optical interference
- Continue interaction with industry
  - Regulation will take time
- Space industry corporate social responsibility
- Designing astronomy facilities in the satellite constellation era
- Applicability of Outer Space Treaty
  - Need for new guidelines?!

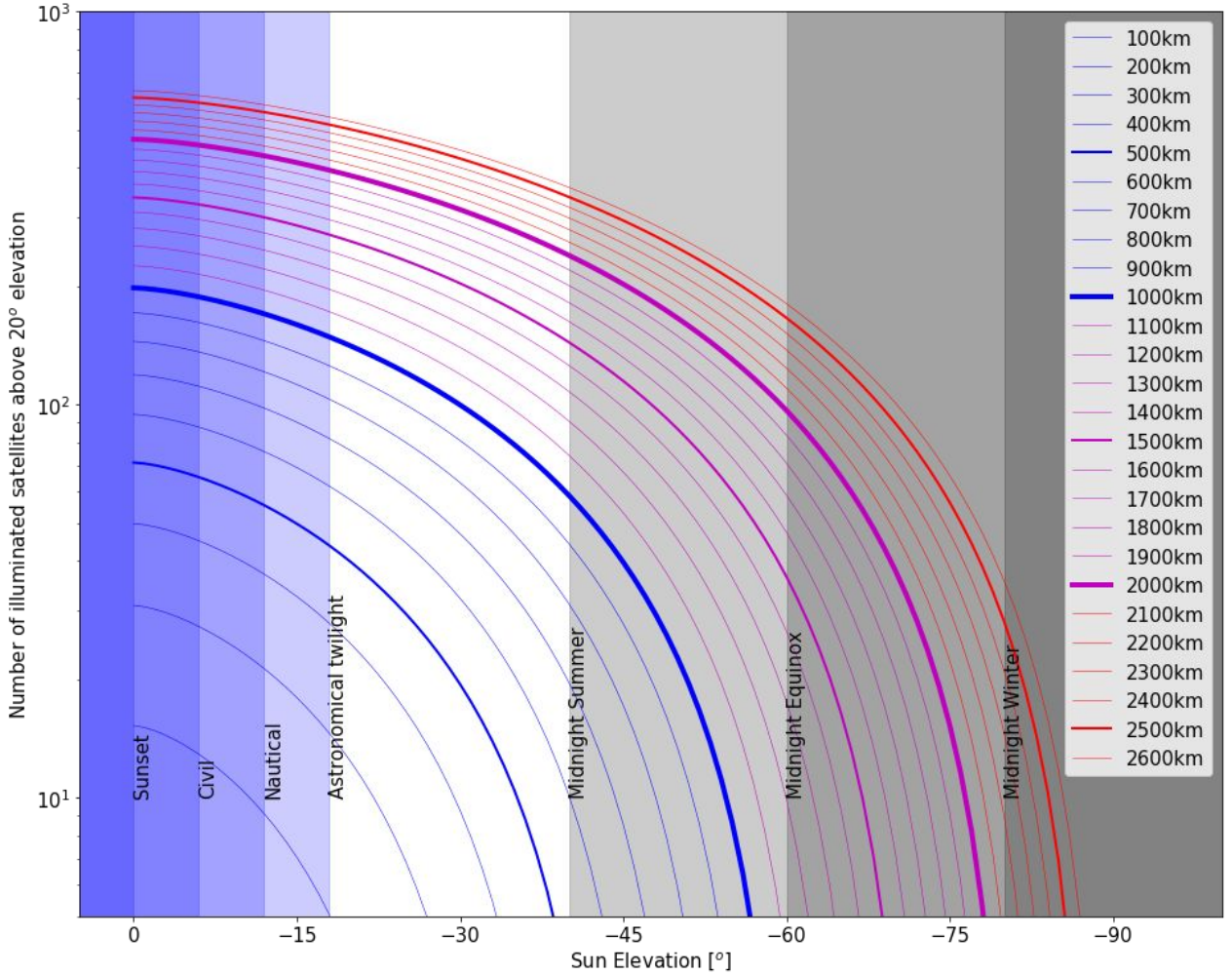
Outcome

...in 1 line

High-altitude satellites are a problem

Credit

Oli Hainaut



Fake constellations:

- 10 000 sat. each
- Altitude 100 → 2600km

Effect on the observations

...for some typical observations...

no observations ←|

Starlink2 + OneWeb2

Sun Elevation [deg]

					Sunset 0	Civil -6	Nautical -12	Astron. -18	Night ... -24	-30	-36	-42	-48	-54
Summer	FoV	x FoV	Exp.t	Local time	18:45	19:15	19:46	20:18	20:53	21:31	22:18	24:00	////////	
Equinox	FoV	x FoV	Exp.t	Local time	18:00	18:26	18:53	19:19	19:46	20:13	20:41	21:10	21:40	22:13
Winter	FoV	x FoV	Exp.t	Local time	17:14	17:43	18:11	18:39	19:07	19:34	20:01	20:28	20:55	21:22
				Nsat all	814.1	822.1	822.5	790.1	666.9	473.5	256.1	68.4	0.7	0
				Nsat bright	19.8	20	21.2	3.1	0	0	0	0	0	0
FORS/IMG	6 arcmin	6 arcmin	5 min		12.1%	12.2%	12.2%	11.7%	9.9%	7.0%	3.80%	1.01%	0.01%	0.00%
FORS/Sp	6 arcmin	2arcsec	30 min		23.7%	24.0%	24.0%	23.0%	19.4%	13.8%	7.45%	1.98%	0.03%	0.00%
UVES	10 arcsec	2 arcsec	30 min		0.66%	0.67%	0.67%	0.64%	0.54%	0.38%	0.21%	0.06%	0.00%	0.00%
VST	1 deg	1 deg	5 min		854%	862%	862%	828%	699%	496%	269%	71.7%	0.75%	0.00%
QMOST	2.3 deg	2.3 deg	20 min		46.70	47.16	47.18	45.32	38.26	27.16	14.69	3.92	0.04	0.00
	Number of fibers				58.6	59.1	59.2	56.8	48.0	34.1	18.4	4.9	0.1	0.0
	% of fibers				2.40%	2.43%	2.43%	2.33%	1.97%	1.40%	0.76%	0.20%	0.00%	0.00%
LSST all	3 deg	3 deg	30 s		7339%	7411%	7414%	7122%	6012%	4268%	2309%	617%	6.32%	0.00%

- Fraction of frames hit by a trail
  - Any magnitude, even if faint
  - > 100%: number of trails / frame

Constellations plans in LEO

Starlink Generation 2
(May 2020 filings)

Altitude [km]	Inclination [deg]	Planes	Satellites
328	30	84	7178
334	40	84	7178
345	53	84	7178
373	75	20	1998
499	53	40	4000
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614	116	18	324
360	97	40	2000

30 000 satellites
average altitude: **366 km**

OneWeb Phase 2
(May 2020 filings)

Altitude [km]	Inclination [deg]	Planes	Satellites
1200	87.9	36	1764
1200	40.0	32	23040
1200	55.0	32	23040

47 844 satellites
average altitude: **1200 km**

...and Amazon Kuiper, Telsat, Planet, Samsung, US Military, China,....

Astronomical Observatories