

Satellite constellations and astronomy



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Satellite constellations

Satellites have always been an issue for astronomy.

West Ford (1961-63) launched 480,000,000 2cm-long dipoles to reflect 8GHz (3.5cm) signals, some still in orbit - only stopped because of a global outcry.

The Iridium satellite constellation interferes with radio astronomy observations at 1.6GHz in the protected band

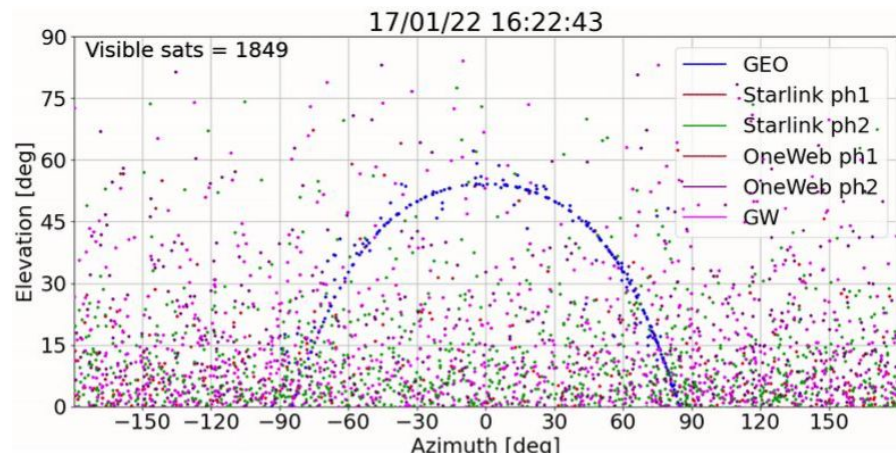
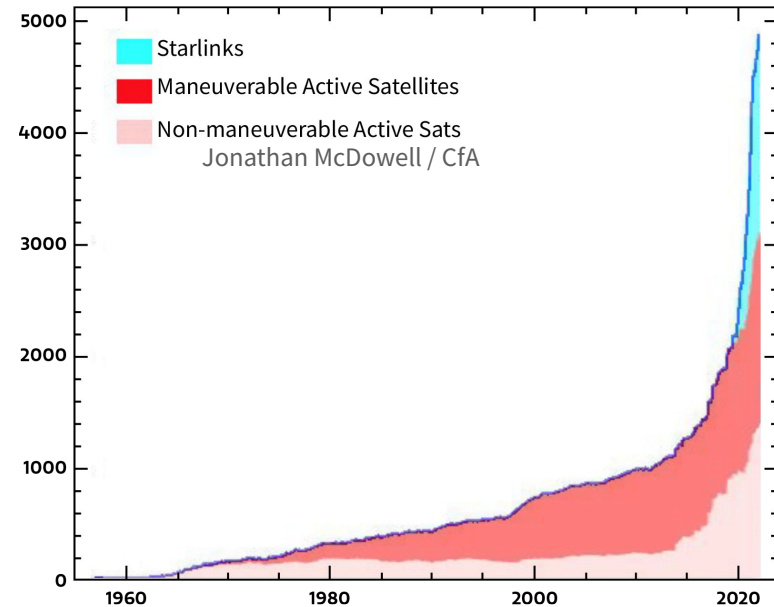
The WMAP CMB satellite is one of many that are frequently seen by optical telescopes.

... and that was before Starlink started launching in 2019. We now have **twice the number of satellites in the last 5 years**.

Mega constellations came as a surprise to astronomy!

Proposals are for **over 100,000 new satellites in the next decade**, via Starlink/OneWeb/Kuiper/... Increasing number of companies thinking about this!

Also: military links (e.g., US military interest in Starlink, live demo of Starlink in Ukraine...)



Accidental optical light

Constellations have a **significant effect in optical and infrared.**

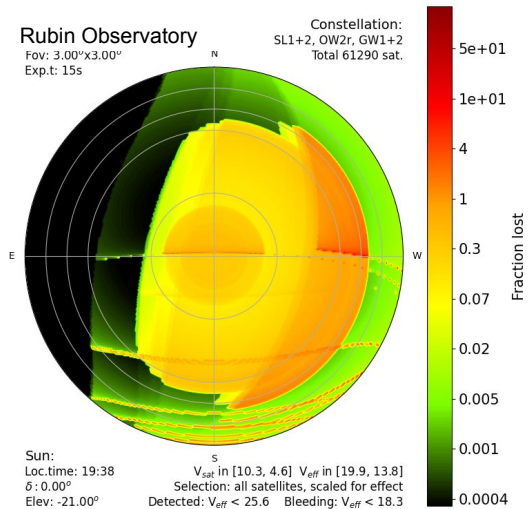
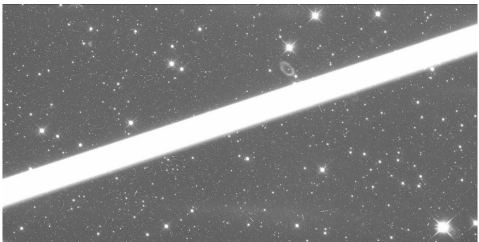
Particularly **reflections from the sun** in late evenings / early mornings

Up to $V=+3$ in parking orbits. **Need 7th magnitude** or better.

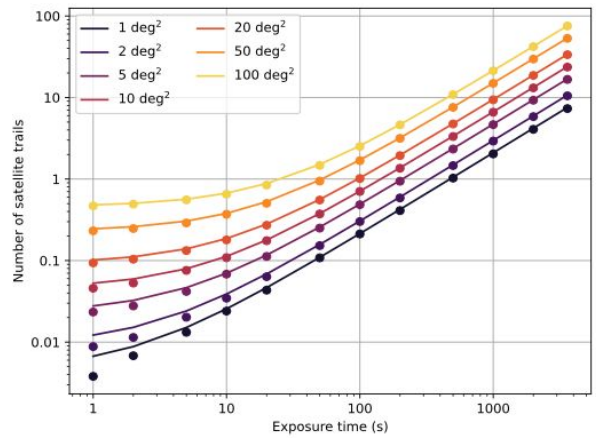
Significant effect on future optical telescope surveys like LSST with Vera C. Rubin Observatory.

Very clear examples of impact already....!

Even seen with Hubble...



SATCON2 algorithms report



Bassa et al.
arXiv:2108.12335

Satellite	Operational altitude [km]	Mag at op. alt.	Mag dispersion	Mag at 1000km
Starlink original	550km	4.6	0.7	5.9
		4.0	0.7	5.3
		4.2	(model)	5.5
Starlink DarkSat	550km	5.1	(single)	6.4
Starlink VisorSat	550km	6.2	0.8	7.5
		5.8	0.6	7.1
OneWeb	1200	7.6	0.7	7.2

Active radio transmissions

QUIJOTE observes the **oldest light in the universe**, and **our Galaxy on the largest angular scales**.

Geostationary satellites are **brighter than the Sun** (even in 2012) - we mask $\sim 10^\circ$ around $\text{dec}=0$ as a result.

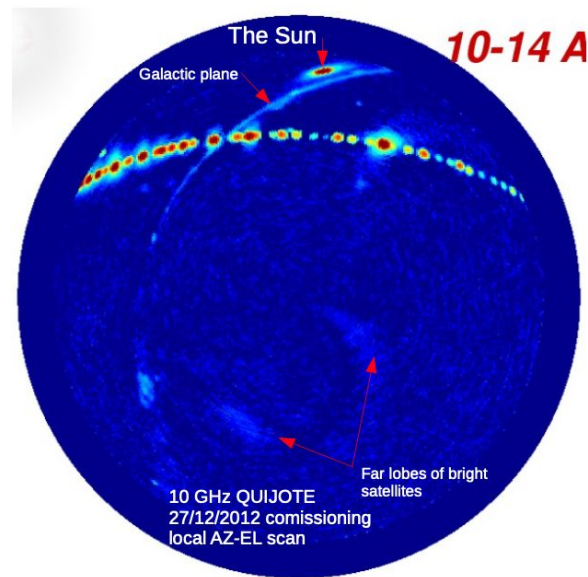
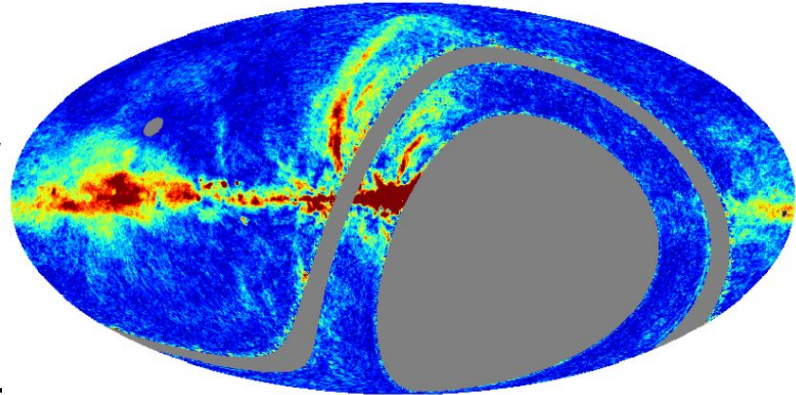
A bigger problem: **Sidelobes** can be seen **well away from the position the telescope is pointing**.

This **significantly affects large angular scale observations**.

Even though we use **special radio telescopes that minimize sidelobes** at the 99% level. Extra baffles helped, but won't solve the problem completely.

Except now, **satellites are everywhere**, plus moving fast, difficult to predict impact. Can no longer depend on quiet zones + distance from people to minimise impact!

SKA ($>€1\text{bn}$) will also see these. Maybe **CMB S4** ($\sim €1\text{bn}$)? Also many other telescopes, such as the Sardinia Radio Telescope, Yebez, ... - any observing at these frequencies!



What we can do

Not much alone... need to work with industry

corporate interests and politics > astronomy and pure research.

SATCON and D&QS meetings in 2020-21 have been discussing this, with significant IAC involvement. Each meeting produced a report (available at, e.g., <https://noirlab.edu/public/products/techdocs/>), for IAU and COPUOS (UN).

IAC was involved in scientific and technical meeting of **COPUOS** in February. Now an agenda item for STSC the next year - which is a big deal. Combines involvement of Government of Spain + UN + IAU.

Radio frequency protection is through the **International Telecommunication Union**. **No legal optical protection.**

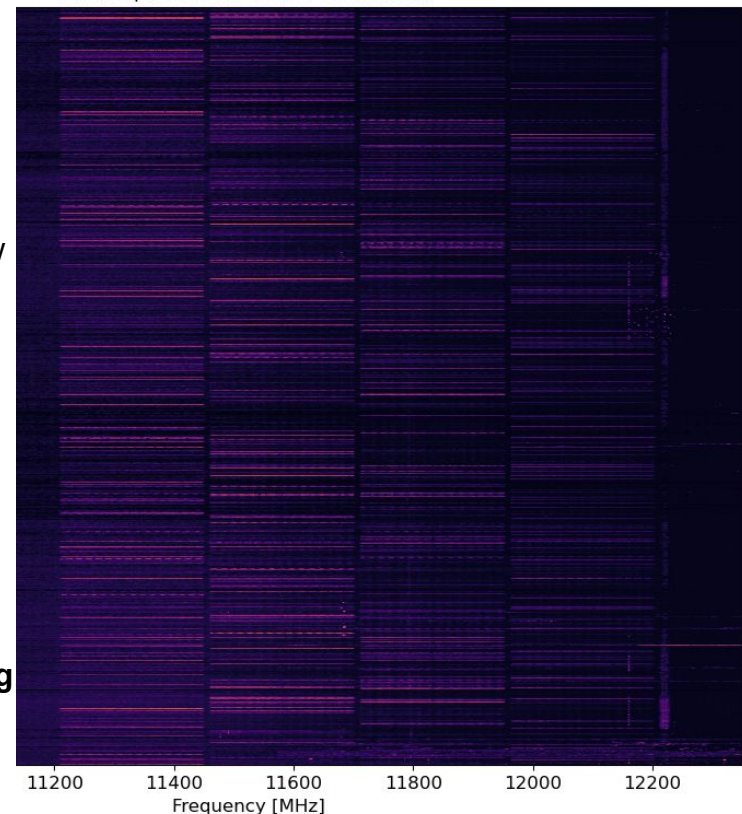
Needs **high-level political involvement** to widen protected frequency bands, against a background of commercial interest

Some engagement from Starlink: 'Darksat' (painting satellite black) didn't work - thermal issues. Adding visors helped reduce reflections - but **latest generation have no visors** (got in the way of new laser links between satellites): **add 0.5 mag**
Also, no required involvement - will future operators do the same?

Urgently need data to see exactly how bad the situation is! Highly variable, broad-band.

(Plot courtesy Federico Di Vruno, SKAO)

Data Capture: 2020-06-25 to 2020-06-27



New IAU Centre for the Protection of the Dark and Quiet Sky from Satellite Constellation Interference.

Led by **NOIRLab** (USA) and **SKAO** (UK), with
'Contributing Members' and 'Affiliated Members'.

Co-directed by Connie Walker & Federico Di Vruno

Four hubs:

- **SatHub** (lead: Meredith Rawls, Washington)
 - Collection & analysis of satellite observations
 - Software tools
 - Training + outreach
- **Policy** (lead: Richard Green, Arizona)
 - Coordinate policy action & diplomacy
- **Community Engagement** (lead: Jessica Heim, Queensland)
 - Beyond professional astronomers
- **Industry and Technology** (lead: Chris Hofer, Amazon)



<https://cps.iau.org/>

Next steps at IAC

Optical monitoring ongoing by IAC80 and TCS (griz) + optical satellite detection code (SATRED) + links with satellite tracking (ask Olga Zamora!)

Start monitoring the RF environment? Planning to do this asap with personal 60cm satellite dish + LNB + Raspberry Pi. Ultimate test is when QUIJOTE MFI2 starts observing (later this year).

Could we formally register OT (and ORM?) with the ITU as a site needing special radio frequency protection? - Jose Alberto is working on this. Also possible to request satellites be turned off over site? (but would need >500km exclusion range?)

Currently informal (being formalised?) involvement with IAU center from:

- Casiana Muñoz Tuñon (+ formal on steering group)
- Toñi Varela (Fundacion Starlight / Sky Quality Group)
- Olga Zamora (optical + involvement in SEA ICOSAEDRO group)
- Mike Peel (radio)
- and you? Get in touch! mpeel@iac.es

(Meetings on this topic so far has been remote due to the pandemic + La Palma eruption: I've never met most people working on this. **Good example of remote collaboration!**)