https://www.sea-astronomia.es/grupo-de-trabajo-sea-icosaedro

GRUPO DE TRABAJO SEA ICOSAEDRO

SEA-ICOSAEDRO

Impacto de las Constelaciones de SAtélites En Detectores de Radio y Ópticos (Impact of Satellite Constellations on Radio and Optical Detectors)

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- **David Galadí Enríquez**: Observatorio de Calar Alto, IAU commission CB7 (Observatory Site Protection)
- **Daniel Marín Arcones**: astrophysicist, Consejería de Educación, Universidades, Cultura y Deportes del Gobierno de Canarias
- **Jorge Núñez de Murga**: Universitat de Barcelona, Observatori Fabra (Reial Acadèmia de Ciències i Arts de Barcelona), IAU commission A1 (Astrometry)
- **Olga Zamora Sánchez**: astrophysicist, Instituto de Astrofísica de Canarias; IAU, Division B (Installations, Technologies and Data Science)

Impact of artificial satellite mega-constellations on astronomical observation, optical and radio Gathering
Gathering nformation from relevant sources
Performing simulations to evaluate the impact
Improving the impact models through observations

1. Artificial satellites from the ground

Spotted every night, after dusk, before dawn

Some are really outstanding: ISS, Iridium flares (these no longer happen)

Predictions for general public:
https://heavens-above.com

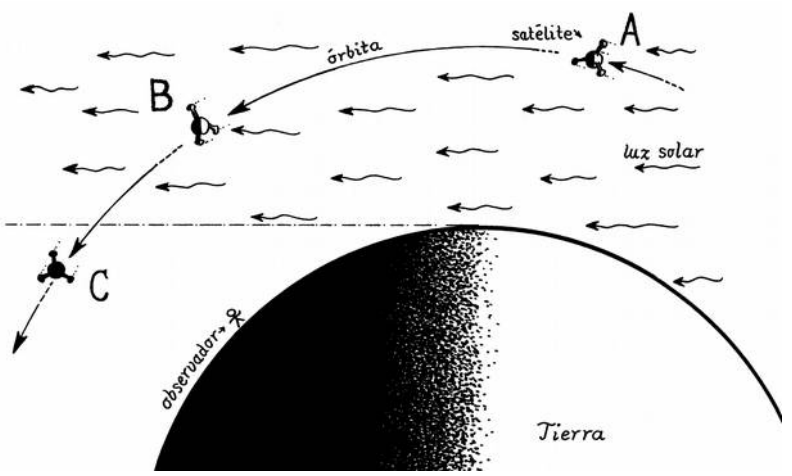

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Foto: Juan Carlos Casado starryearth.com

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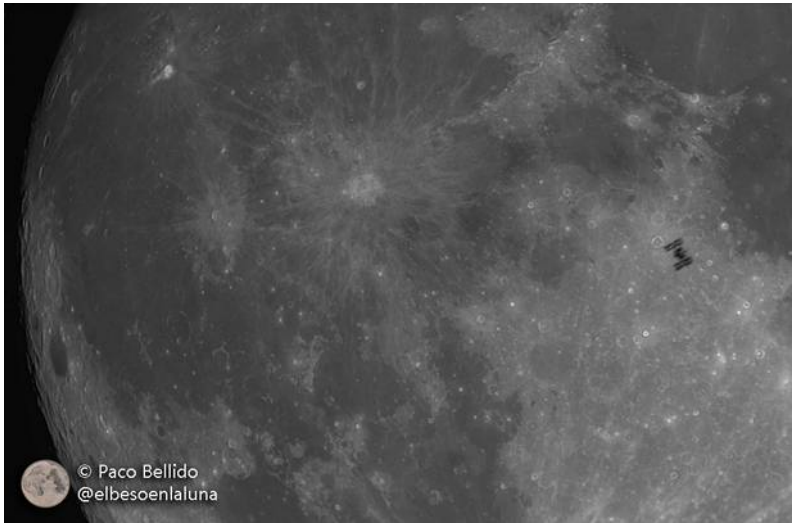

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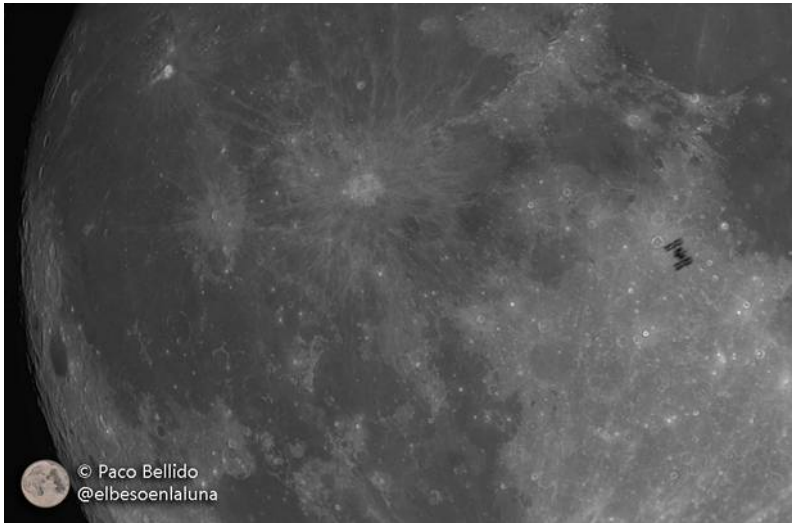
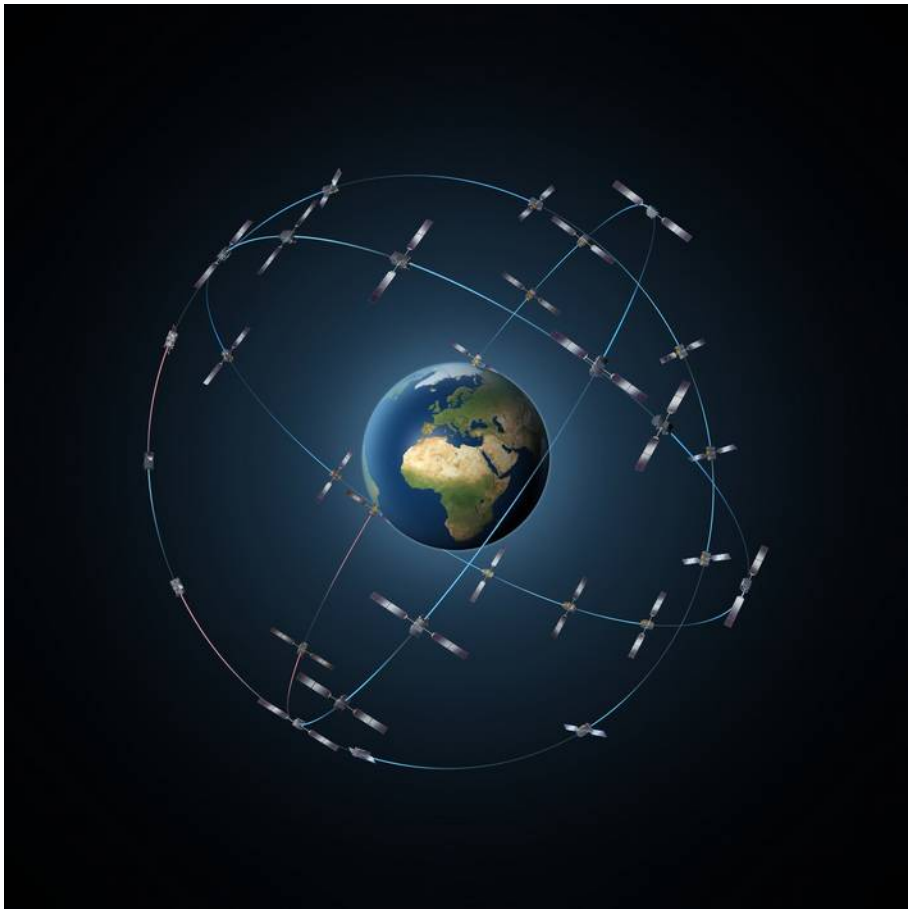


Photo: Juan Carlos Casado starryearth.com

2. Satellite constellations

- Groups of satellites of identical design, distributed in orbits to provide the best land coverage.
- Providing global positioning (GPS, Glonass, Galileo, Beidou) of telecomunication servicies (Iridium)
- Always less than 100 satellites



Pho: European Space Agency

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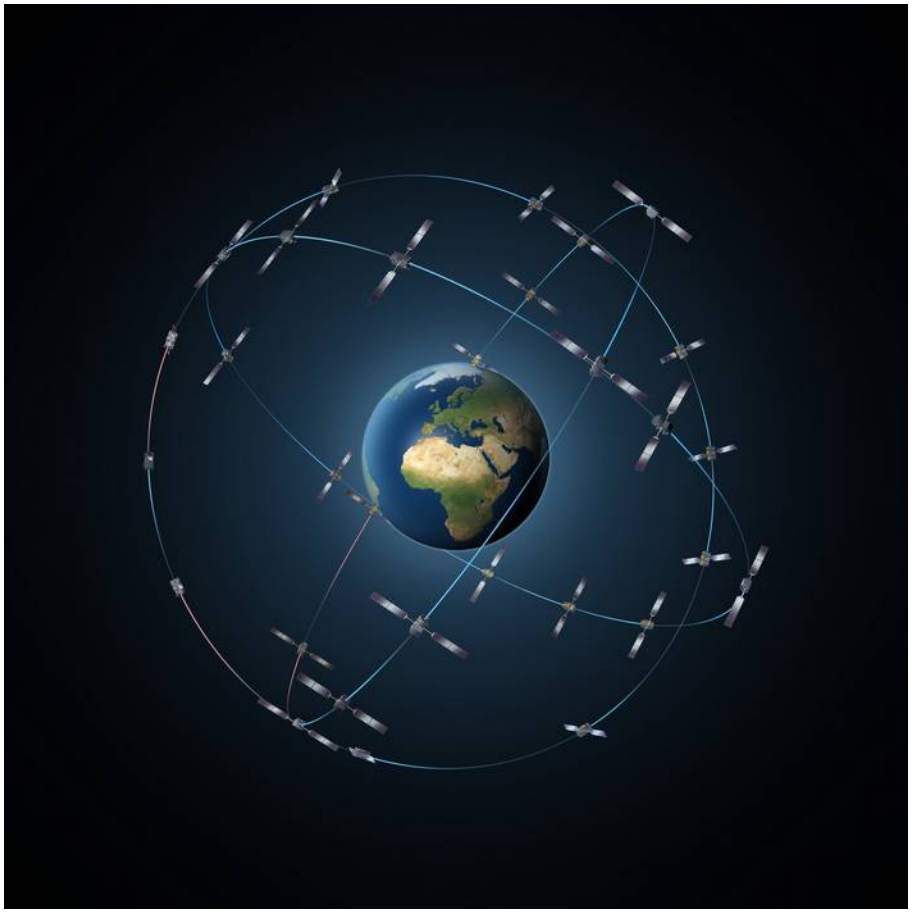
- Currently: some 22 000 artificial objects around the Earth
- Only 2300 of them are active, functioning, satellites

Mega-constellation projects: **from 12 000 to more than 45 000** satellites may be launched during the next years.



Pho: European Space Agency

3. Some projects

Proposed internet satellite constellations[7]

Constellation	Manufacturer	Number	Weight	Unveil.	Avail.	Altitude	Offer	Band	Inter-sat. links
Boeing	Boeing Satellite	1,396-2,956	N/A	2016	N/A	1,200 km 745 mi	broadband	V (40 – 75 GHz)	none [8][9]
LeoSat	Thales Alenia	78-108	1,250 kg 2,755 lb	2015	2022	1,400 km 895 mi	100 Mbit/s increments	Ka (26.5 – 40 GHz)	optical [10]
OneWeb constellation	OneWeb Airbus JV	882-1980[11]	145 kg 320 lb	2015	2020[12]	1,200 km 745 mi	up to 595 Mbit/s[12]	Ku (12–18 GHz) Ka (26.5 – 40 GHz)	none [13][14]
Starlink	SpaceX	4,425-11,943	260 kg	2015	2020[15]	550-1,325 km 341-823 mi	up to 1 Gbit/s[16]	Ku (12–18 GHz) Ka (26.5 – 40 GHz)	optical[17]
O3b mPower (SES S.A.)	Boeing	7		2017	2021	8,000 km 4,970 mi	1 Gbit/s for a cruise ship 45°S to 45°N	Ka (26.5 – 40 GHz)	none
Telesat LEO	Airbus SSTL SS/Loral[a]	117-512[18]	N/A	2016	2021	1,000–1,248 km 621–775 mi	fiber-optic cable-like	Ka (26.5 – 40 GHz)	optical [19][20]
Hongyun[21]	CASIC	156		2017	2022	160–2,000 km 99–1,243 mi			
Hongyan[22]	CASC	320-864[23]		2017	2023	1,100–1,175 km 684–730 mi			
Project Kuiper	Amazon	3236		2019		590–630 km 370–390 mi	56°S to 56°N[24]		

a. ^ first two prototypes

3. Some projects

# Orbit (km)	Number sats	Inclination	Size(m)	Albedo
328	7178	30	1.0	0.25
334	7178	40	1.0	0.25
345	7178	53	1.0	0.25
373	1998	75	1.0	0.25
499	4000	53	1.0	0.25
604	144	148	1.0	0.25
614	324	116	1.0	0.25
360	2000	97	1.0	0.25
1200	1764	87.9	1.0	0.25
1200	23040	40	1.0	0.25
1200	23040	55	1.0	0.25

Starlink 2: 30 000

One Web 2: 47826

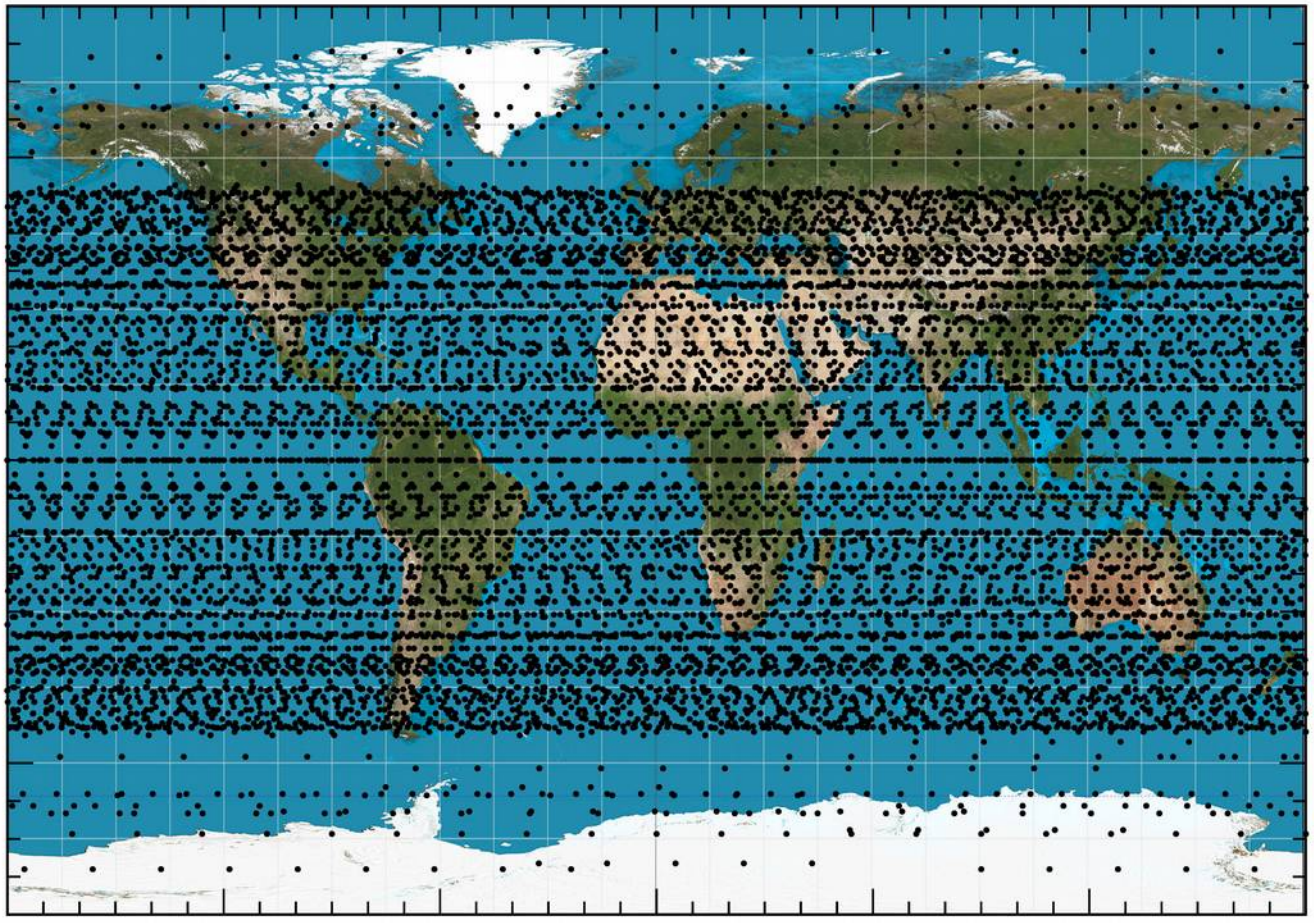
3. Radio astronomy

- Concerns about interference or even damage to detectors
- Primary radio astronomy band 10.6-10.7 GHz (main mega-constellations downlink is at 10.7-12.75 GHz)
- Spectral line 14.47-14.50 GHz (main mega-constellation uplink at 14.00-14.50 GHZ)
- Electronic Communications Committee (report ECC 271) approved this, what makes this legally binding, at least in Europe
- Possible changes in constellation design: need to follow
- International Telecommunications Union (ITU) decided satellite operation sharing with the primary radio astronomy band 42.5-43.5 GHz
- There are bands not reserved for astronomy, but interesting, and they are also endangered: Committee on Radio Astronomy Frequencies (CRAF) considers requesting some special protection

5. Study case: Starlink phase 1, 12 000 sats

Shell altitude (km)	Sats in shell	Inclination (º)
550	1584	53
1110	1600	53.8
1130	400	74
1275	375	81
1325	450	70
335.9	2493	42
340.8	2478	48
345.6	2547	53

5. Study case: Starlink phase 1, 12 000 sats



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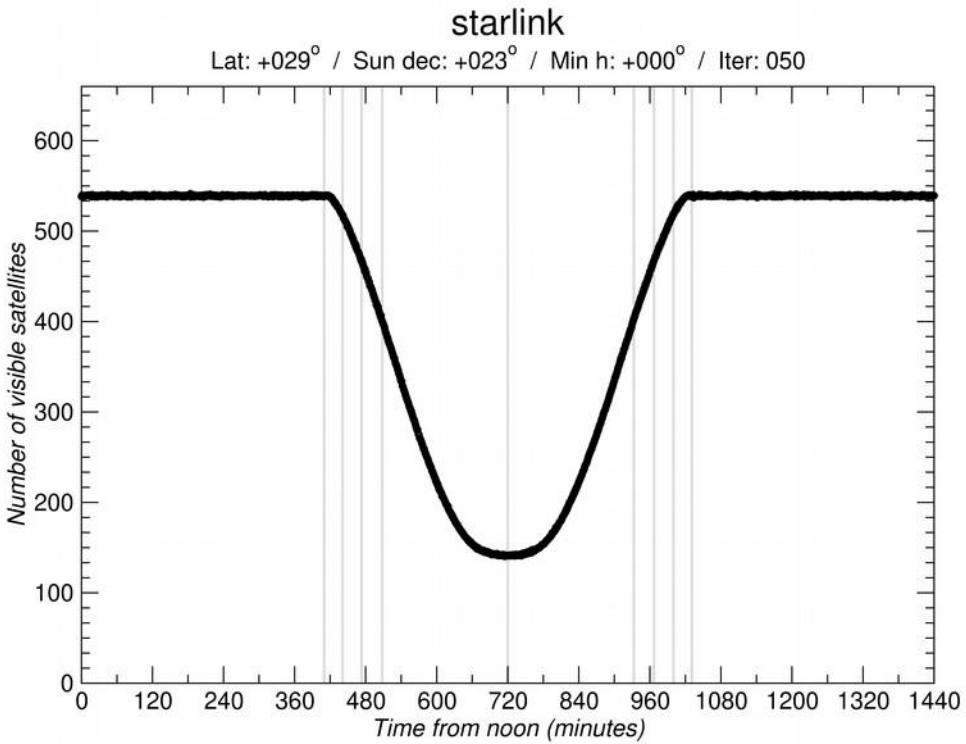

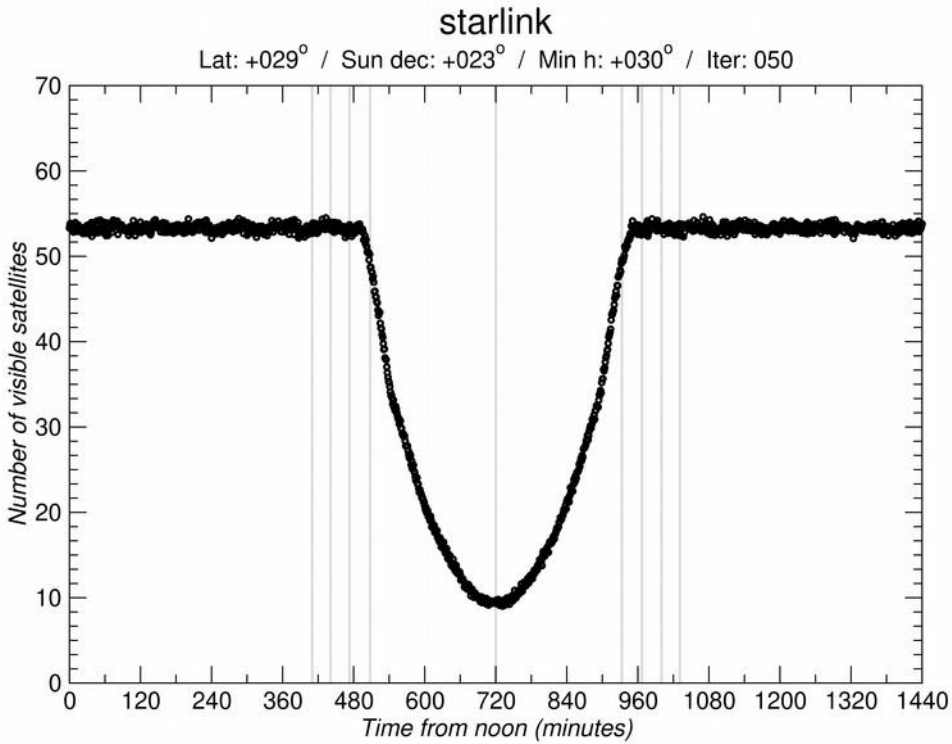

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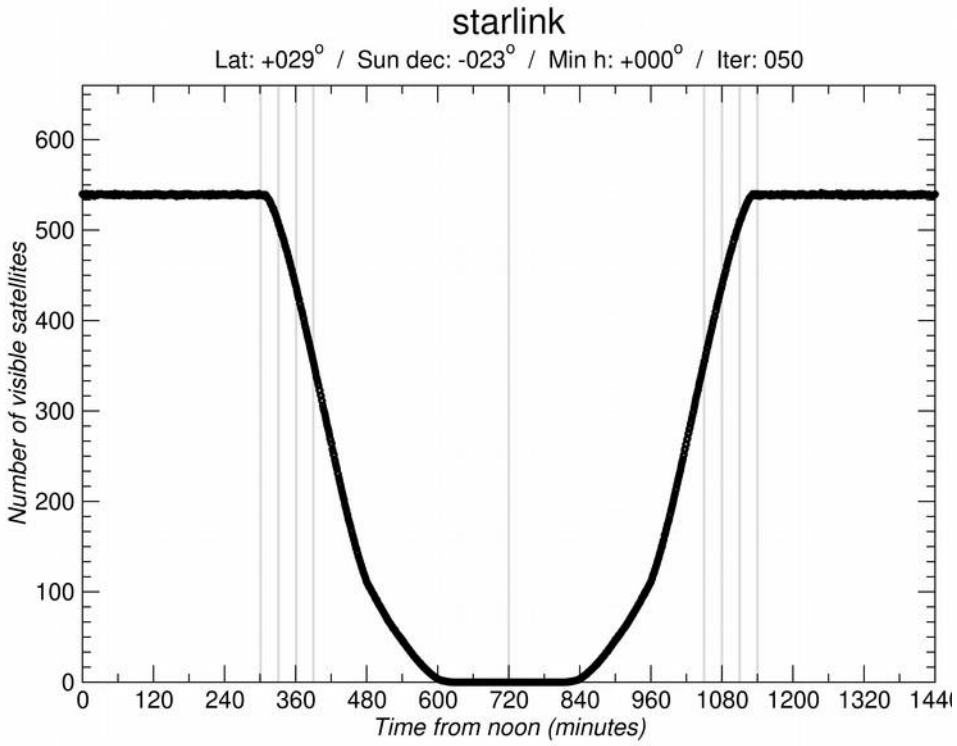

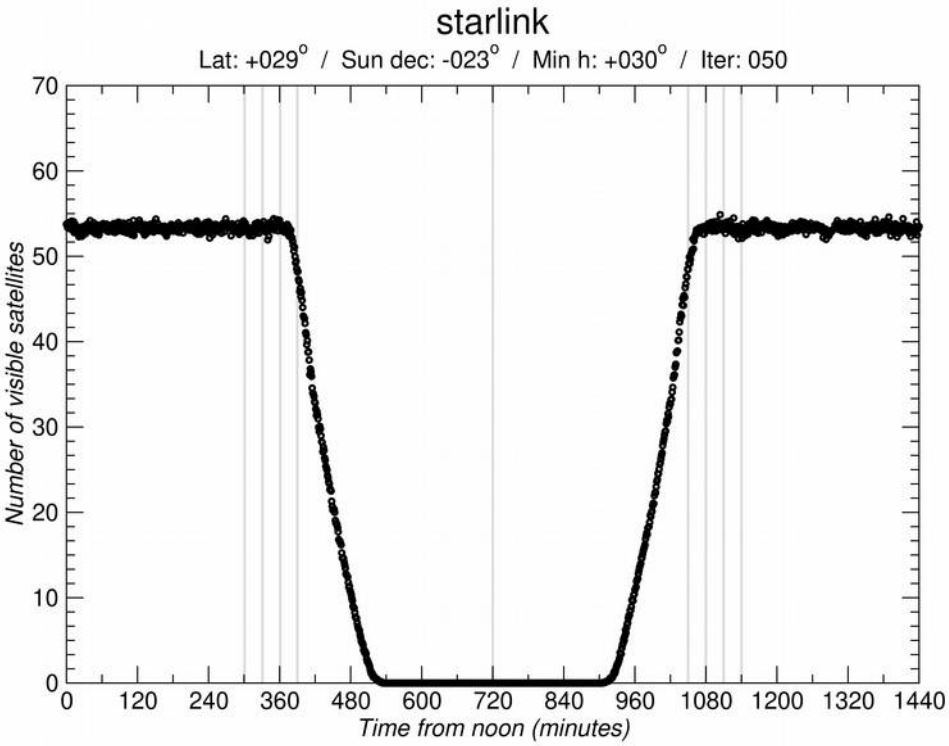

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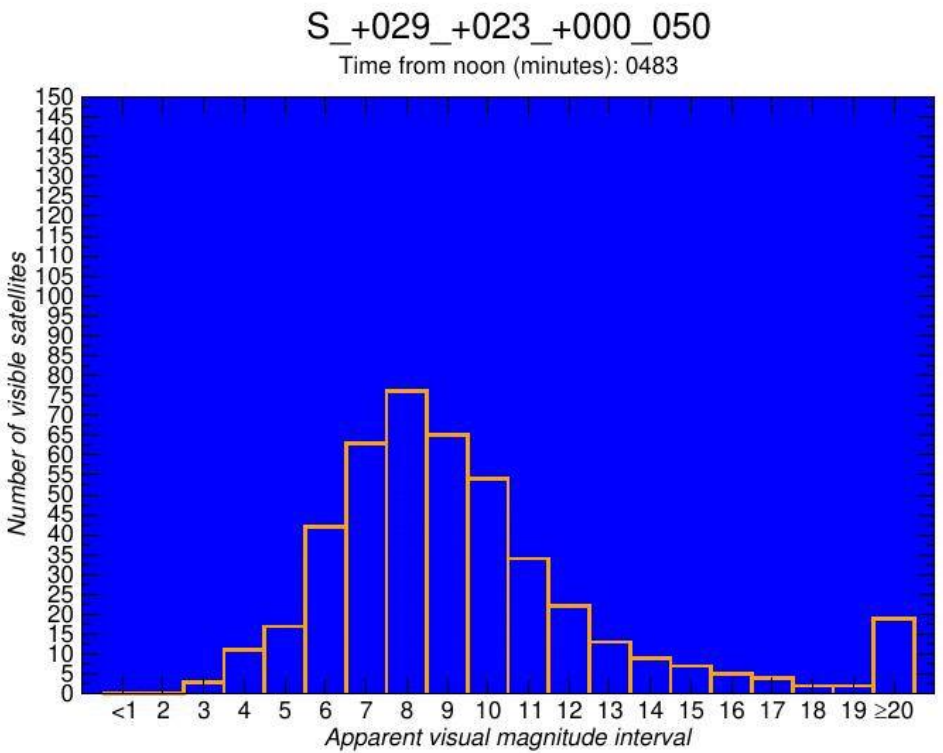

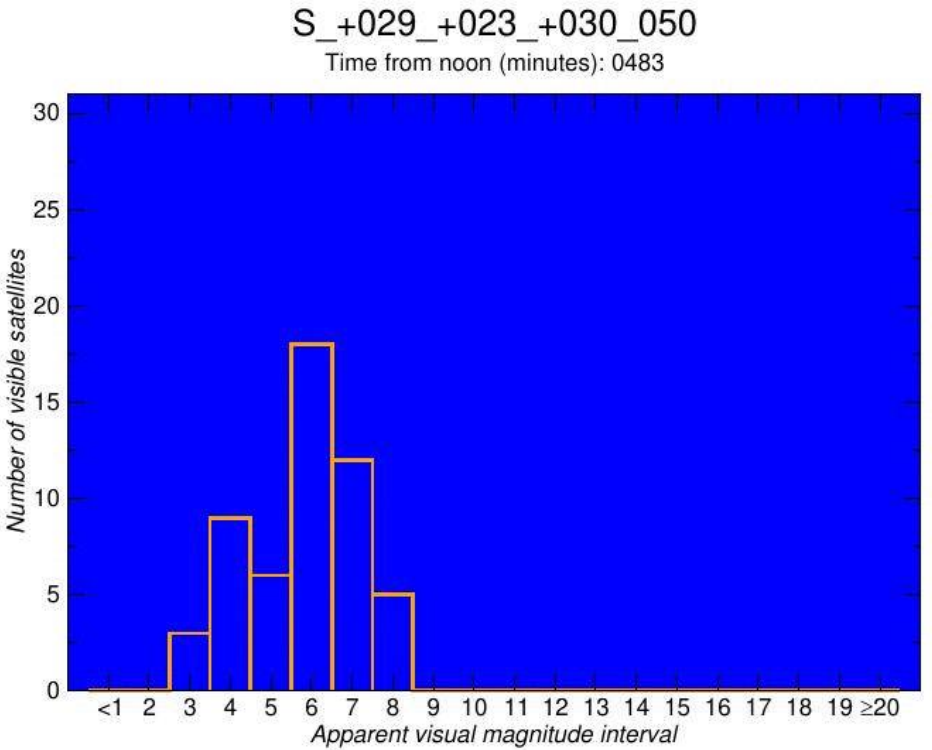

Constellation profile: starlink.dat
Statistics over 0100 crossings

		***Latitude*= +040 °**		***FOV*= 0144 ’**	***T*= 0060 s**		***Sun delcination*= +023 °**		
			PM			**AM**			
	***Sun elevation* →**	**-12°**	**-25°**	**-37°**	**-37°**	**-25°**	**-12°**	**← *Sun elevation***	
S	Crossing expectance	0000.43	0000.04			0000.04	0000.39	Crossing expectance	**S**
	Expected path (’)	0046.03	0003.37			0003.28	0041.20	Expected path (’)	
	V (mag)	04.39±01.15	06.13±00.04			06.13±00.04	04.32±01.11	*V* (mag)	
	Speed (’/s)	37.26±16.60	11.83±00.15	00.00±00.00	00.00±00.00	11.83±00.15	38.26±16.38	Speed (’/s)	
W	Crossing expectance	0000.49	0000.16			0000.16	0000.49	Crossing expectance	**W**
	Expected path (’)	0048.81	0016.92			0015.50	0052.23	Expected path (’)	
	V (mag)	05.42±01.16	06.51±00.16			06.17±00.15	04.36±01.13	*V* (mag)	
	Speed (’/s)	32.71±13.13	14.73±00.81	00.00±00.00	00.00±00.00	14.80±00.75	33.28±12.84	Speed (’/s)	
N	Crossing expectance	0000.50	0000.29			0000.30	0000.52	Crossing expectance	**N**
	Expected path (’)	0050.26	0029.53			0029.59	0052.38	Expected path (’)	
	V (mag)	05.85±01.19	06.64±00.66			06.59±00.69	05.78±01.15	*V* (mag)	
	Speed (’/s)	30.75±16.83	18.56±07.05	00.00±00.00	00.00±00.00	19.00±07.37	31.38±16.22	Speed (’/s)	
E	Crossing expectance	0000.50	0000.17			0000.14	0000.49	Crossing expectance	**E**
	Expected path (’)	0052.33	0014.94			0015.02	0054.71	Expected path (’)	
	V (mag)	04.47±01.17	06.16±00.15			06.47±00.13	05.48±01.19	*V* (mag)	
	Speed (’/s)	32.08±13.23	14.71±00.81	00.00±00.00	00.00±00.00	14.85±00.86	31.97±13.36	Speed (’/s)	
Z	Crossing expectance	0000.32	0000.10			0000.09	0000.30	Crossing expectance	**Z**
	Expected path (’)	0034.59	0010.89			0009.85	0034.35	Expected path (’)	
	V (mag)	04.09±01.28	05.57±00.16			05.55±00.14	03.93±01.15	*V* (mag)	
	Speed (’/s)	54.14±25.61	20.92±01.41	00.00±00.00	00.00±00.00	21.17±01.26	56.54±23.60	Speed (’/s)	
Pointing directions:					**S, W, N, E, at +45° elevation**			**Z: zenith**	

Crossing expectance: *p*. Expected number of traces per shot. If *N* shots are done under the same circumstances, then *pN* traces are expected in the whole set of images.
Expected path: *L*. If *N* shots are done under the same circumstances, then *pN* traces will be present and, in average, each trace will be of length *L/p* arcminutes.
Average apparent magnitude: *V*. Average apparent visual magnitude of tracing satellites, and its standard deviation.
Average apparent angular speed: Average apparent angular speed of tracing satellites in arcminutes per second, and its standard deviation.

Constellation profile: starlink.dat
Statistics over 0100 crossings

***Latitude*= +040 º**		***FOV*= 0144 ’**			***T*= 0060 s**			***Sun delcination*= +000 º**	
		PM			**AM**				
	***Sun elevation* →**	**-12º**	**-25º**	**-37º**	**-37º**	**-25º**	**-12º**	**← *Sun elevation***	
S	Crossing expectance	0000.40	0000.13			0000.13	0000.39	Crossing expectance	**S**
	Expected path (’)	0045.35	0013.02			0012.79	0040.10	Expected path (’)	
	V (mag)	04.68±01.14	06.14±00.15			06.12±00.14	04.66±01.16	*V* (mag)	
	Speed (’/s)	36.89±16.67	13.78±01.33	00.00±00.00	00.00±00.00	13.88±01.26	37.44±16.94	Speed (’/s)	
W	Crossing expectance	0000.48	0000.23	0000.15		0000.05	0000.45	Crossing expectance	**W**
	Expected path (’)	0051.60	0022.13	0014.86		0004.20	0048.09	Expected path (’)	
	V (mag)	05.76±01.16	06.56±00.72	06.61±00.14		06.14±00.08	04.29±01.16	*V* (mag)	
	Speed (’/s)	33.06±13.05	18.59±06.62	14.82±00.78	00.00±00.00	14.11±00.79	32.87±12.96	Speed (’/s)	
N	Crossing expectance	0000.53	0000.33	0000.21	0000.23	0000.29	0000.51	Crossing expectance	**N**
	Expected path (’)	0053.96	0029.71	0020.00	0021.53	0027.56	0050.96	Expected path (’)	
	V (mag)	05.44±01.17	06.11±00.69	06.53±00.14	06.52±00.14	06.15±00.67	05.44±01.15	*V* (mag)	
	Speed (’/s)	29.70±16.43	19.19±07.41	14.52±01.59	14.64±01.52	18.86±07.20	29.60±16.26	Speed (’/s)	
E	Crossing expectance	0000.50	0000.04		0000.14	0000.22	0000.48	Crossing expectance	**E**
	Expected path (’)	0052.26	0003.93		0013.26	0021.26	0050.84	Expected path (’)	
	V (mag)	04.43±01.20	06.16±00.04		06.60±00.14	06.54±00.72	05.86±01.19	*V* (mag)	
	Speed (’/s)	31.26±13.37	14.05±00.54	00.00±00.00	14.80±00.81	18.78±06.57	31.89±13.24	Speed (’/s)	
Z	Crossing expectance	0000.33	0000.10			0000.09	0000.31	Crossing expectance	**Z**
	Expected path (’)	0035.68	0010.04			0009.97	0032.86	Expected path (’)	
	V (mag)	04.03±01.20	05.56±00.15			05.55±00.14	04.17±01.27	*V* (mag)	
	Speed (’/s)	54.55±24.29	21.08±01.32	00.00±00.00	00.00±00.00	21.16±01.25	52.22±25.56	Speed (’/s)	
Pointing directions:					**S, W, N, E, at +45º elevation**			**Z: zenith**	

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Constellation profile: starlink.dat
Statistics over 0100 crossings

Latitude= **+040 °**			***FOV=*** **0144 ’**		***T=*** **0060 s**			***Sun delcination=*** **-023 °**	
		PM			**AM**				
	Sun elevation →	**-12°**	**-25°**	**-37°**	**-37°**	**-25°**	**-12°**	← ***Sun elevation***	
S	Crossing expectance	0000.43	0000.12			0000.12	0000.44	Crossing expectance	**S**
	Expected path (’)	0045.28	0012.62			0012.15	0048.39	Expected path (’)	
	V (mag)	05.11±01.19	06.40±00.14			06.42±00.15	04.96±01.13	*V* (mag)	
	Speed (’/s)	36.07±17.19	13.92±01.25	00.00±00.00	00.00±00.00	13.81±01.29	38.20±16.55	Speed (’/s)	
W	Crossing expectance	0000.52	0000.22	0000.15		0000.04	0000.48	Crossing expectance	**W**
	Expected path (’)	0054.01	0022.57	0014.94		0003.57	0048.64	Expected path (’)	
	V (mag)	05.77±01.19	06.66±00.69	06.77±00.15		06.13±00.05	04.24±01.13	*V* (mag)	
	Speed (’/s)	32.14±13.26	18.35±06.30	14.74±00.79	00.00±00.00	13.85±00.62	33.51±12.54	Speed (’/s)	
N	Crossing expectance	0000.50	0000.24			0000.21	0000.53	Crossing expectance	**N**
	Expected path (’)	0050.18	0023.39			0022.03	0054.93	Expected path (’)	
	V (mag)	05.05±01.16	06.21±00.14			06.20±00.13	04.96±01.17	*V* (mag)	
	Speed (’/s)	30.49±16.30	14.68±01.55	00.00±00.00	00.00±00.00	14.80±01.45	31.83±16.54	Speed (’/s)	
E	Crossing expectance	0000.49	0000.03		0000.16	0000.21	0000.50	Crossing expectance	**E**
	Expected path (’)	0052.53	0003.21		0015.29	0020.27	0052.88	Expected path (’)	
	V (mag)	04.39±01.19	06.14±00.04		06.78±00.16	06.61±00.72	05.74±01.17	*V* (mag)	
	Speed (’/s)	32.10±13.27	13.80±00.63	00.00±00.00	14.67±00.83	18.72±06.63	32.35±13.16	Speed (’/s)	
Z	Crossing expectance	0000.32	0000.10			0000.10	0000.31	Crossing expectance	**Z**
	Expected path (’)	0034.45	0009.68			0010.31	0033.27	Expected path (’)	
	V (mag)	04.11±01.25	05.57±00.15			05.56±00.16	03.96±01.16	*V* (mag)	
	Speed (’/s)	53.27±25.18	20.98±01.39	00.00±00.00	00.00±00.00	20.99±01.40	55.74±23.82	Speed (’/s)	
Pointing directions:					**S, W, N, E, at +45° elevation**			**Z: zenith**	

Crossing expectance: ***p.*** Expected number of traces per shot. If *N* shots are done under the same circumstances, then *pN* traces are expected in the whole set of images.
Expected path: ***L.*** If *N* shots are done under the same circumstances, then *pN* traces will be present and, in average, each trace will be of length *L/p* arcminutes.
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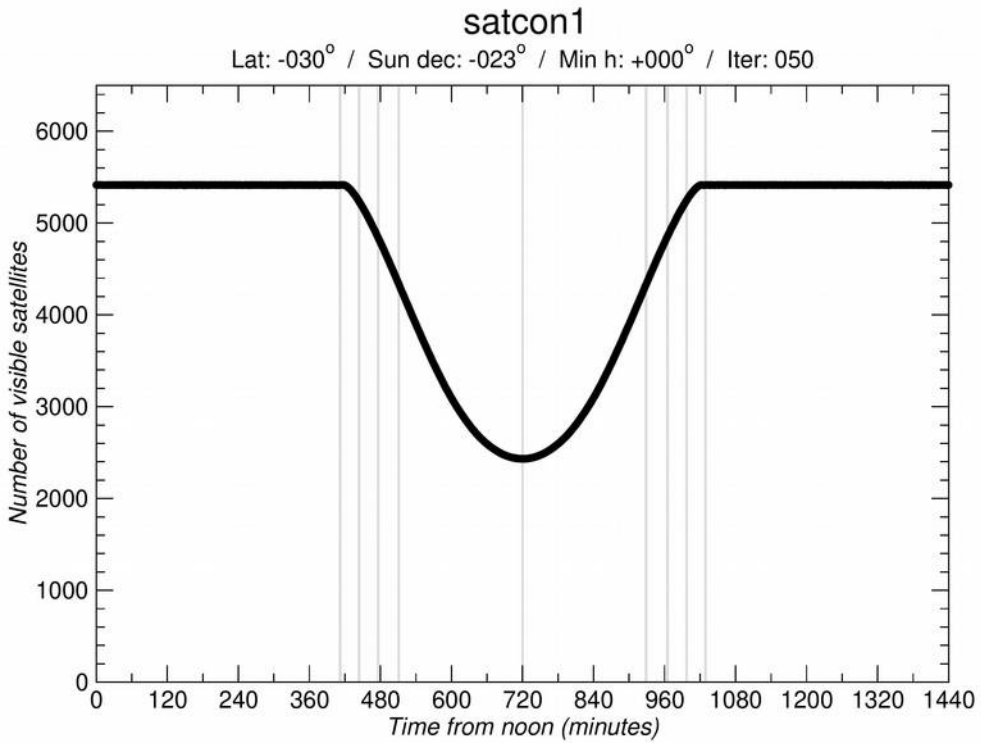
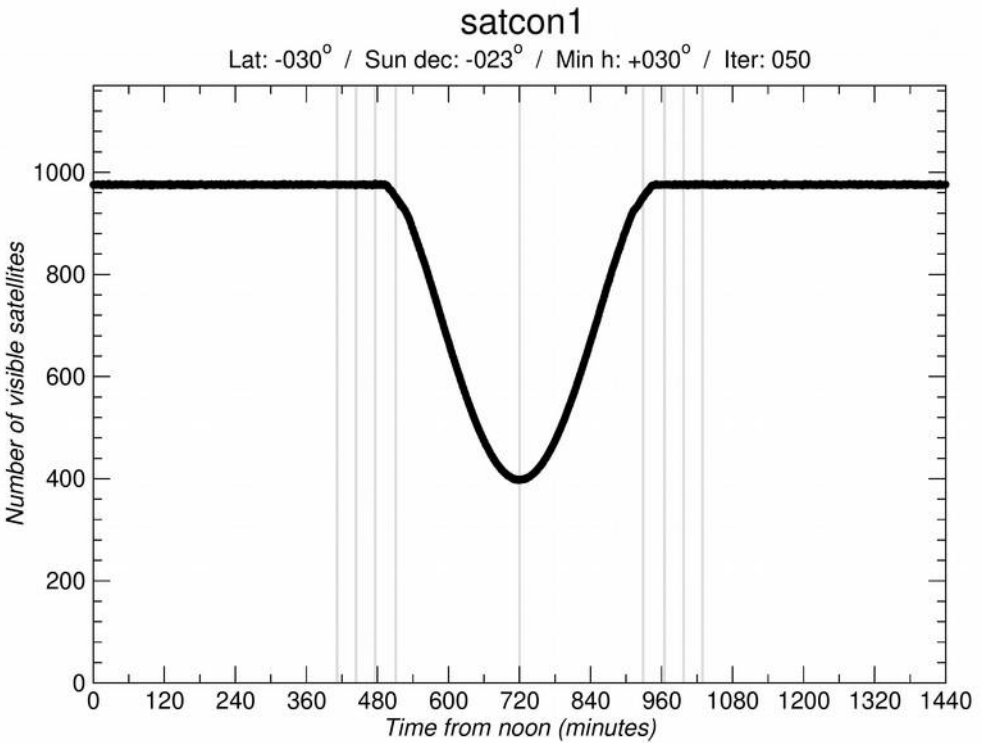
Average apparent angular speed: Average apparent angular speed of tracing satellites in arcminutes per second, and its standard deviation.

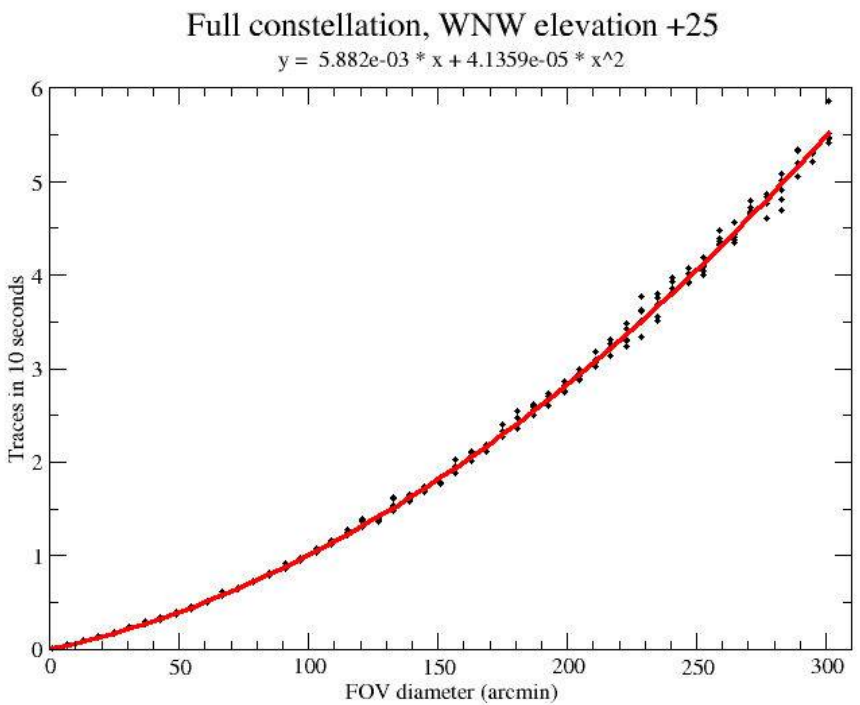
6. Some results for increased number of satellites

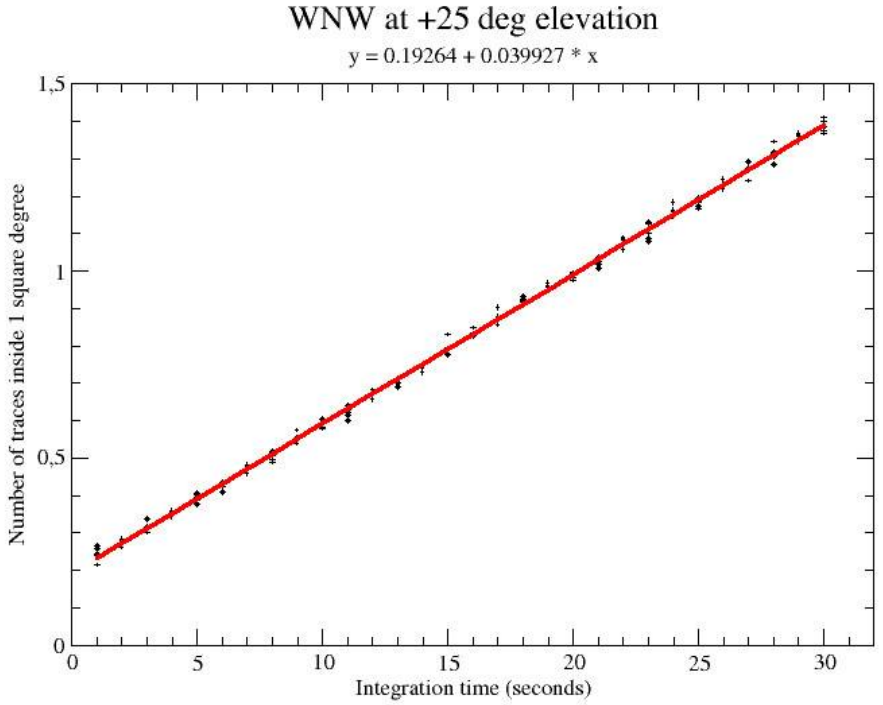




6. Some results for increased number of satellites

$$N = \pi \left(\frac{L}{2} \right)^2 \delta + L T \rho$$





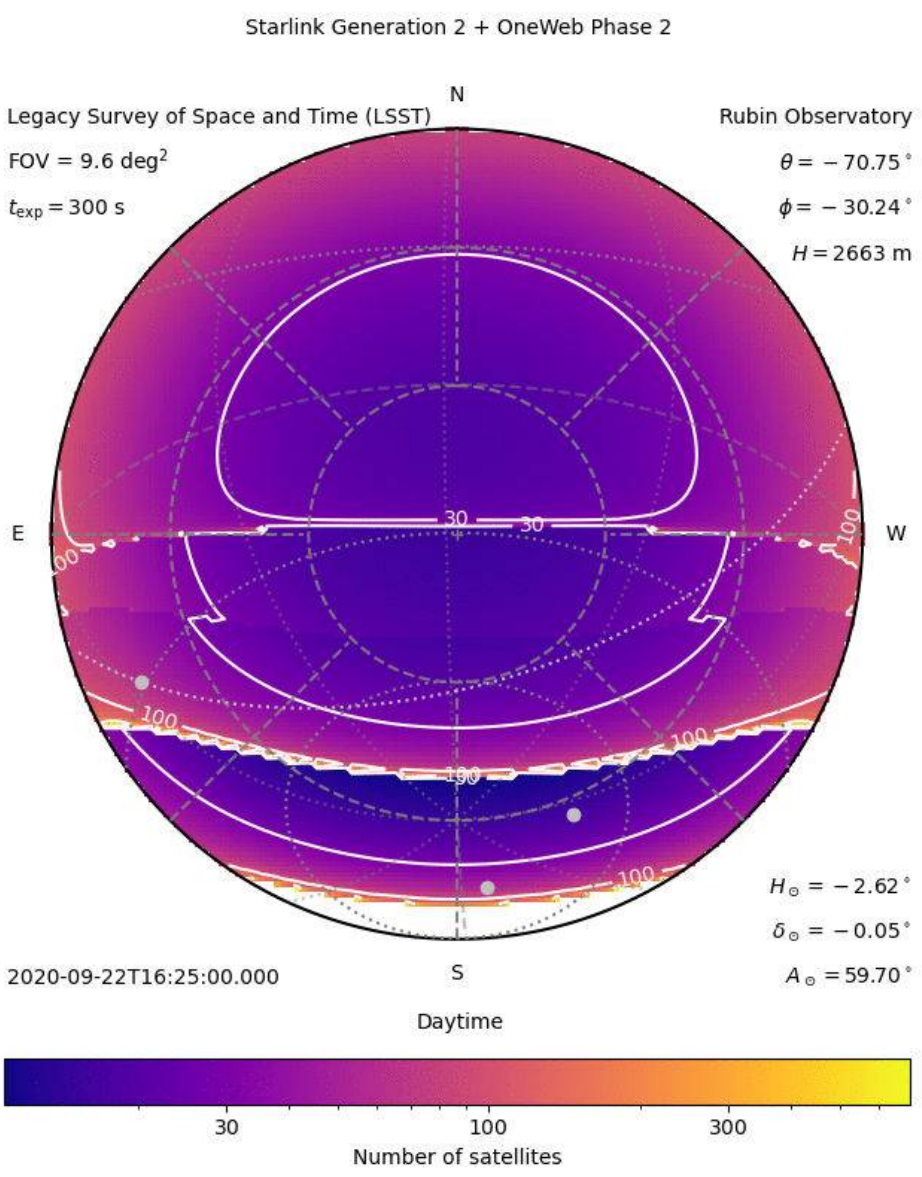
7. Lines of advance

- Improving simulation and prediction: not numerical, but anaytical models

7. Lines of

- Improving sim

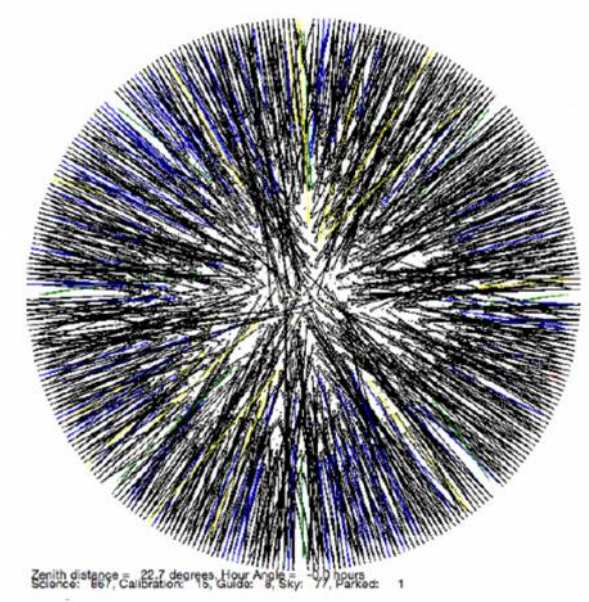
els

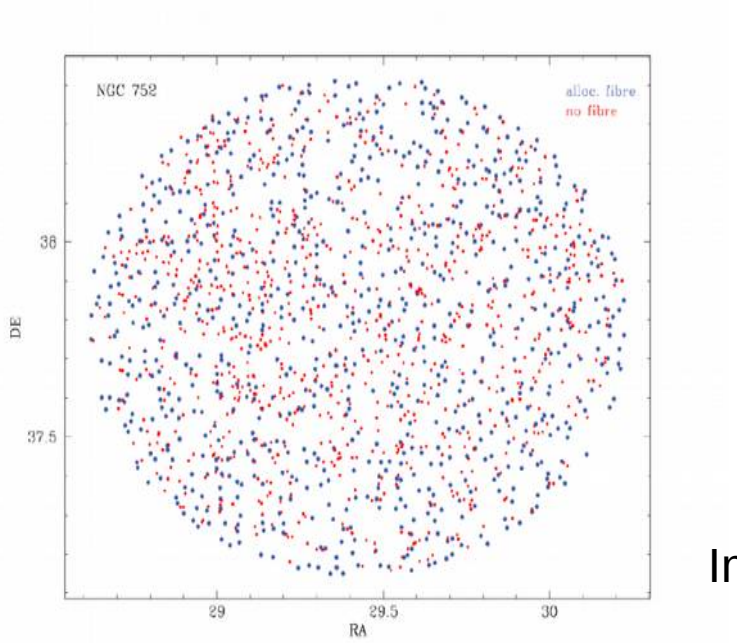


Cees Bassa

7. Lines of advance

- Improving simulation and prediction: not numerical, but anaytical models
- Simulating another observation techniques: multi-fiber surveys (vgr WEAVE)





Images: Antonella Vallenari

7. Lines of advance

- Improving simulation and prediction: not numerical, but anaytical models
- Simulating another observation techniques: multi-fiber surveys (vgr WEAVE)
- Improving predictions: photometry – based on observations (Fabra ROA Montsec Telescope