Optical and NIR Reflective Brightness Measurements of Low Earth Orbit satellites, from a Global Observing Network

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NIST Commercial Space and Astronomy Partnering in Best Practices and Guidelines for Brightness Mitigation Webinar

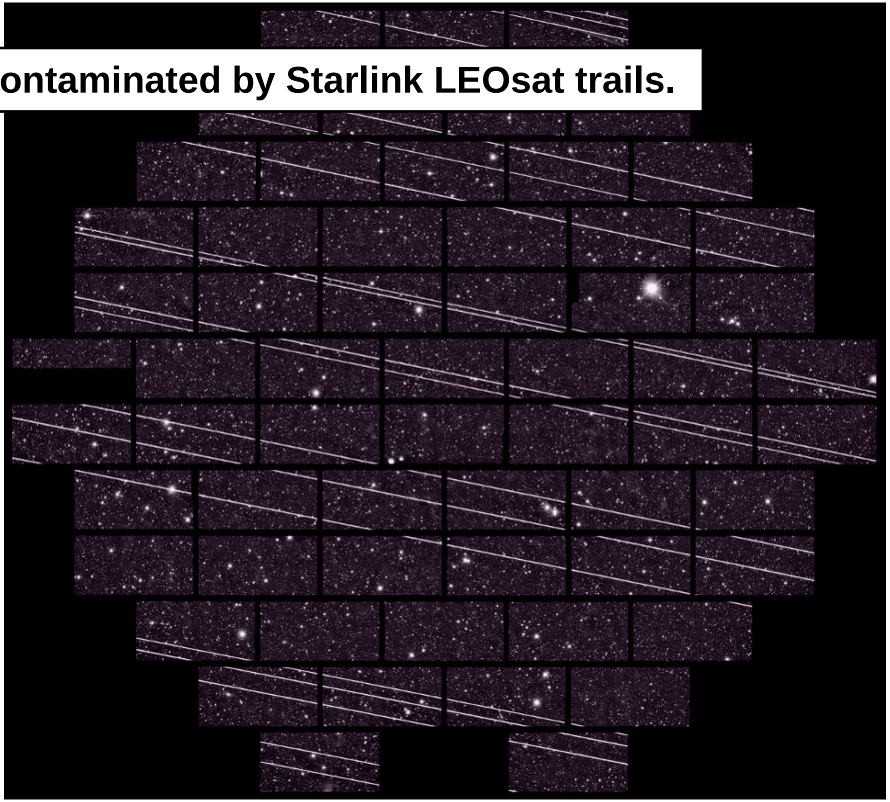
Tuesday 28th June 2022

UNIVERSIDAD DE ATACAMA

Low Earth orbit megaconstellation satellites

Amateur and professional images contaminated by Starlink LEOsat trails.

Composite image of the Comet Neowise, using 17 exposures of 30s, with a Canon 200mm lens. The multiple streaks are from Starlink LEOsats crossing the camera aperture during the exposures. Credit Daniel López.



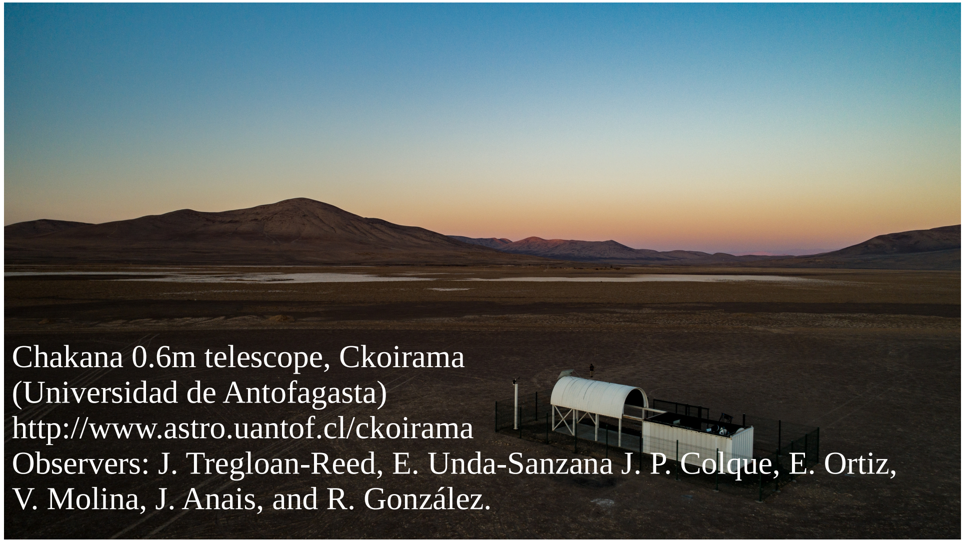
Around 19 Starlink satellites were imaged shortly after launch in November 2019 using the Blanco 4m telescope. Credit: Clara Martínez-Vázquez and Cliff Johnson. NSF’s National Optical-Infrared Astronomy Research Laboratory/CTIO/AURA/DELVE.

Low Earth orbit megaconstellation satellites: 2020

Observations of STARLINK-1113 & 1130 (Darksat), March 2020:

Optical to Near-Infrared

Sloan g’	Sloan r’	Sloan i’
475.4nm	620.4nm	769.8nm



Chakana 0.6m telescope, Ckoirama
(Universidad de Antofagasta)
http://www.astro.uantof.cl/ckoirama
Observers: J. Tregloan-Reed, E. Unda-Sanzana J. P. Colque, E. Ortiz,
V. Molina, J. Anais, and R. González.

Near-Infrared

J-band	Ks-band
1250.0nm	2150.0nm

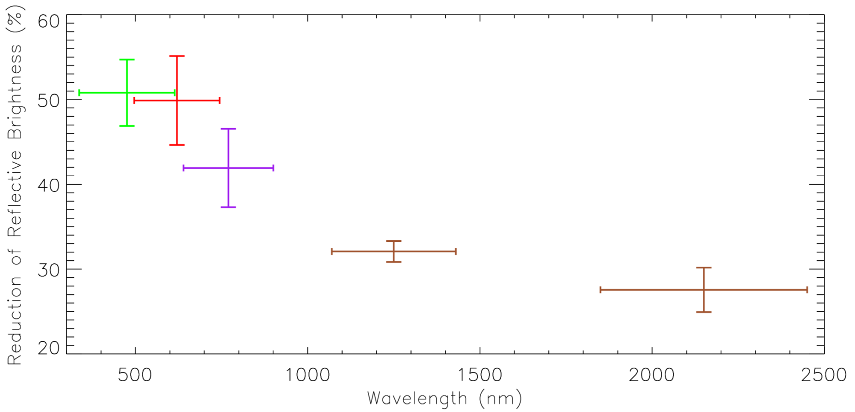
VISTA 4.1m telescope, ESO Paranal
Observers: B Haeussler, F. Gaete, A. Otarola

Low Earth orbit megaconstellation satellites: 2020

Reflective Brightness:

Observations to measure the reflective brightness of Starlink satellites in early 2020, showed that the standard design had V~5.5 mag (Tregloan-Reed et al. 2020, Tyson, et al. 2020), while the first attempt by Starlink to reduce the reflective brightness, called Darksat was partially successful in reducing the reflective brightness by around 55% in the visible (V~6.5; mag Tregloan-Reed et al. 2020, Tyson, et al. 2020) and ~28% in the NIR (Tregloan-Reed et al. 2021).

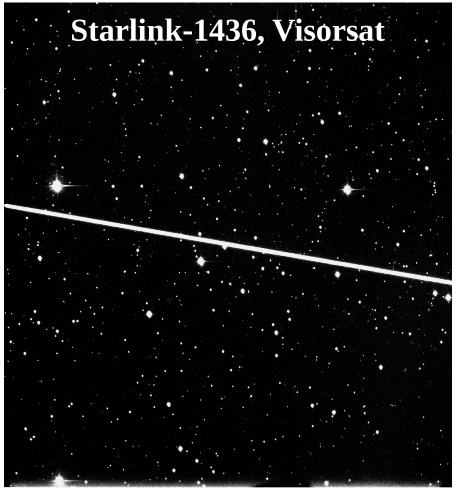
Starlink	Facility	Filter	Observed Mag.	Calibrated Mag.
1130 (Darksat)	Chakana 0.6 m	g’	7.46 ± 0.04	6.52 ± 0.04
1130 (Darksat)	Chakana 0.6 m	r’	6.49 ± 0.02	5.63 ± 0.07
1130 (Darksat)	Chakana 0.6 m	i’	5.93 ± 0.03	5.00 ± 0.03
1130 (Darksat)	VISTA 4.1 m	J	5.36 ± 0.01	4.21 ± 0.01
1130 (Darksat)	VISTA 4.1 m	Ks	5.10 ± 0.02	3.97 ± 0.02
1113	Chakana 0.6 m	g’	6.59 ± 0.05	5.75 ± 0.05
1113	Chakana 0.6 m	r’	5.44 ± 0.05	4.88 ± 0.05
1113	Chakana 0.6 m	i’	5.02 ± 0.04	4.41 ± 0.04
1113	VISTA 4.1 m	J	5.10 ± 0.01	4.79 ± 0.01
1113	VISTA 4.1 m	Ks	4.12 ± 0.02	3.62 ± 0.02

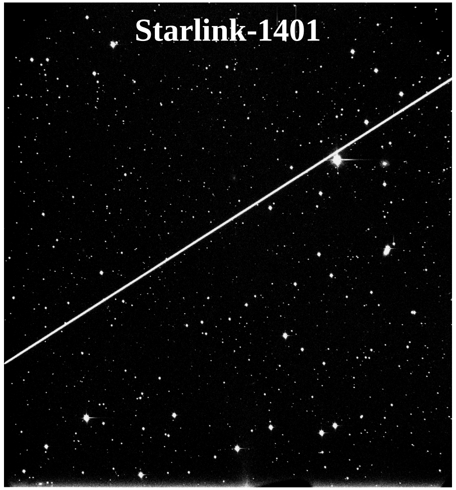


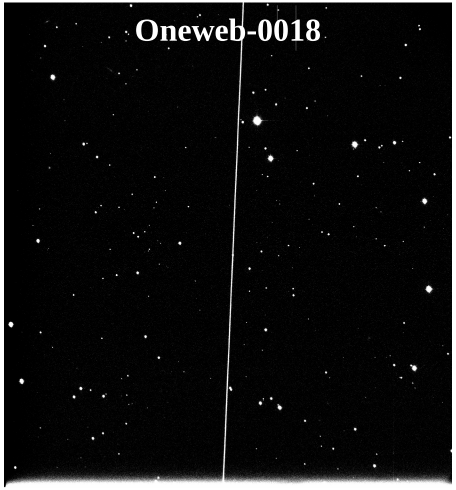
Tregloan-Reed et al. 2020, A&A, 637, L1
Tregloan-Reed et al. 2021, A&A, 647, A54

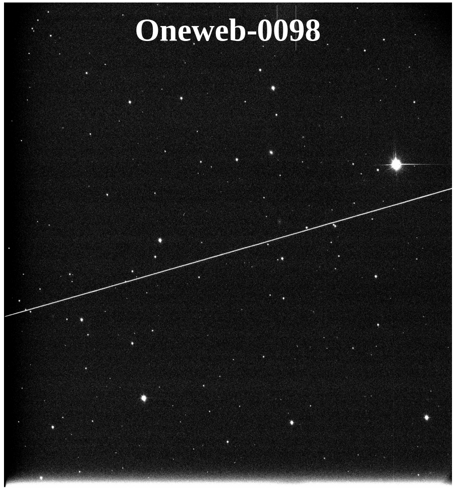
Developing a global observing network: 2021

Observations from the CAHA 1.23m telescope, Calar Alto, Spain:









Special thanks to L. Mancini (Department of Physics, University of Rome 2, Italy), T. Henning, M. Schlecker, L. Flores, and J. Syed (Max Planck Institute for Astronomy, Heidelberg, Germany).

Observations of Oneweb satellites were partially supported by student observations training MINEDUC-UA project, code ANT 1795.

Tregloan-Reed et al. In Prep.

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1436 (Visorsat)	CAHA 1.23 m	V	7.20 ± 0.08	6.44 ± 0.08
1405	CAHA 1.23 m	V	6.50 ± 0.09	5.56 ± 0.10

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The limiting magnitude equation given in the SATCON 1 and the IAU/UNOOSA D&QS reports is:

7 + 2.5 log(orbit_height/550km)

For an orbital height of 1200km this equates to ~ V>7.9 mag.

This initial result appears to show that Oneweb satellites **are in the safe zone.**

with V= 8.14 +/- 0.04

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When the orbital height is scaled to 550 km, Oneweb satellites appear to be equivalent to Visorsat in reflective brightness.

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Developing a global observing network: 2021-2022

Observations from the the Danish 1.54m telescope, ESO La Silla, Chile:

The Danish 1.54m telescope at the ESO La Silla observatory in Chile is operated 6 month a year by the Danish community, and 6 month a year by the Czech astronomical community. The Danish operation, is focused on the microlensing search and characterisation of exoplanets, organized as an international team called MiNDSTEp (Microlensing Network for the Detection of Small Terrestrial Exoplanets).

Parallel with the exoplanet search program, a number of other monitoring programs, mainly outside the time where the microlensing exoplanet candidates are visible are conducted. For the 2021 season this includes observations of low Earth orbit satellites.

The 2021 season began in May and continued through to September. Despite technical issues with the dome motor suspending observations for two months, over 700 Starlink and Oneweb satellites were observed using the U, B, V, R, and I Johnson passbands:

LEOsat Company Name	Number of U band obs.	Number of B band obs.	Number of V band obs.	Number of R band obs.	Number of I band obs.	Total number of Observations
OneWeb	38	66	80	90	63	337
Starlink	66	71	71	109	63	380
Total	**104**	**137**	**151**	**199**	**126**	**717**

Developing a global observing network: 2021-2022

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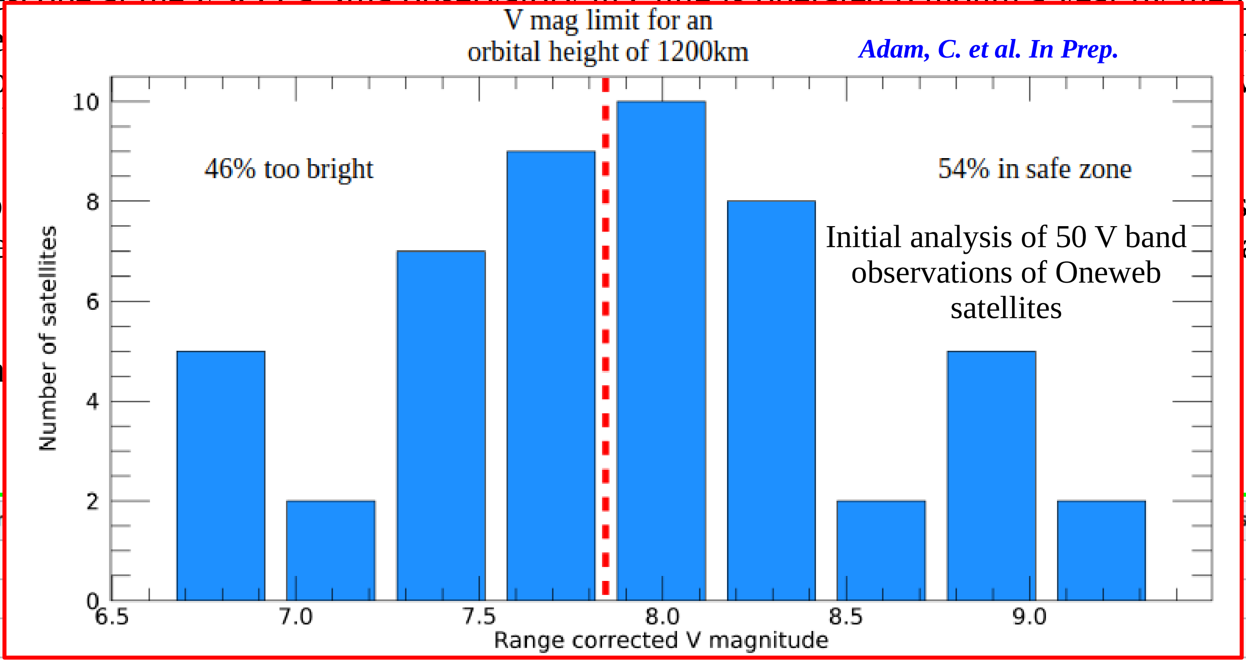

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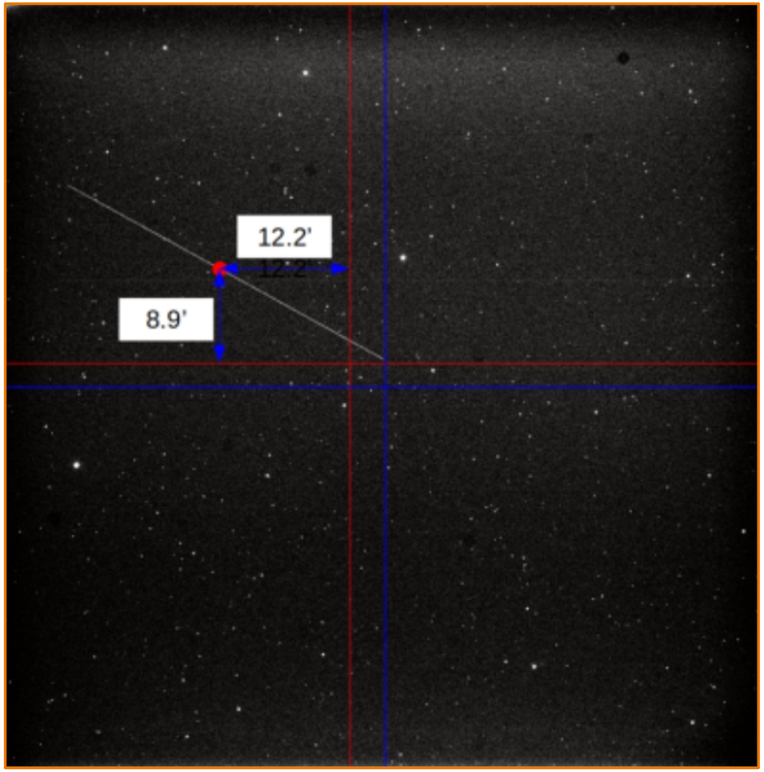
The 2022 season began last month and is continuing through to October. To date over 200 Starlink and Oneweb satellites have been observed, with observations concentrating on the new Starlink visor free design utilising inter satellite laser communication.

LEOsat Company Name	Number of U band obs.	Number of B band obs.	Number of V band obs.	Number of R band obs.	Number of I band obs.	Total number of Observations
Starlink	0	28	131	23	17	199
OneWeb	0	0	4	5	36	45
Total	**0**	**28**	**135**	**28**	**53**	**244**

Developing a global observing network: 2021-2022

Survey observations of LEO satellites at the Chungbuk National University Observatory, Korea:

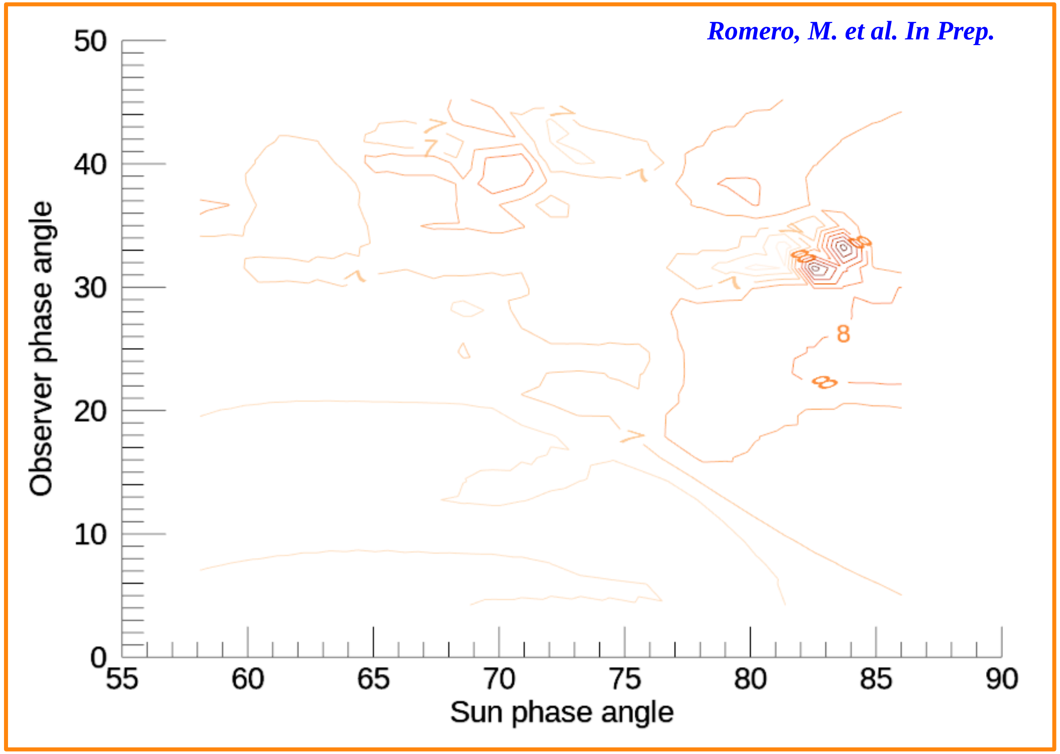


Observers Joh-Na and Yonggi Kim.

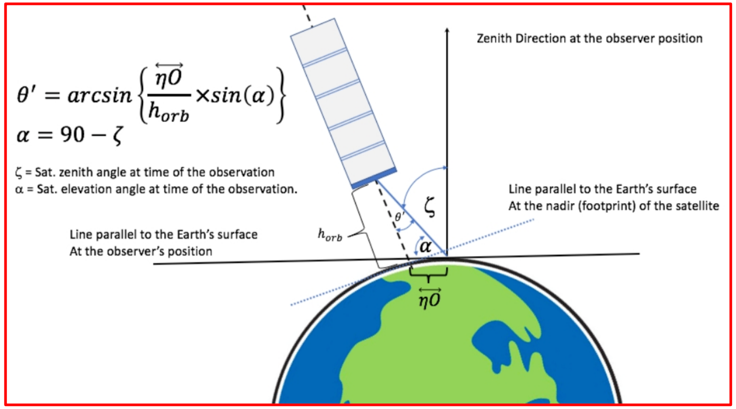
- Observation of Oneweb-0210 obtained with the 0.6m telescope at Chungbuk National University Observatory, South Korea. To date over 800 successful observations of Starlink and Oneweb satellites have been conducted.
- The field of view is 72 x 72 arcminutes and the exposure time is two seconds.
- The image centre is indicated by the blue cross hairs, while the red cross hairs show the forecasted position of the satellite at the central exposure time from a TLE (Two-Line-Element containing positional and velocity vectors).
- The red spot indicates the satellite's true position, which is 15.1 arcmin off from the forecasted position.
- When conducted for a sufficiently large sample size, a statistical measurement of the TLE accuracy can be determined.
- Understanding the unknown temporal degradation of the propagated accuracy of the TLEs requires observations from telescopes at various longitudes (i.e. time zones). Thus allowing the accuracy of the TLEs to be measured as a function of time.

Developing a global observing network: 2021-2022

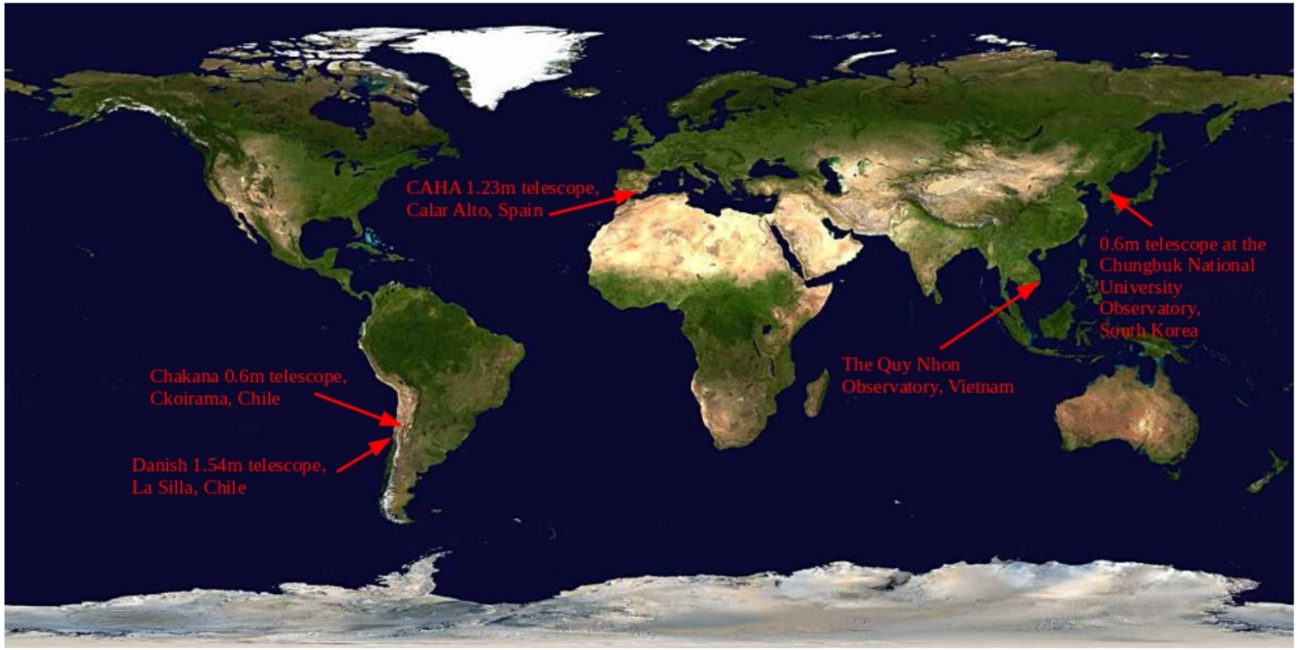
Survey observations of LEO satellites at the Chungbuk National University Observatory, Korea:



- Initial analysis of 92 Oneweb satellites V magnitudes once corrected for range, provide a V mag of 8.23 +/- 0.93, agreeing with the Danish 2021 data within the 1-sigma uncertainties.
- Work is ongoing to determine how the different phase angles impact the observed reflective brightness of the satellites.
- Initial examination seems to indicate that Oneweb satellites are dimmest at high Sun phase angles and moderate observer angles.



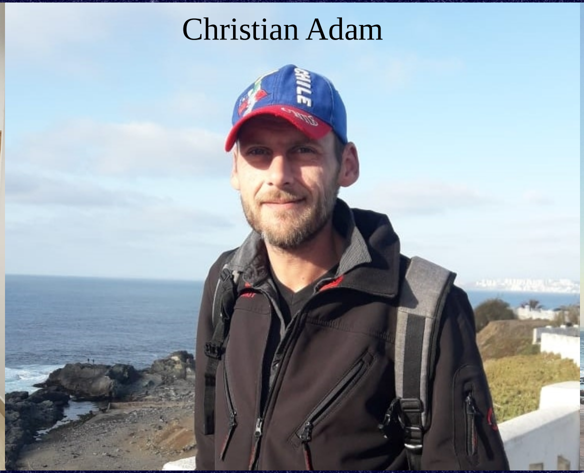
Developing a global observing network: 2022+



From www.h-schmidt.net

- Current telescopes devoting time to LEOsat observations are located in Chile, Spain, Vietnam and South Korea.
- Measure any orbital-attitude aspect to satellite brightness for different geographical locations.
- Measure TLE accuracy as a function of longitude (time zone), to aid satellite visibility forecasting.

Special thanks to our Postdoc and students



Special thanks to our team members and observers!

Centro de Astronomía (CITEVA) Universidad de Antofagasta
E. Unda-Sanzana, J. P. Colque, E. Ortiz, V. Molina, J. Anais, R. González, C. Adam

European Southern Observatory Chile
A. Otarola, B. Haeussler, F. Gaete, S. Mieske, S. Brilliant, J. Anderson

Calar Alto remote observers and proposal P.Is
L. Mancini
(Department of Physics, University of Rome 2, Italy),
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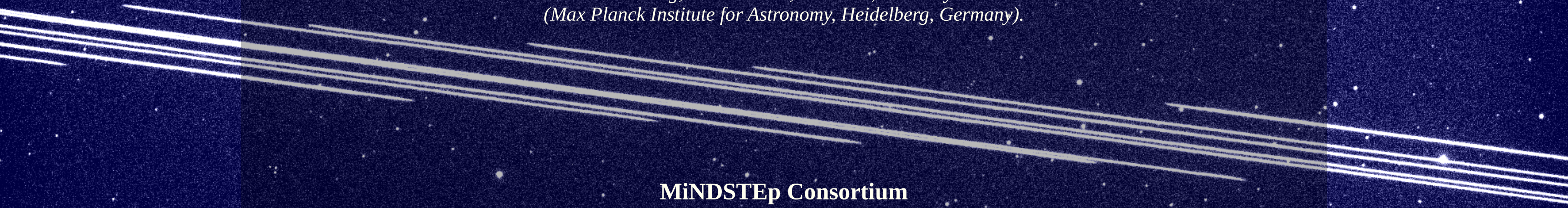

MiNDSTEp Consortium
U. Jørgensen, M. Dominik, J. skottfelt, and the MiNDSTEp 2021 and 2022 observing team

Chungbuk National University Observatory, South Korea
Yonggi Kim, Joh-Na, and T. Hinse

ExploraScience Quy Nhon observatory, Vietnam – first light early 2022
Duong Tuan Anh

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