Optical and NIR magnitude measurements of low Earth orbit satellites, from a global observing network

Jeremy Tregloan-Reed
CLEOsat Group
Instituto de Astronomía y Ciencias Planetarias
Universidad de Atacama
Chile
jeremy.tregloan-reed@uda.cl

The Chilean Low Earth Orbit satellite (CLEOsat) group

- Chile is disproportionately affected by the impact of LEO mega-constellation communication satellites due to the high concentration of the world's leading observatories and pristine dark sky conditions of the Atacama desert.

- The CLEOsat group, with the endorsement of the Chilean Astronomical Society (SOCHIAS) is formed by members of the Chilean astronomical community (faculty, researchers, postdocs, and students).

- The CLEOsat group's primary mission is to assess the impact of LEO mega-constellation communication satellites on the night sky, and their effects on optical and radio astronomy.

- The CLEOsat group will liaise and coordinate Chilean efforts to maximise returns on analysis, observations, software development and hardware testing with the proposed new NOIRLab and SKAO Centre for the Protection of the Dark Sky from Satellite Constellation Interference.

The Chilean Low Earth Orbit satellite (CLEOsat) group

- Chile is disproportionately affected by the impact of LEO mega-constellation communication satellites due to the high concentration of the
- The C Chilean astron
- The C ight sky, and th
- The C elopment and H Satellite Constellation Interference.

Current CLEOsat group members

Jeremy Tregloan-Reed – Universidad de Atacama
Marío Soto Vicencio – Universidad de Atacama
Eduardo Unda-Sanzana – Universidad de Antofagasta
Edger Ortiz – Universidad de Antofagasta
Christian Adam – Universidad de Antofagasta
Ángel Otarola – European Sourthern Observatory, Santiago

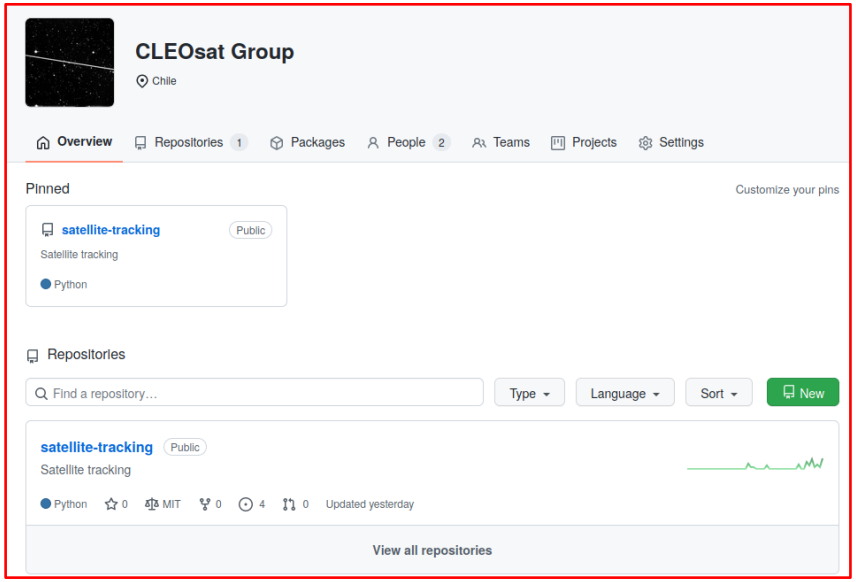
Forecasting visible LEO satellites

Our Python script downloads the latest TLE data from

https://celestrak.com/NORAD/elements/supplemental/.txt*

Using the latest TLE data, our script (contributions by A. Otarola, E. Ortiz, and J. Tregloan-Reed) uses the Pyorbital package to determine the date/time (UTC), RA and DEC of all visible LEOsats from a given location and twilight. The code is available on the CLEOsat group GitHub page:

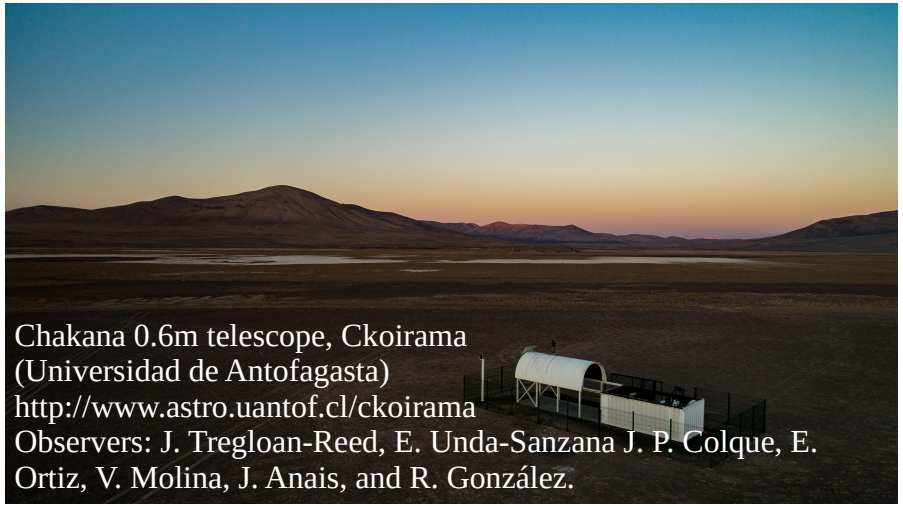
https://github.com/CLEOsat-group



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

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

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

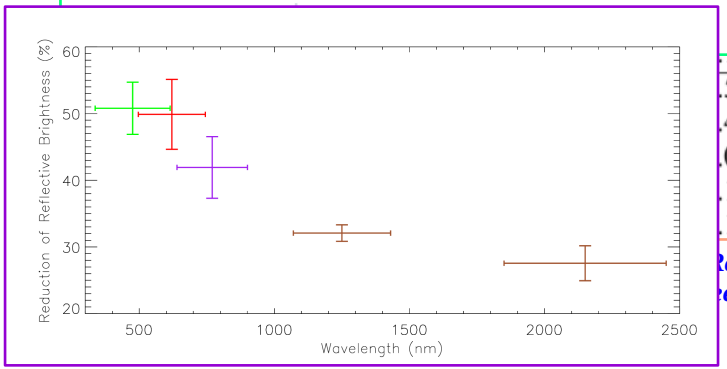
- The observed magnitude is the result of the integrated flux of the satellite trail from the image.
- The calibrated magnitude is after corrections for the satellites range and phase angles, to place the satellite at local zenith where the range is equal to the orbital height.
- This allows a fair comparison in the reflective brightness between satellites.

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

A&A 637, L1 (2020)
Letter to the Editor

First observations and magnitude measurement of Starlink's Darksat

J. Tregloan-Reed[1], A. Otarola[2], E. Ortiz[3], V. Molina[1], J. Anais[1], R. González[1], J. P. Colque[1] and E. Unda-Sanzana[1]



A&A 647, A54 (2021)

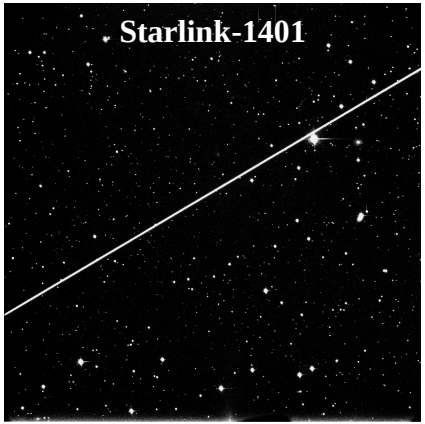
Optical-to-NIR magnitude measurements of the Starlink LEO Darksat satellite and effectiveness of the darkening treatment

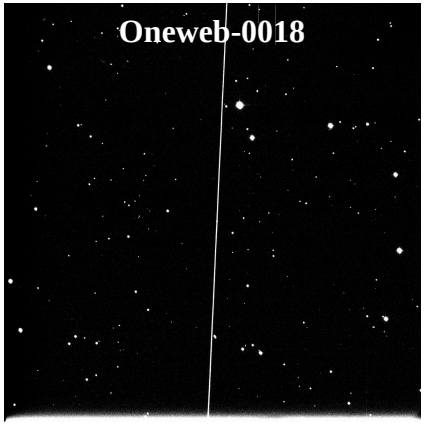
J. Tregloan-Reed[1], A. Otarola[2,3], E. Unda-Sanzana[4], B. Haeussler[3], F. Gaete[3], J. P. Colque[4], C. González-Fernández[5], J. Anais[4], V. Molina[4], R. González[4], E. Ortiz[6], S. Mieske[3], S. Brillant[3] and J. P. Anderson[3]

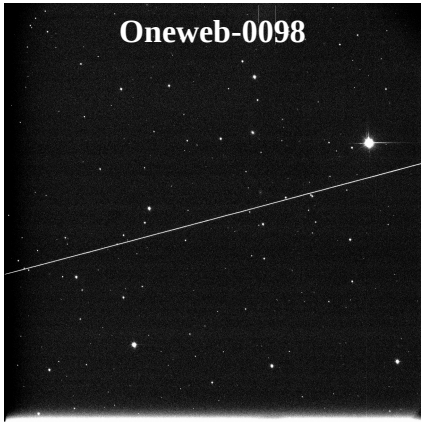
Received: 8 September 2020 | **Accepted:** 4 January 2021

- The observed magnitude is the result of the integrated flux of the satellite trail from the image.

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.

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

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
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

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

or so we believe!

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.

Ongoing Survey observations of LEO satellites with the Danish 1.54m telescope, ESO La Silla

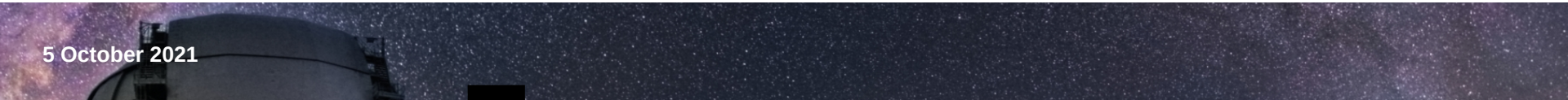
- The Danish 1.54m telescope at the ESO La Silla observatory in Chile is operated six month a year by the Danish community, and six month a year by the Czech astronomical community. The Danish operation, is focused on the microlensing search and characterisation of exoplanets, organized as an international 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 continues through to October 20th. Despite a loss of just under three months due to a dome motor burn out, **at present there have been 563** successful observations of Starlink and Oneweb satellites using the U (365.6 nm), B (435.3 nm), V (547.7 nm), R (634.9 nm), and I (879.7 nm) Johnson passbands:

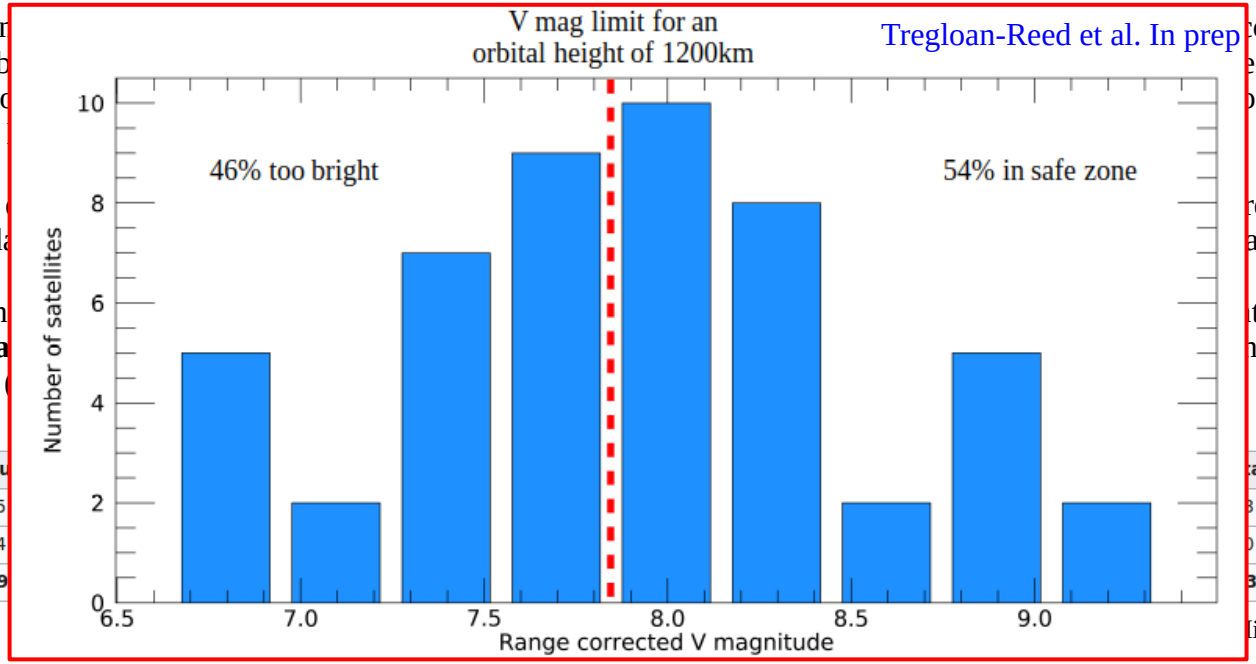
LEOsat Company Name	Number of U band obs.	Number of B band obs.	Number of V band obs.	Number of R band obs.	Number of I band obs.	Total number of Observations
OneWeb	25	66	50	61	51	253
Starlink	44	46	58	104	58	310
Total	**69**	**112**	**108**	**165**	**109**	**563**

MiNDSTEp observers wiki



Ongoing Survey observations of LEO satellites with the Danish 1.54m telescope, ESO La Silla

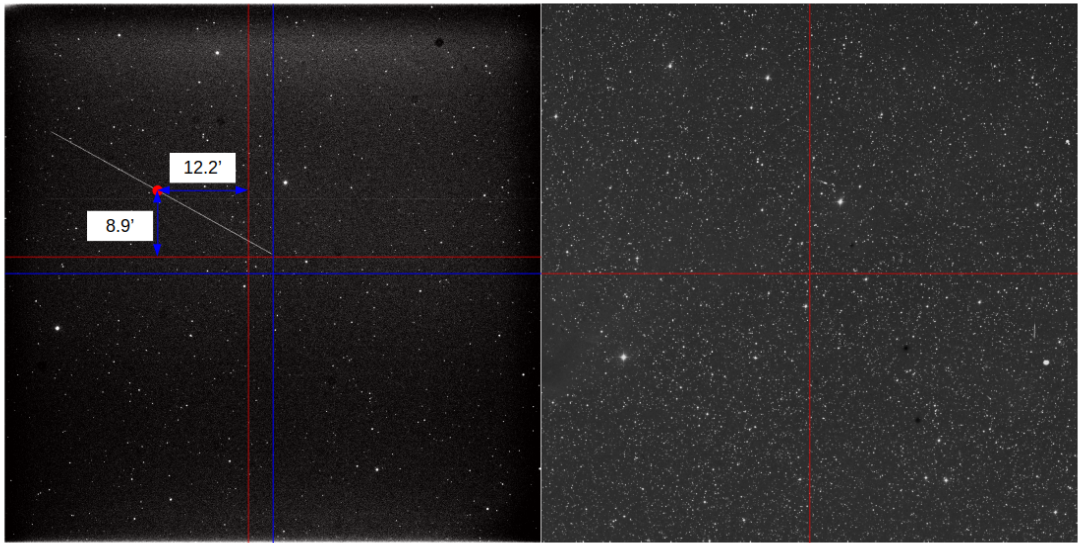
- The Danish 1.54m … community, and six month a year b… ensing search and characterisation … or the Detection of Small Terrestrial …
- Parallel with the … re the microlensing exoplanet candida… atellites.
- The 2021 season… ths due to a dome motor burn out, a… ne U (365.6 nm), B …



LEOsat Company Name	Nu…	…al number of Observations
OneWeb	25	3
Starlink	44	0
Total	**69**	**3**

…liNDSTEp observers wiki

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



Observers Joh-Na and Yonggi Kim.

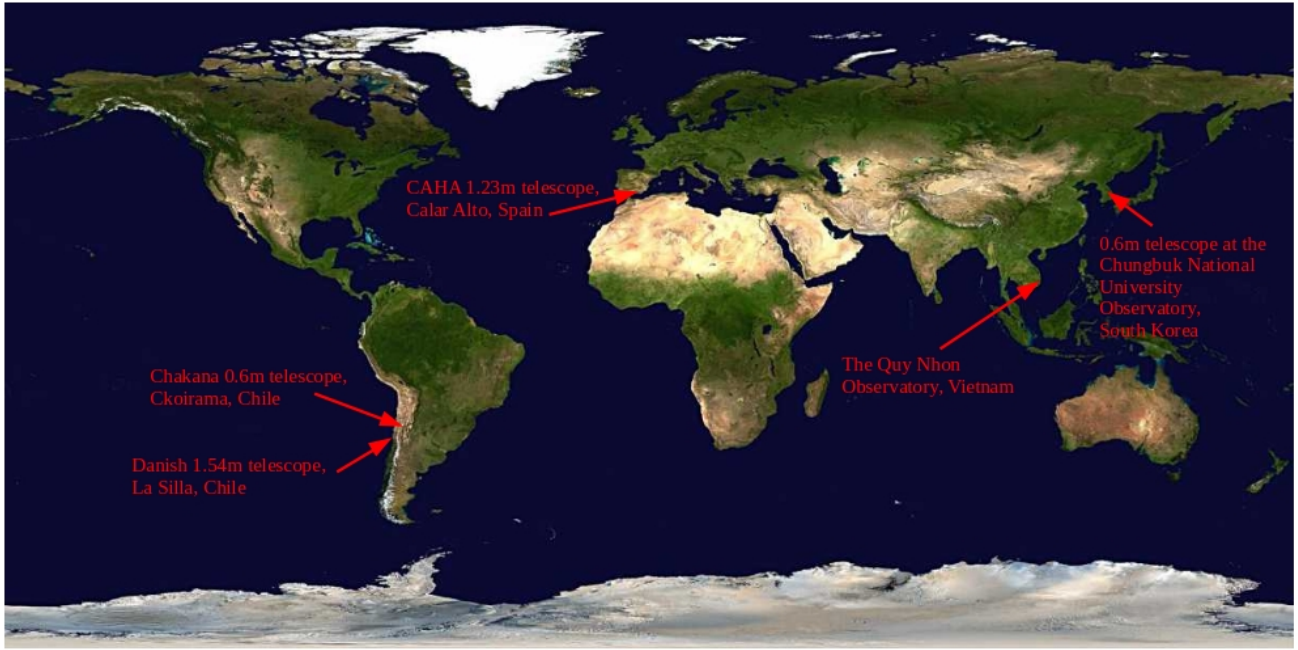
- Observation of Oneweb-0210 obtained with the 0.6m telescope at Chungbuk National University Observatory, South Korea.
- The field of view is 72 x 72 arcminutes and the exposure time is two seconds.
- The image centre is indicated by the blue cross hairs, while the red cross hairs show the forecasted position of the satellite at the central exposure time from a TLE.
- The red spot indicates the satellite's true position, which is 15.1 arcmin off from the forecasted position.

Ongoing Survey observations of LEO satellites at the ExploraScience Quy Nhon observatory, Vietnam

Observer Duong Tuan Anh

- Test observation of a Starlink satellite from the Quy Nhon observatory.
- Further tests are on hold due to the long tropical depression.
- Full telescope operations expected to begin early 2022.

Developing a global LEOsat observing network



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 team members and observers!

DARK & QUIET SKIES

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),
T. Henning, M. Schlecker, L. Flores, and J. Syed
(Max Planck Institute for Astronomy, Heidelberg, Germany).

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

Lead Contact
Jeremy Tregloan-Reed
Instituto de Astronomía y Ciencias Planetarias
Universidad de Atacama
jeremy.tregloan-reed@uda.cl