II observations with MAGIC & the CTAO-North LSTs

Image Credit: Alicia López Oramas

A. Cifuentes, J. Cortina and T. Hassan (CIEMAT) for the MAGIC and CTAO-LST collaborations

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MINISTERIO DE CIENCIA, INNOVACIÓN Y UNIVERSIDADES
Ciemat
Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas
CTAO
LST COLLABORATION
MAGIC
Major Atmospheric Gamma Imaging Cerenkov Telescopes

Overview

1. MAGIC SII performance
2. Preliminary MAGIC + LST-1 SII results on calibrators
3. MAGIC + LSTs SII prospects
4. Summary

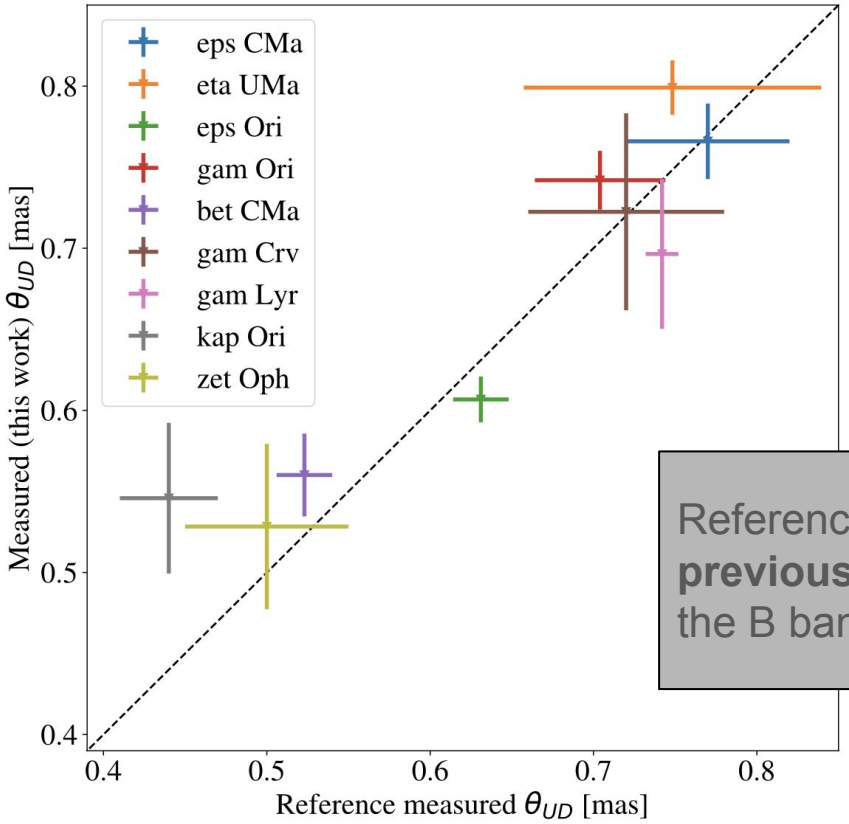
MAGIC SII performance

MAGIC SII performance

- Observations in the period between 2022 January and December.
- First scientific results measuring the angular diameter of **22 stars** up to $\mathbf{B_{mag} = 3.7}$ and angular diameters as small as **0.3 mas**.
- Angular diameters provided for **13 stars** for the **first time in the B band**.
- Performance was evaluated, **matching the expectations**.
- **Prospects on the sensitivity improvements** once the the Large-Sized Telescopes (LSTs) from the Cherenkov Telescope Array Observatory (CTAO) are added to the system.

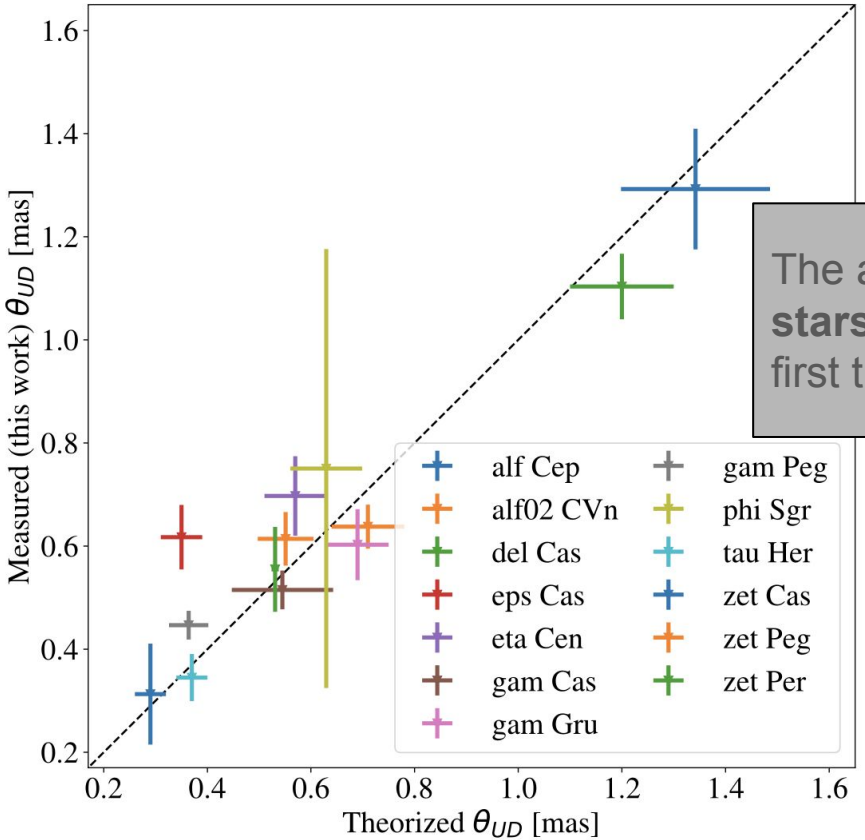
"Performance and first measurements of the MAGIC stellar intensity interferometer," MNRAS 529,4387–4404 (Apr. 2024).

MAGIC SII: Measurements on reference stars



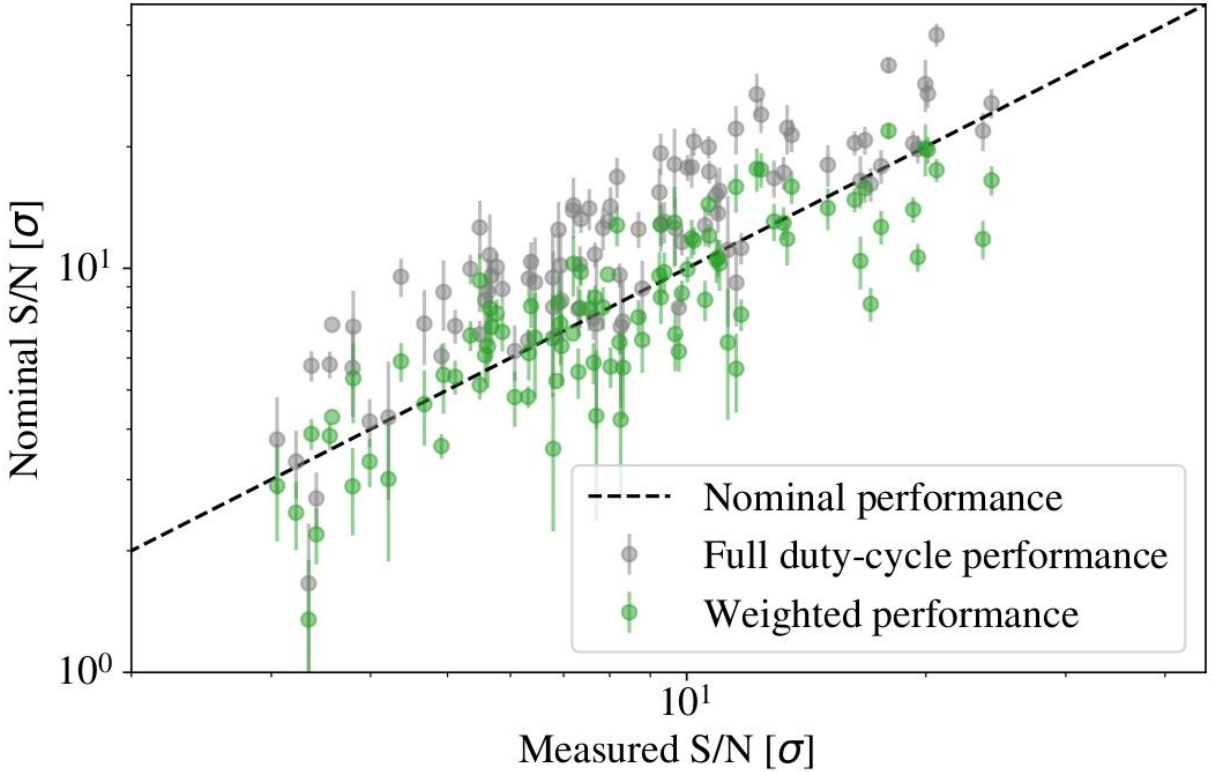
Reference stars: 9 stars with **previous measurements** in the B band.

MAGIC SII: New measurements



The angular diameter of **13 stars** was measured for the first time in the **B band**.

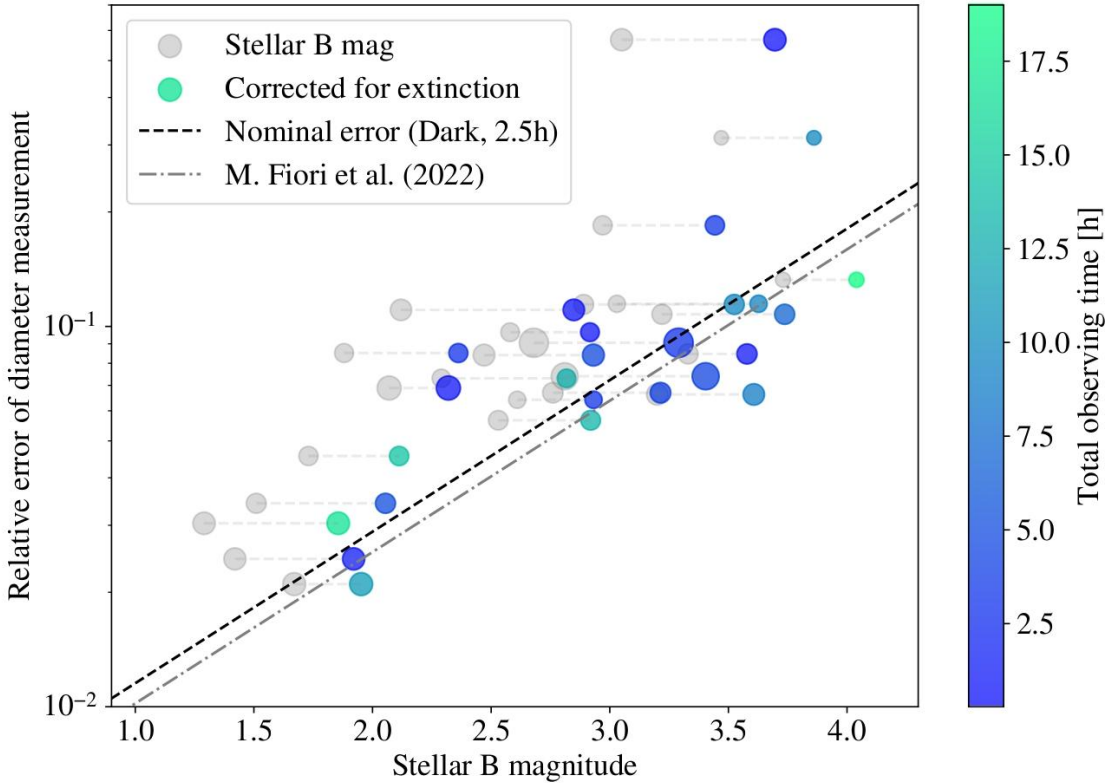
MAGIC SII: System performance



- Photon flux might **change** at different nights due to the **observation conditions**.
- After weighting the exposure time with the photon flux, **S/N expectations are matched**.

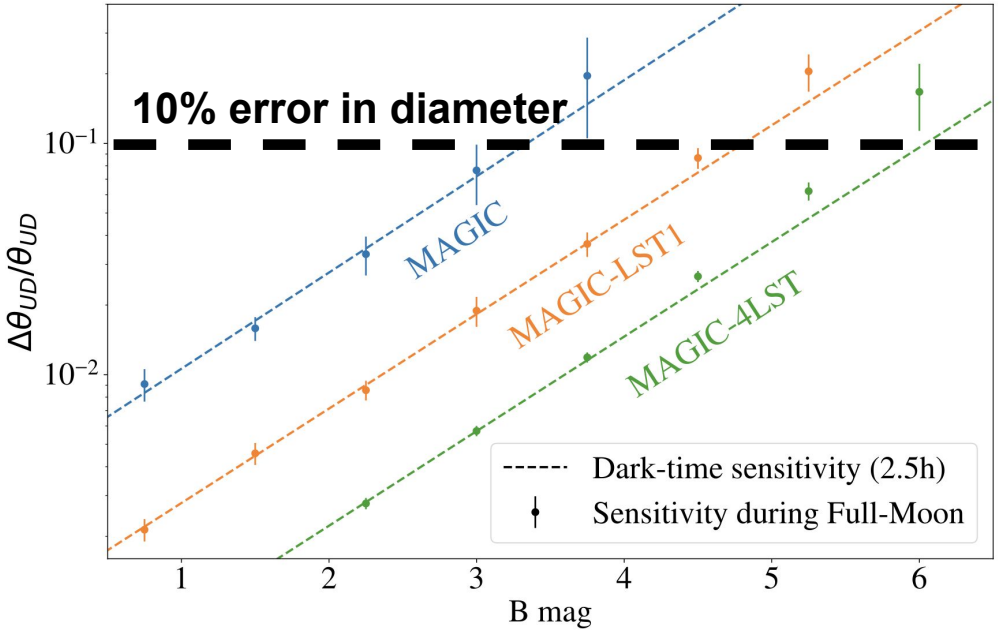
MAGIC SII: Relative uncertainty as a function of the B mag

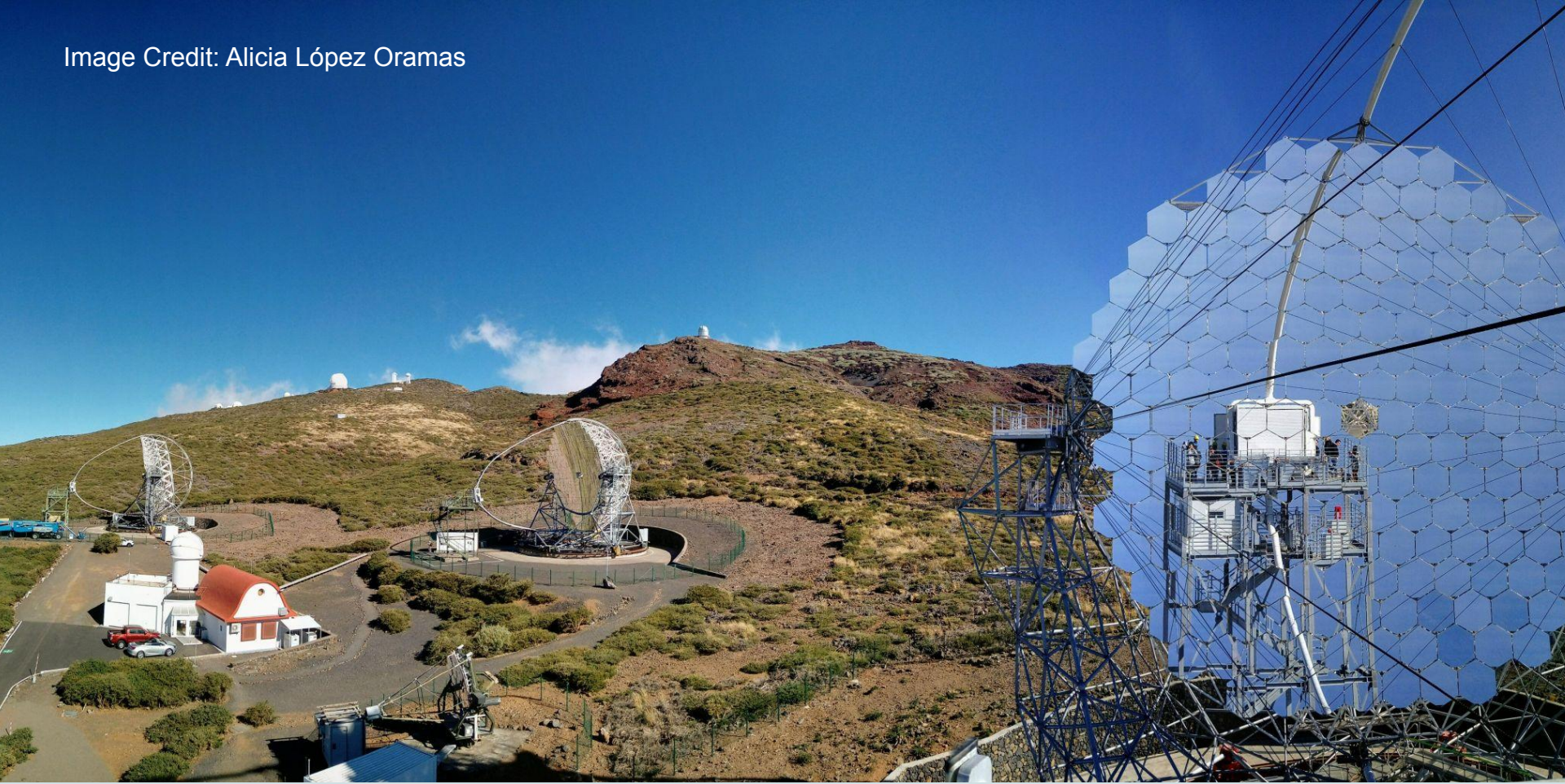
- Nominal relative error expectations are **matched**.
- MAGIC SII can realistically target stars until $\mathbf{B_{mag} \sim 4}$
- Our results prove the **potential of planned improvements** to boots sensitivity.



MAGIC SII: Current and expected sensitivity

- We expect sensitivity to increase by a **factor 4** (**factor 10**) for MAGIC + LST1 (MAGIC + 4LSTs).
- Reach **mag_B = 6** for 10% error in diameter in **2.5 hours** with 4 LSTs.
- **MAGIC + LST1 is taking data now!**





MAGIC + LST1 SII

MAGIC + LST1 SII

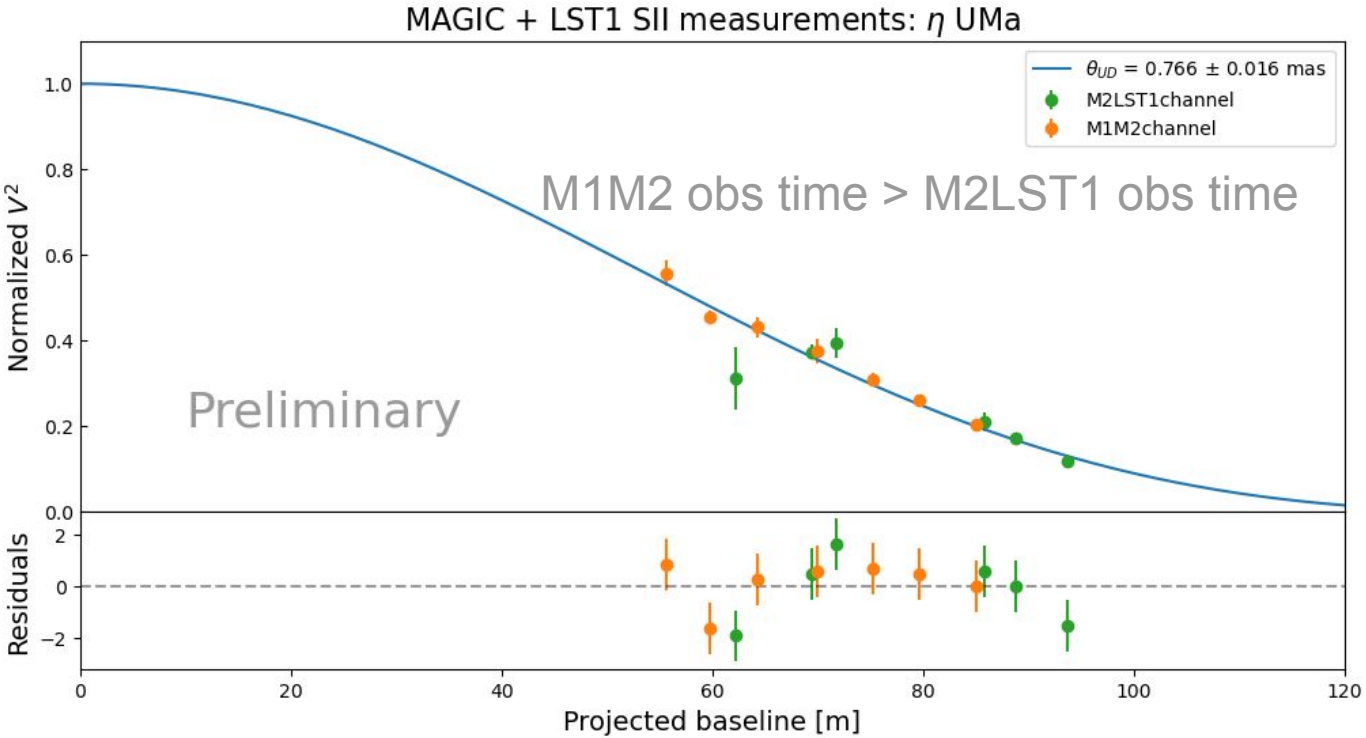
- MAGIC + LST-1 SII observations performed **every Full Moon period** since January 2024.
- **~50 hours** of MAGIC + LST-1 data already taken.
- Mostly **MAGIC calibrators** being observed at the moment.
  - Measurements from different telescope pairs are **consistent**.
  - Broader coverage in baselines→**Improved angular resolution**.
  - Higher statistics → **Smaller errors for the same observing time**.

MAGIC + LST-1 SII preliminary results

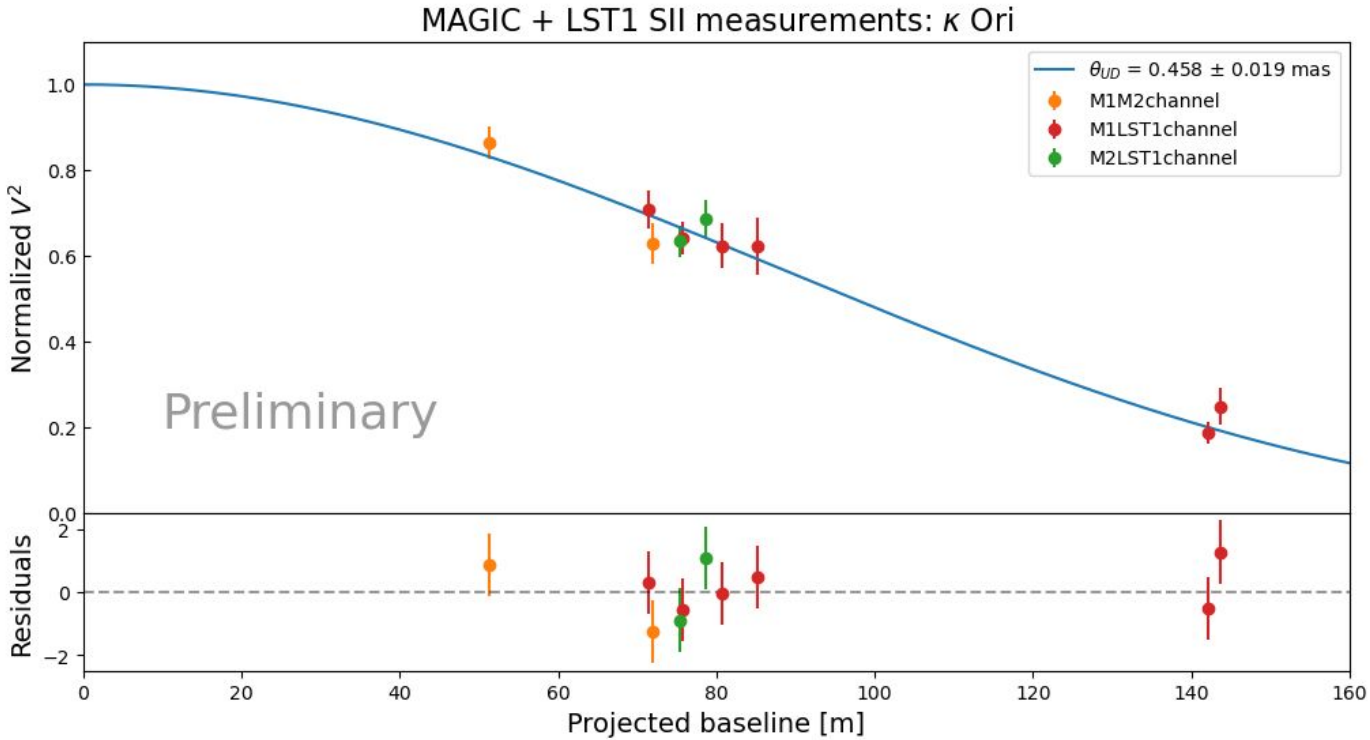
The following results are still preliminary!!

- Results for **calibrators** already observed by MAGIC.
- **Only data from 2024** is used (also for MAGIC).
- Angular diameters are shown with their **statistical errors**, full calibration and systematics evaluation is still **pending**.

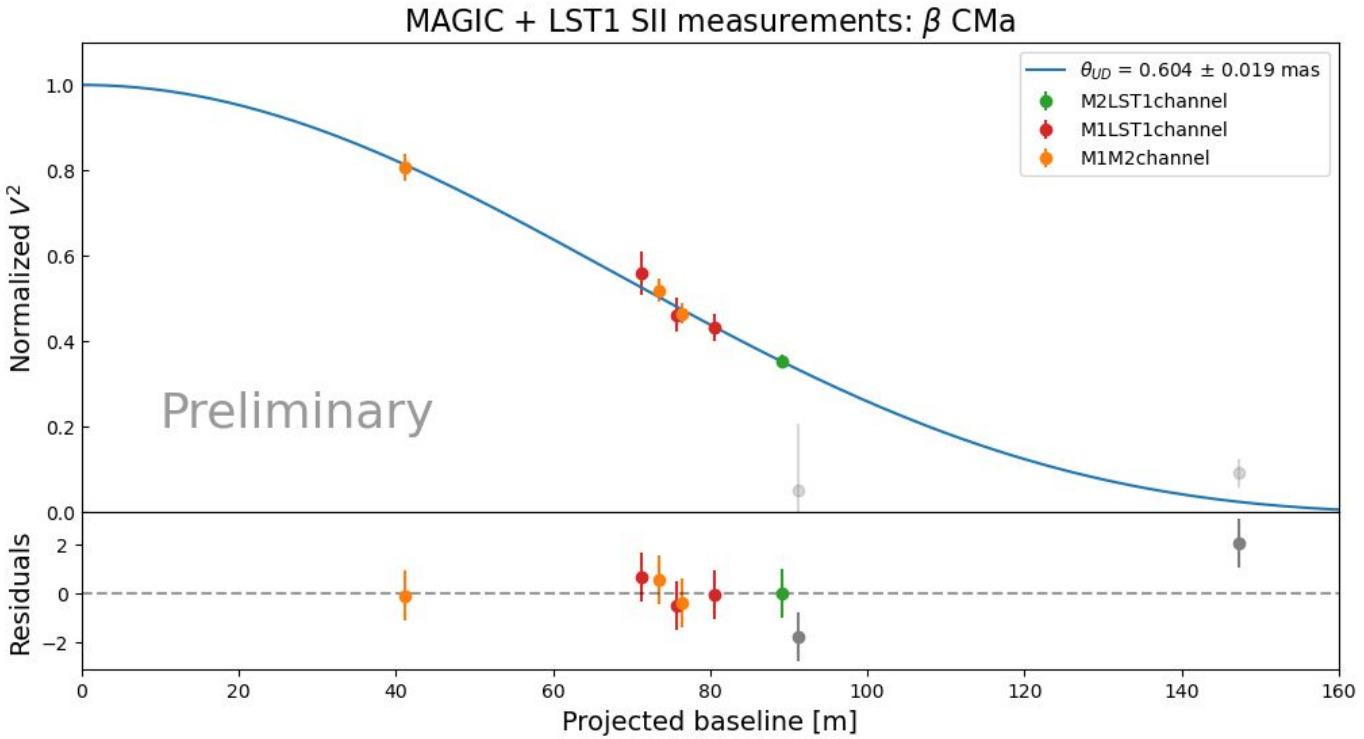
MAGIC + LST-1 SII preliminary results



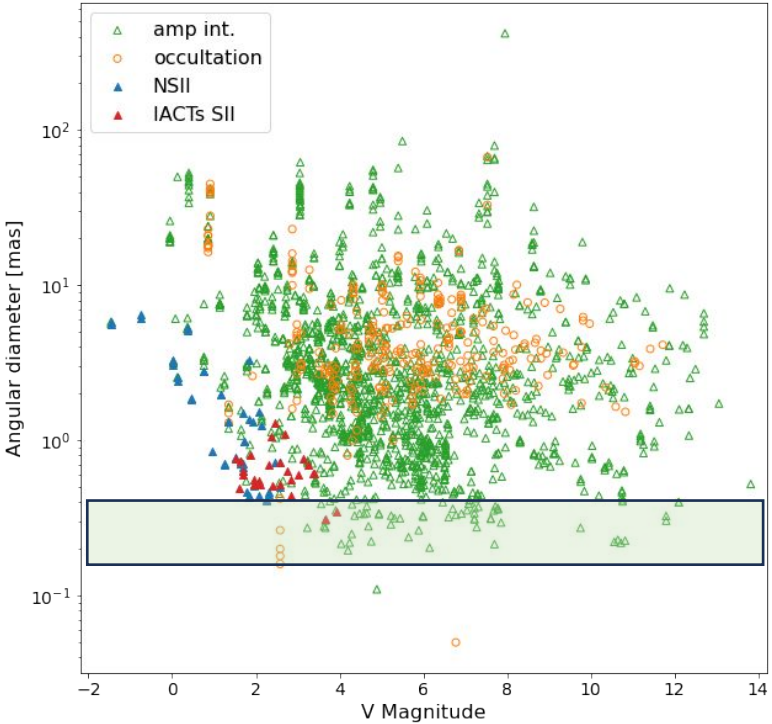
MAGIC + LST-1 SII preliminary results



MAGIC + LST-1 SII preliminary results



Science with MAGIC + LST1 SII: New measurements

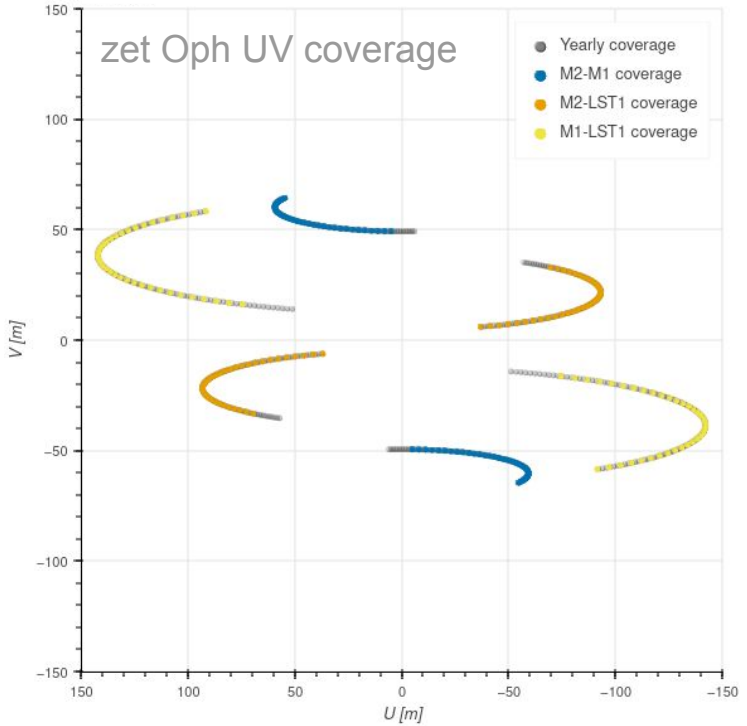


Measurements of stellar angular diameters (based on CHARA and JMDC catalogs).

With MAGIC + LST1 SII we can target **weaker** and **smaller** stars.

Science with MAGIC + LST1 SII: Fast rotators

- More baselines → **Denser UV coverage.**
- Together with **improved angular resolution and sensitivity.**
- **Complex systems** (like fast rotators or binaries) can already be studied with MAGIC + LST1 SII.



MAGIC + 4 LSTs SII

Expansion to MAGIC + 4LSTs

- The same setup used in the LST1 is being implemented in the next three LSTs of CTAO-North.
- Upgrade of the correlator is also ongoing.
- The target installation date is end of 2025 (remember Juan’s presentation).
- MAGIC + 4LSTs will further improve the **angular resolution, sensitivity and UV coverage**. → **New and very relevant science will done!**

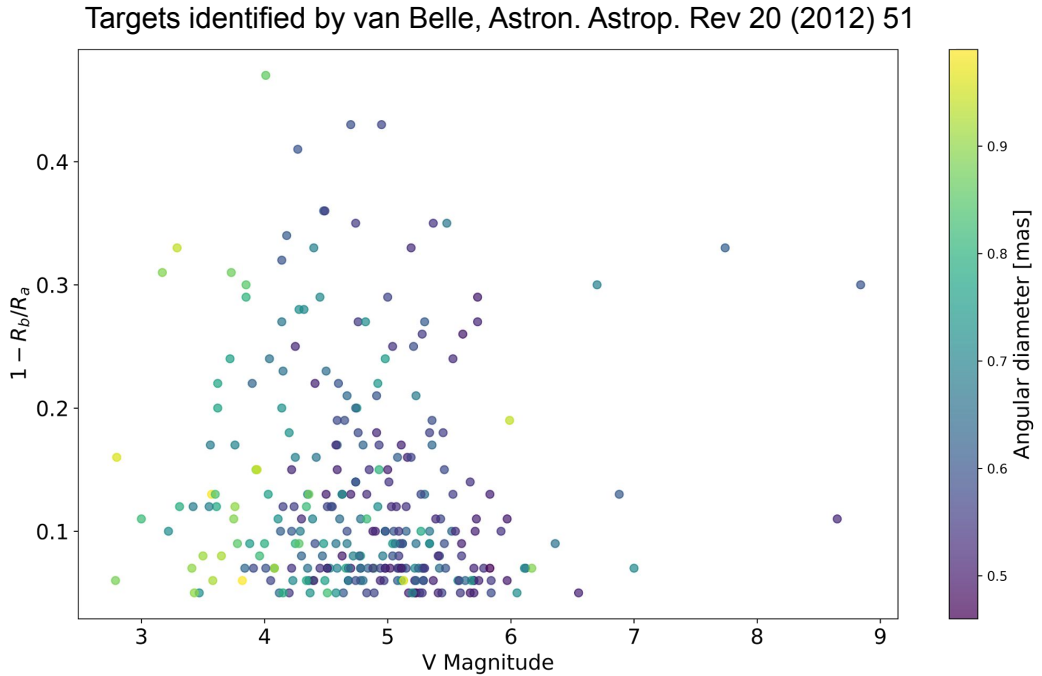
Future expansion to MAGIC + 4LSTs

April 2024. Credit: IAC


Future expansion to MAGIC + 4LSTs
MAGIC-1
MAGIC-2
LST-1
LST-2
LST-3
LST-4
April 2024. Credit: IAC


April 2024. Credit: IAC
Future expansion to MAGIC + 4LSTs
From 3 to 15 unique baselines!
MAGIC-1
MAGIC-2
LST-1
LST-2
LST-3
LST-4

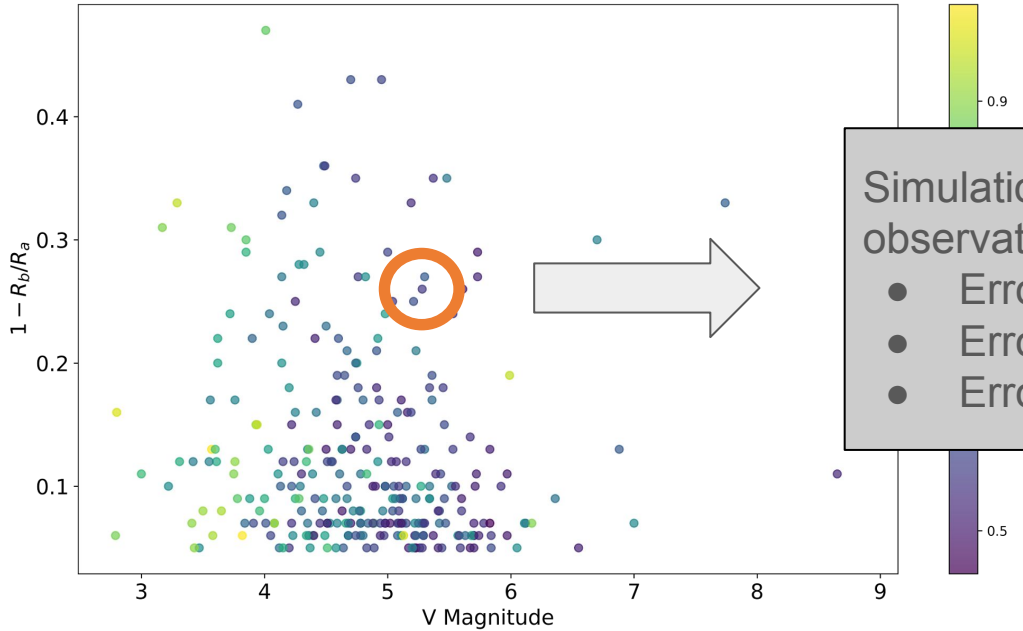
Science with MAGIC + 4LSTs SII: Fast rotators



Multiple targets within reach of MAGIC + LST-1, most targets within reach of MAGIC + 4LSTs.

Science with MAGIC + 4LSTs SII: Fast rotators

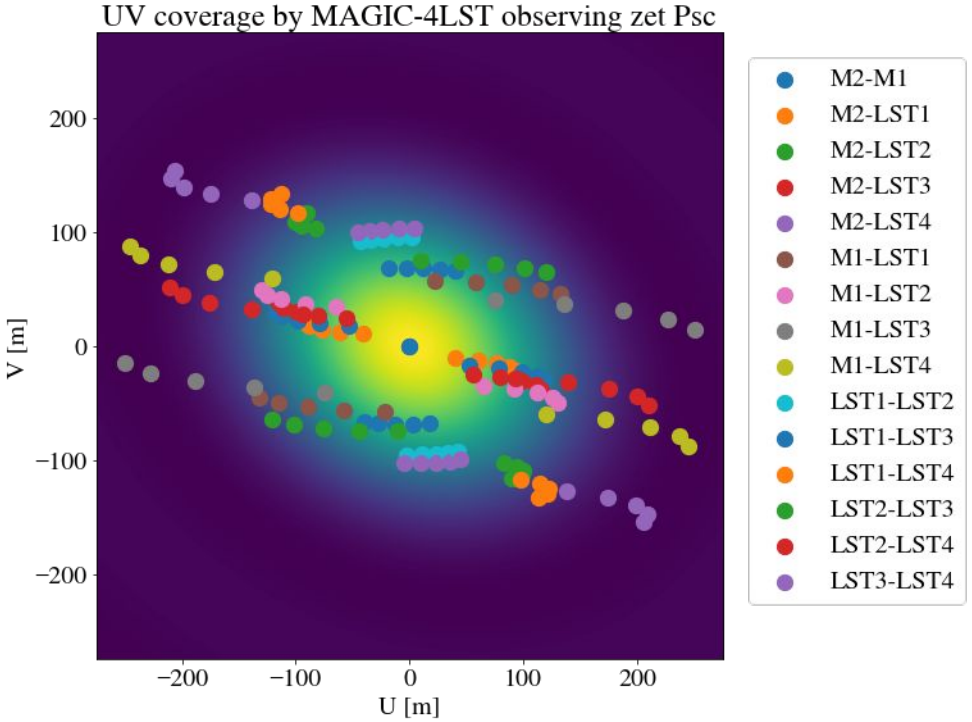
Targets identified by van Belle, Astron. Astrop. Rev 20 (2012) 51



Simulation of 5 hours of MAGIC+4LSTs observations:

- Error in mean diameter ~2 %
- Error in orientation ~5 deg
- Error in “non-sphericity ratio” ~5%

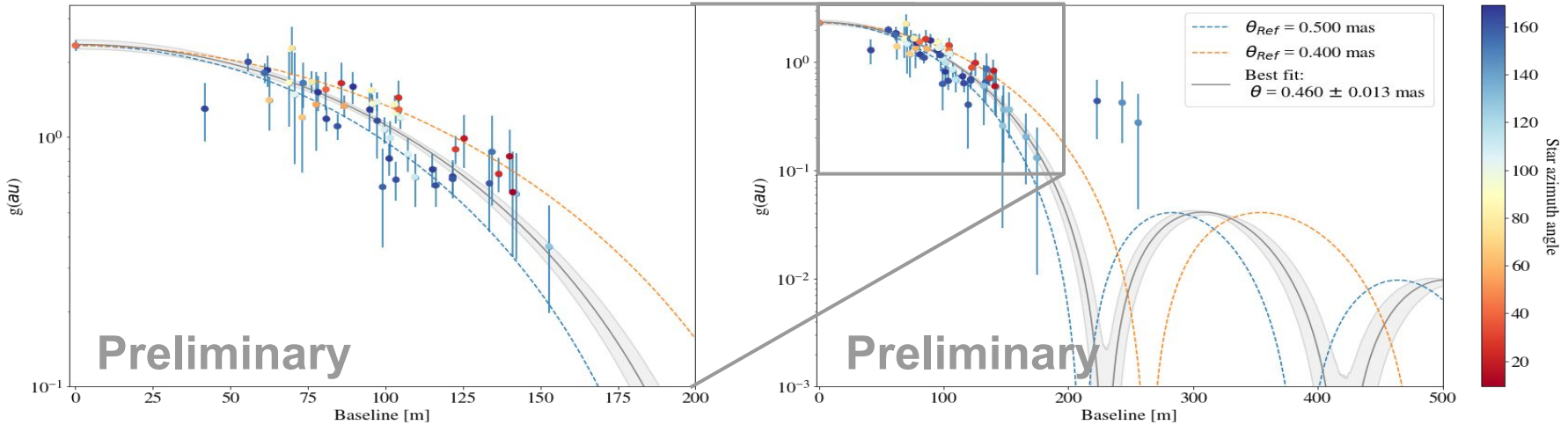
Science with MAGIC + 4LSTs SII: Fast rotators



Simulation of 5 hours of MAGIC+4LSTs observations.

Science with MAGIC + 4LSTs SII: Fast rotators

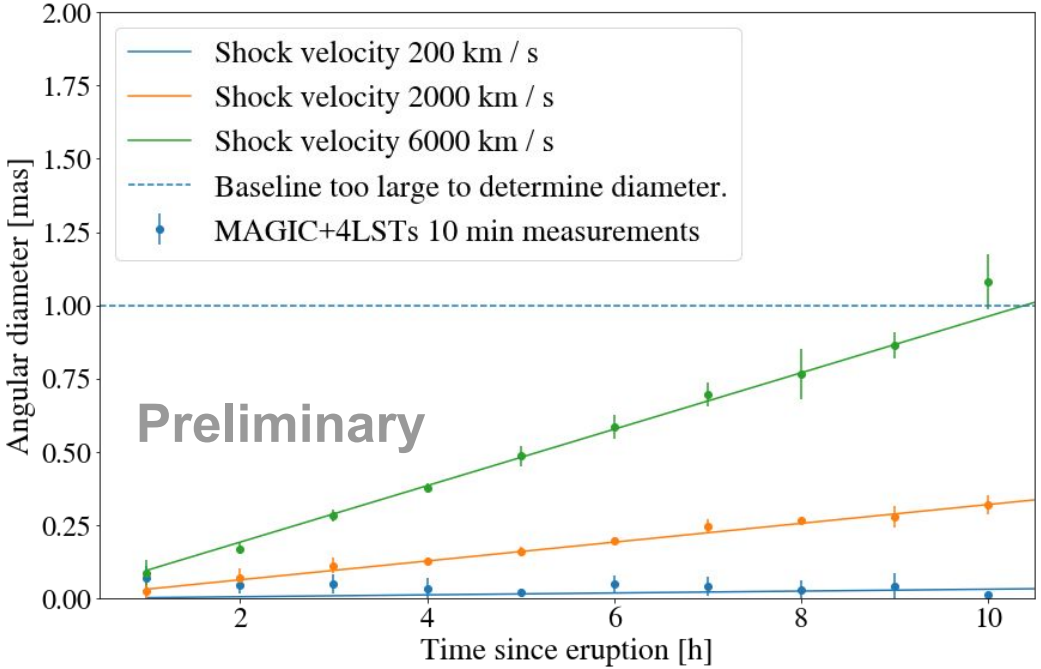
MAGIC-4LSTs observations on zet Psc



Simulation of 5 hours of MAGIC+4LSTs observations.

Science with MAGIC + 4LSTs SII: Novae

Simulation of observations of a 5.5 mag nova at a distance of 3 kpc with MAGIC + 4LSTs



- 5.5 mag novas are happening every ~2 years in the northern sky (Shafter, A. W. et al, 2017).
- The angular size of a nova with low expansion velocity could be measured for **days or even a month.**
- Once the angular diameter of the nova is larger than 1mas, the available baselines are too large to detect the nova.
- Dense UV coverage allows to measure asymmetries in the expanding shell.

Summary

- First scientific results from MAGIC SII already published, measuring the angular diameter of **22 stars** up to $\mathbf{B_{mag}}$ **= 3.7** and angular diameters as small as **0.3 mas** → Implementation scalable to MAGIC + 4LSTs SII.
- MAGIC+LST1 SII has been regularly taking data since January 2024.

  First results are promising!
- The system will be expanded to the next LSTs of CTAO-North.
- MAGIC + 4LSTs SII **improved sensitivity**, **angular resolution** and **dense UV coverage** will open up the study of many **scientific cases**.

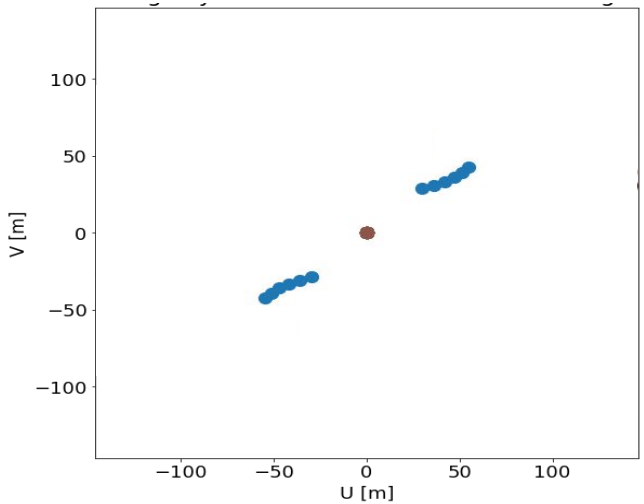
Proposals for observations are welcome!

- Next MAGIC call for proposals will be in **November 2024**.
- Proposals are **welcome** at MAGIC even if you are not a member of the collaboration.
- If you want to submit a proposal, **do not hesitate to contact us!** (SII proposals have a slightly different format).

Backup slides

MAGIC + 4LSTs: Improvements on UV coverage

MAGIC only



MAGIC + 4LSTs