SII software school: Lesson I Preparations and first

Quick introduction to SII analysis

T. Hassan on behalf of
the magic_spysii dev team

European Research Council
Established by the European Commission

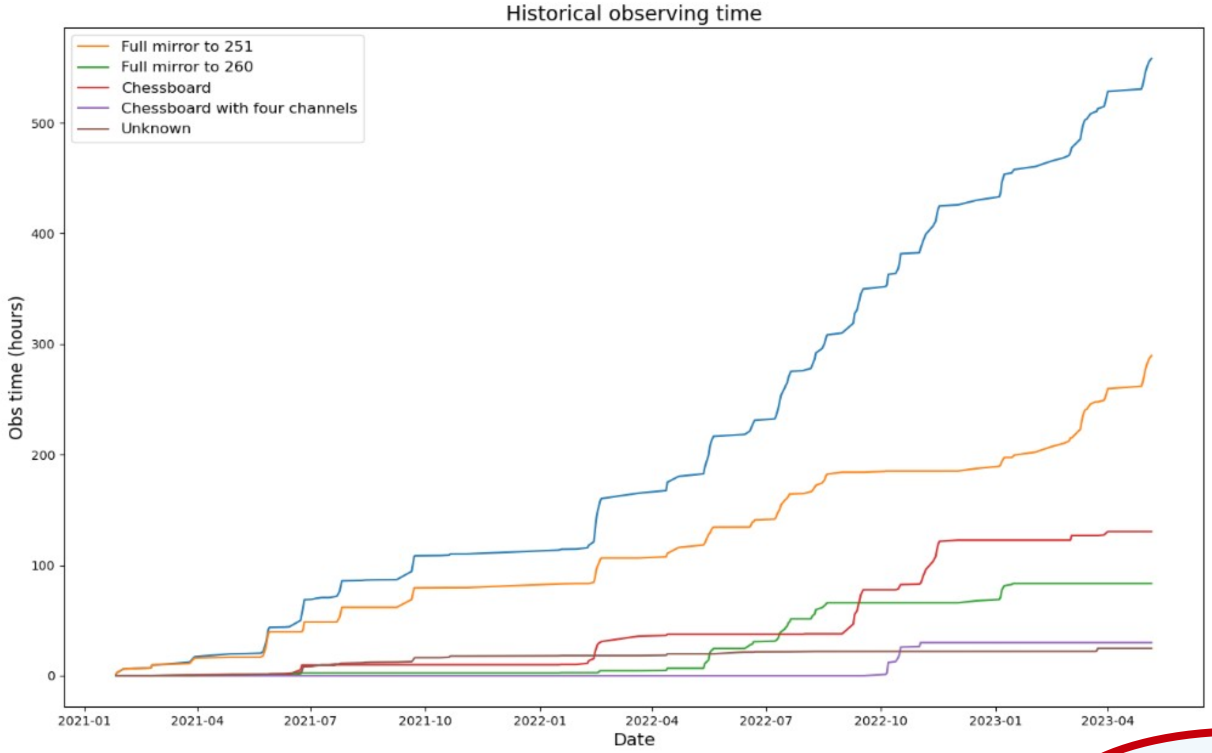
Ciemat
Centro de Investigaciones
Energéticas, Medioambientales
y Tecnológicas

First lesson: Main points to discuss

- Quick introduction to interferometry analysis
- Description of the setup, and its evolution
- Requirements (apart from **studying** the performance paper!):
  - Access to the magic_spysii repository (will be made public soon)
  - Access to mic machines (and LST machines, if needed)
  - A bit of storage available
- Problems or questions?

MAGIC-SII: Datataking status

- Since the new setup was commissioned, more than 500h of observation have been performed

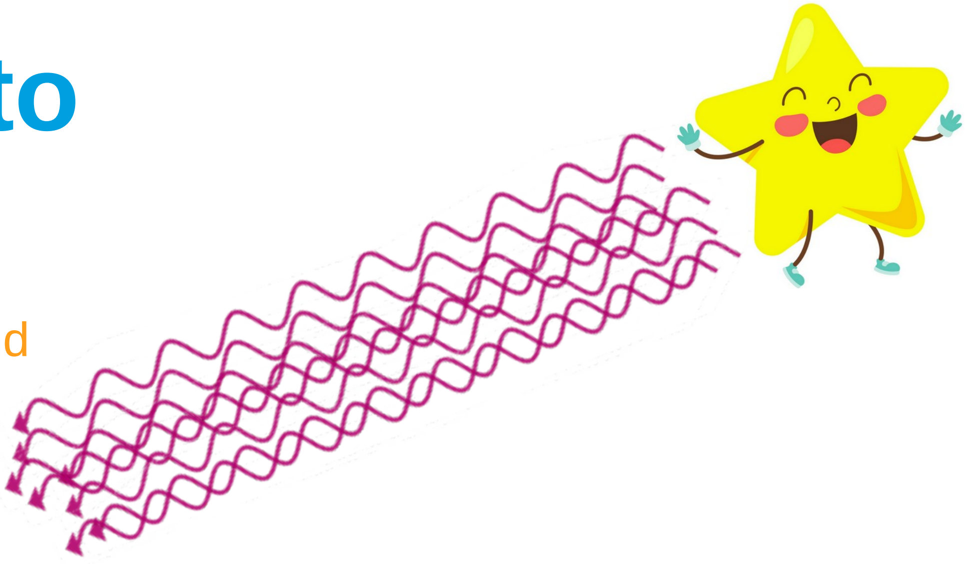


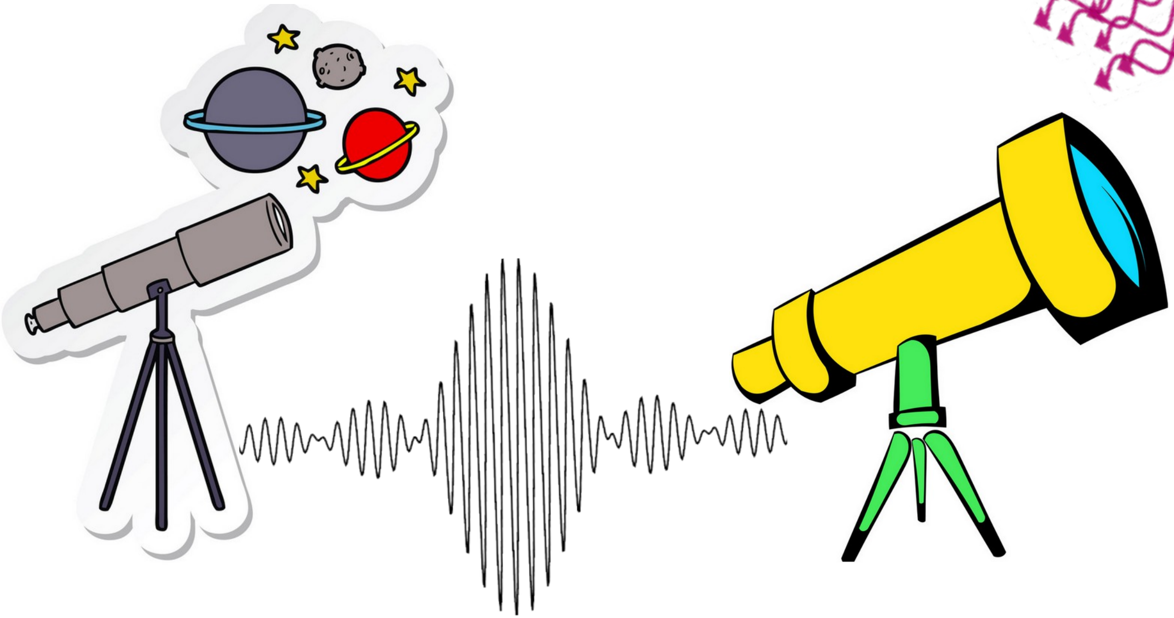
- MAGIC observing shifts have been extended to partially cover Moon nights

A. Cifuentes

Gentle introduction to interferometry

Amazing angular resolution, but hard to understand





Gentle introduction to interferometry

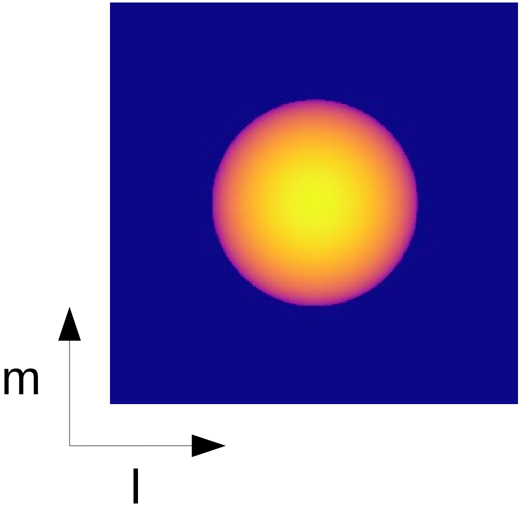
Amazing angular resolution, but hard to understand

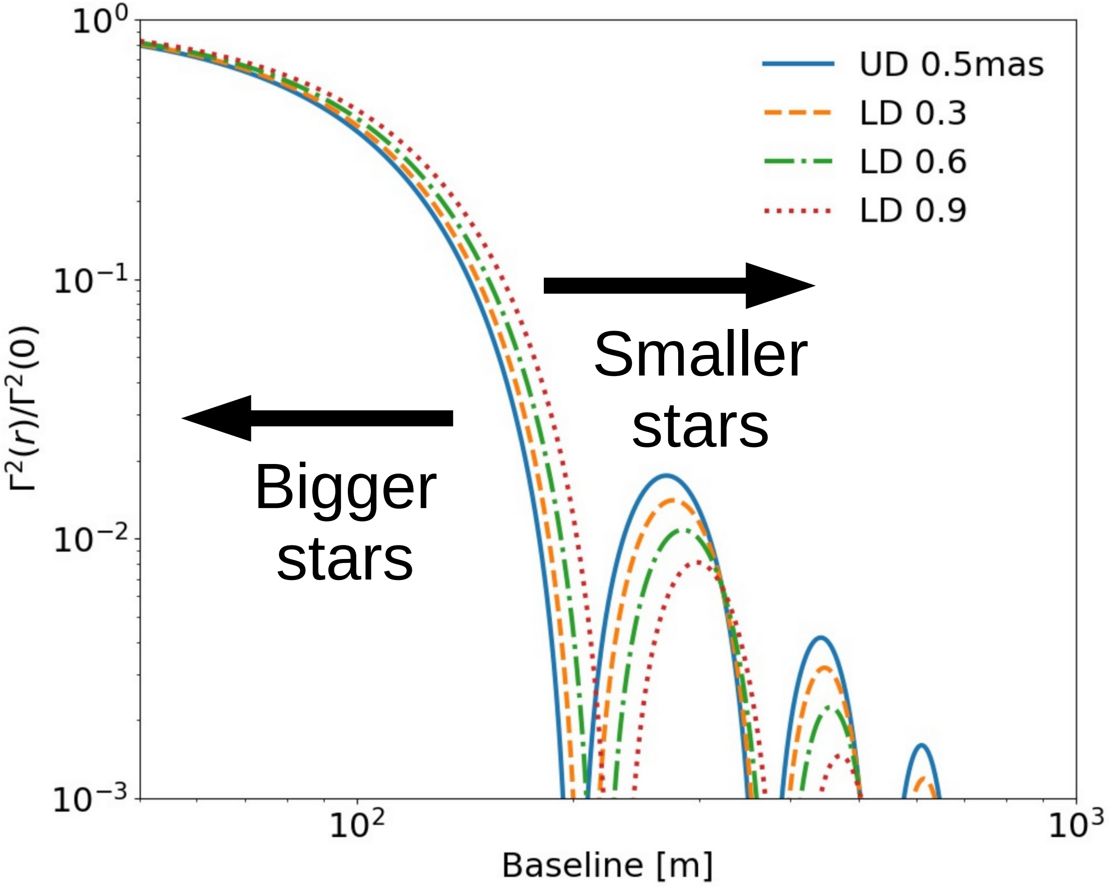
- Objectives:
  - Basic general introduction to SII analysis
  - Remind everyone the large variety of “configurations” possible with MAGIC+LST1
- Questions are welcome! Please interrupt me...

Introduction to SII: Analysis basics

- Van Cittert-Zernike Theorem:

Sky model

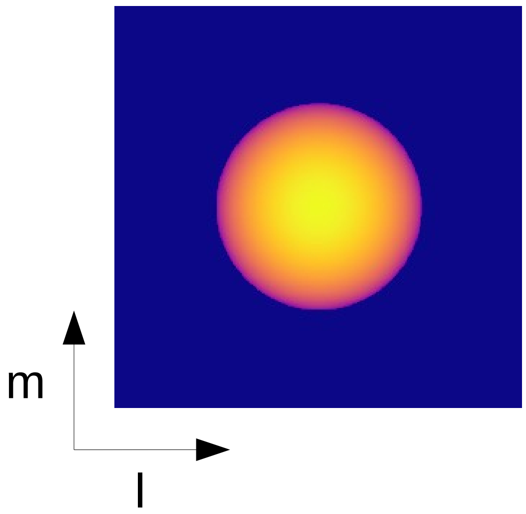




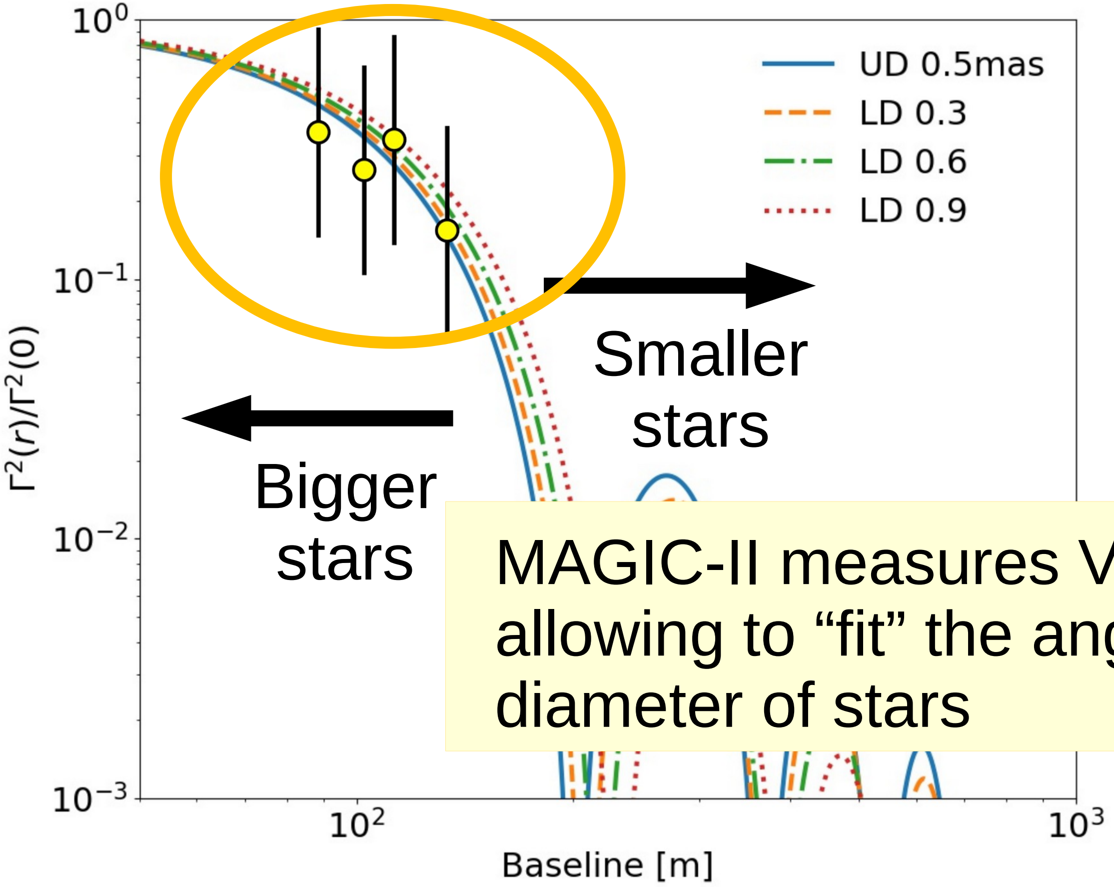
Introduction to SII: Analysis basics

- Van Cittert-Zernike Theorem:

Sky model

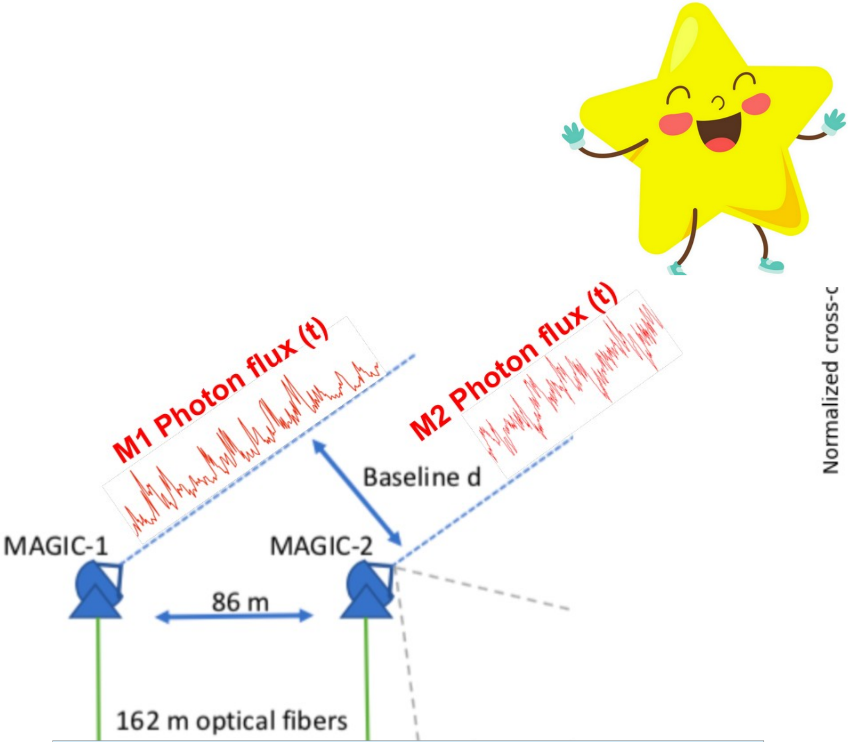


MAGIC-II observations

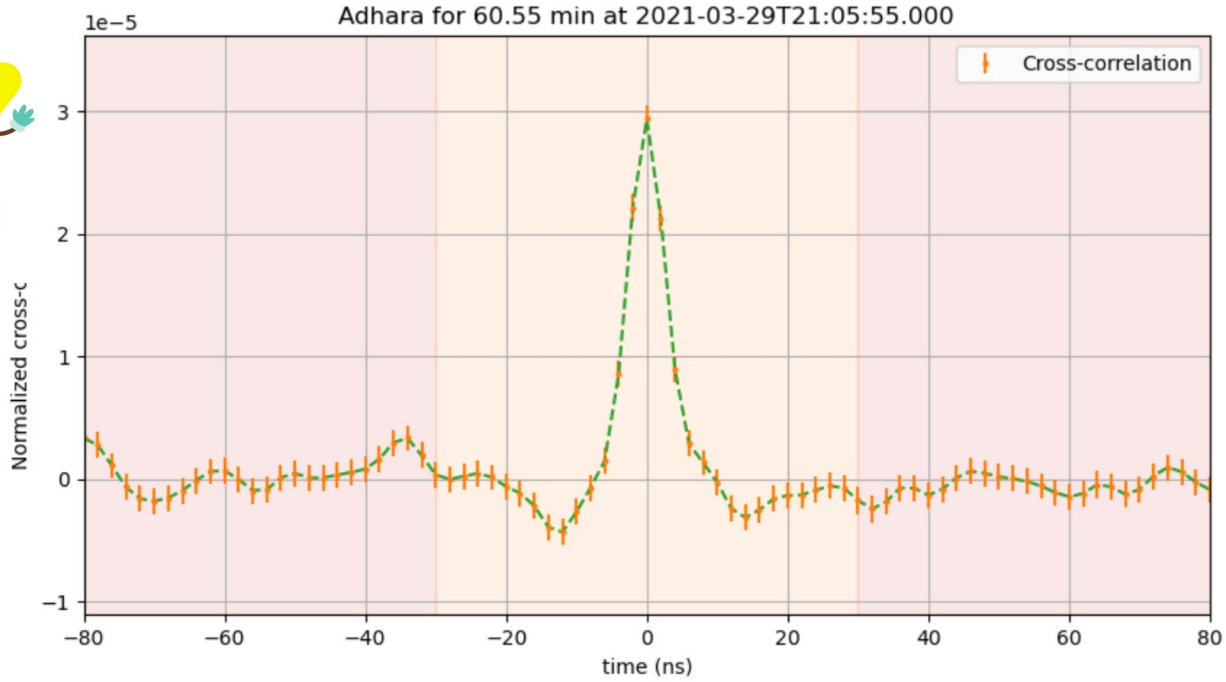


MAGIC-II measures V^2, allowing to “fit” the angular diameter of stars

Introduction to SII: Analysis basics



MAGIC-II correlator
(digitizers + GPUs)



Computes Pearson’s correlation

Introduction to SII: Analysis basics

$$V^2 \sim \frac{\rho}{\sqrt{DC_1 DC_2}}$$

MAGIC-SII: Analysis basics wrap up

- By measuring V^2, MAGIC is able to do ultra-high resolution measurements in the optical, by fitting the “visibility” of the observed stars

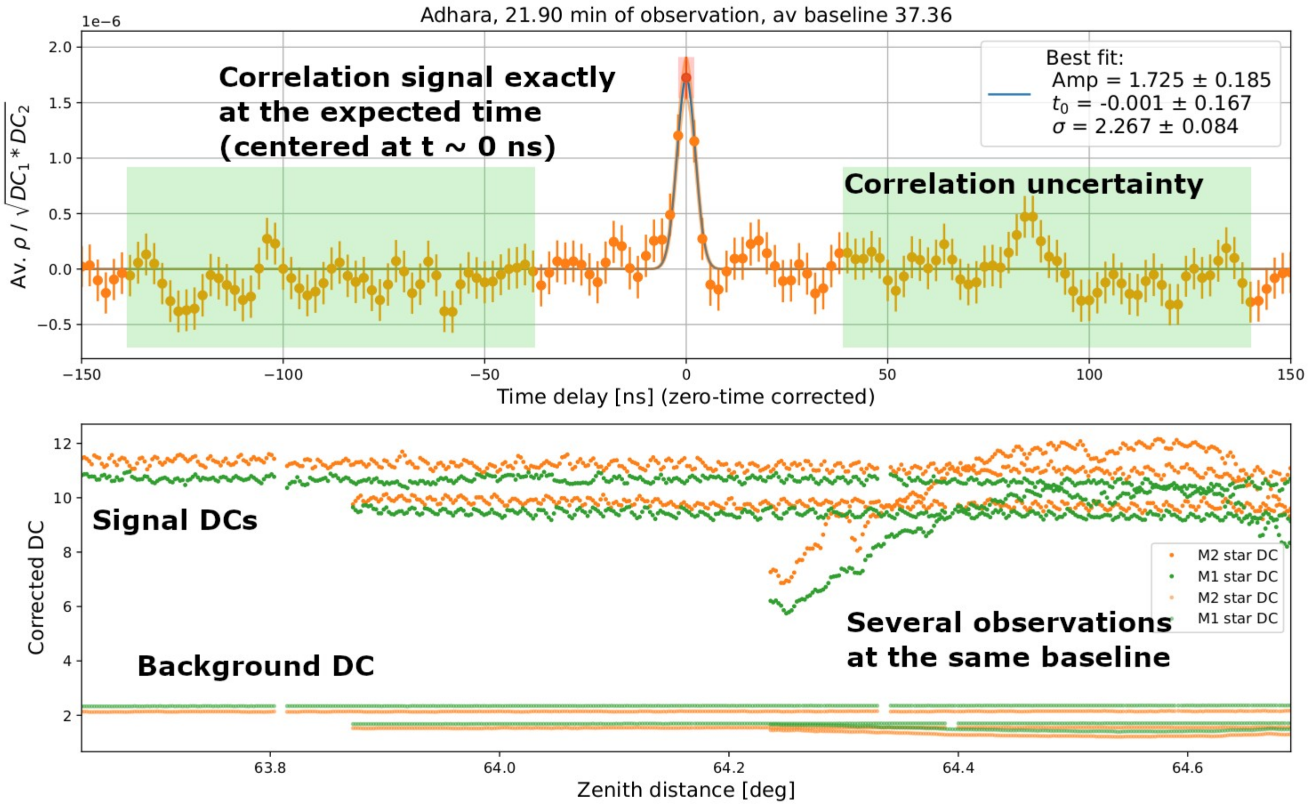
- The correlator computes Pearson’s correlation (ρ), and by correcting it with the measured DCs of the observation, we get V^2 (+ uncertainty)

- Even if MAGIC is only 2 telescopes (fixed baseline) as stars move accross the sky, the proyected baseline changes

    - Adhara is the perfect star: super bright, ideal angular diameter and in a sky location that allows a very wide range of baselines

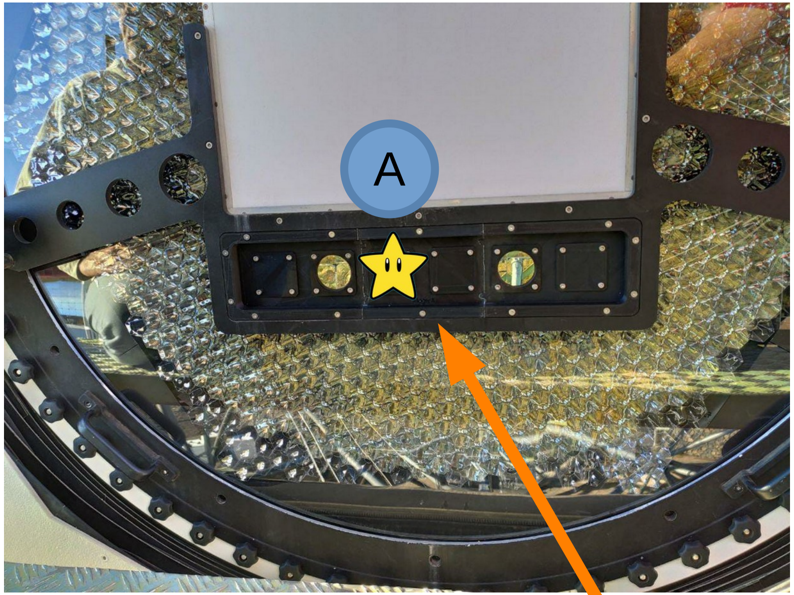
MAGIC-SII Analysis – Our measurement

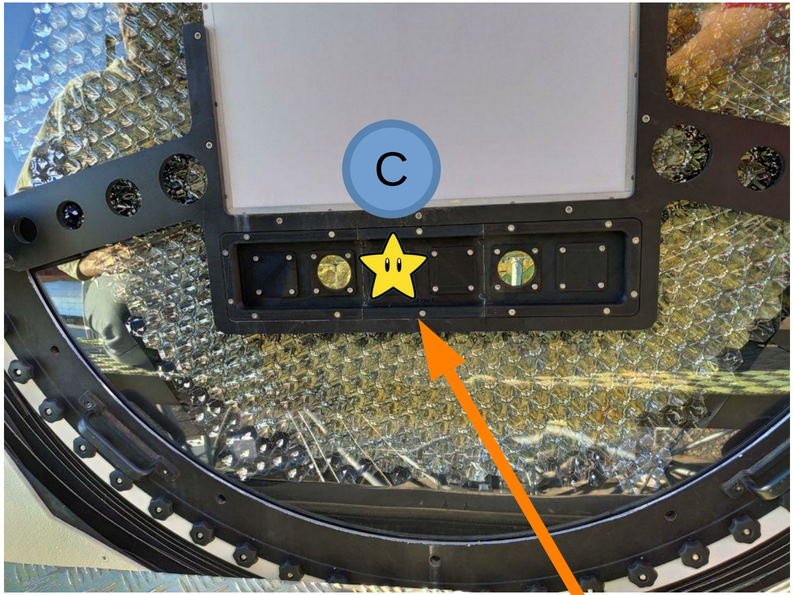
- For a given observation:



MAGIC-SII setup: The power of AMC

- This functionality adds enormous versatility to MAGIC: **full-mirror**

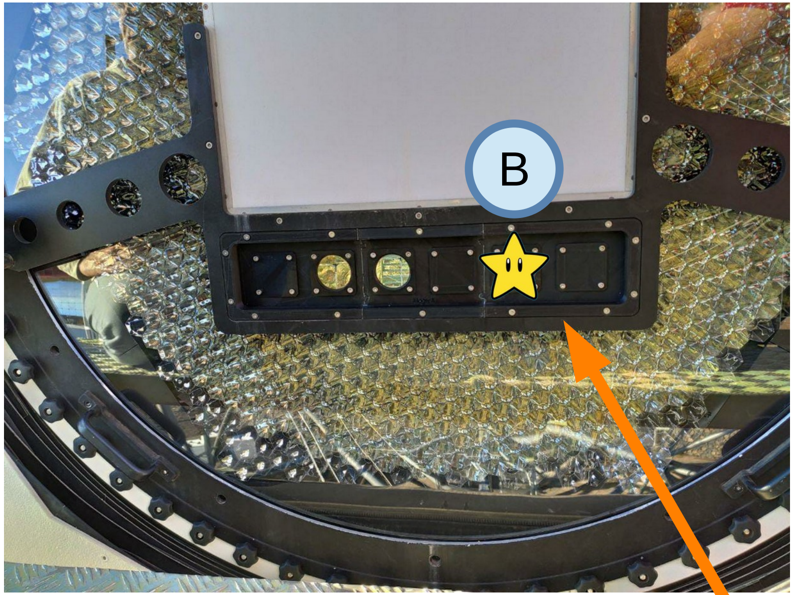


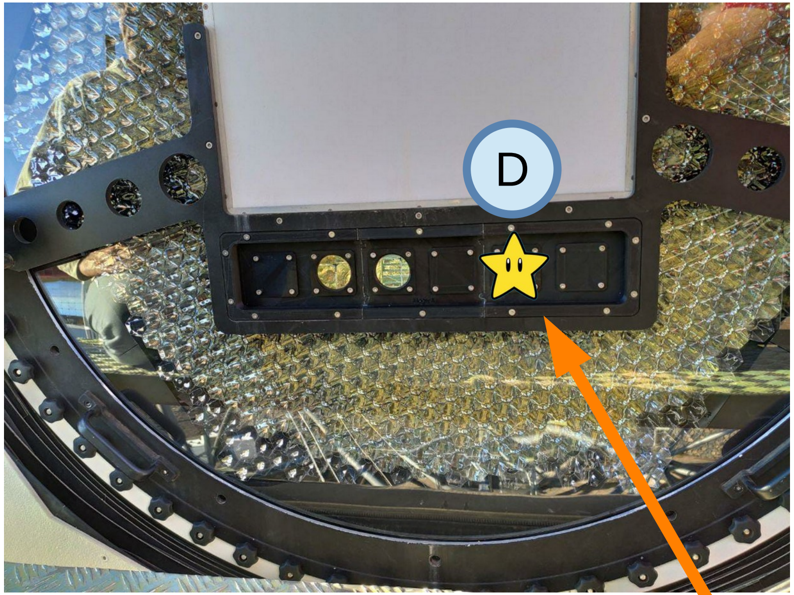


AMC allows to focus all starlight in the pixel you want

MAGIC-SII setup: The power of AMC

- This functionality adds enormous versatility to MAGIC: **full-mirror**

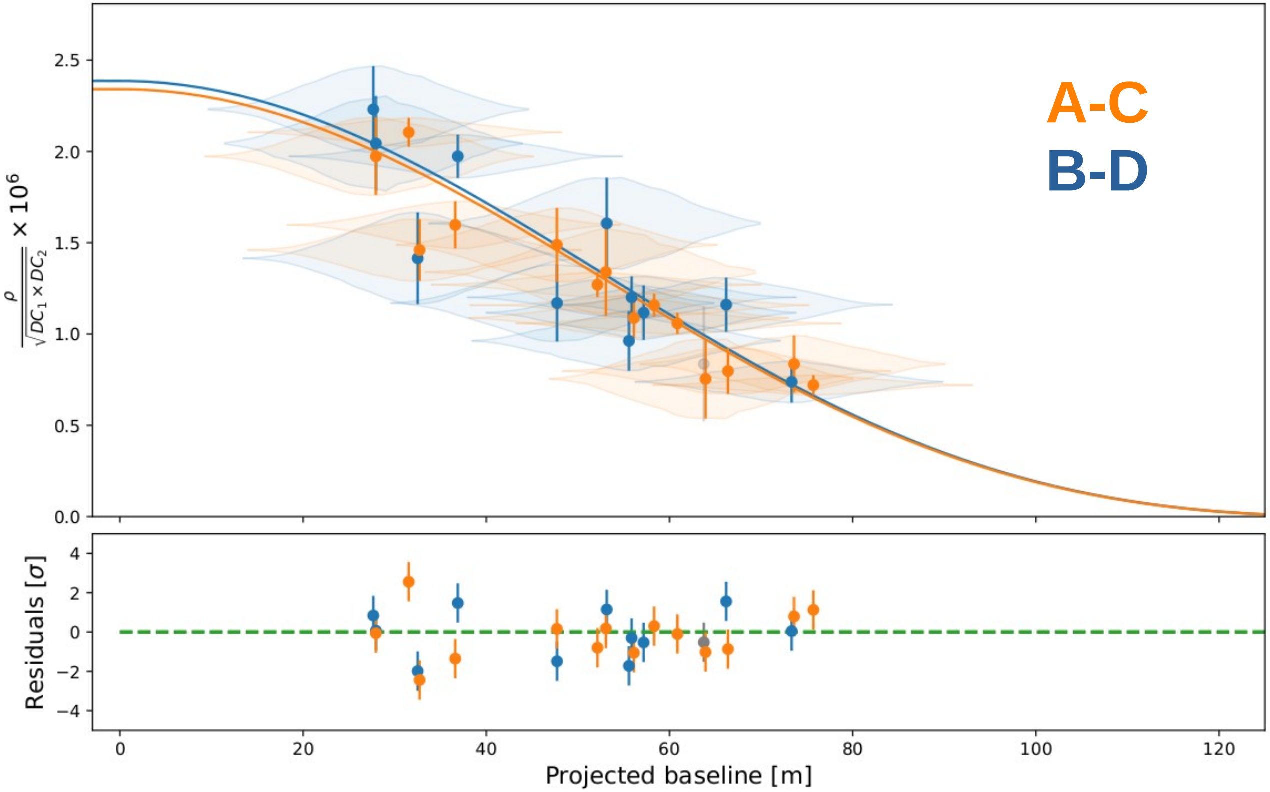




AMC allows to focus all starlight in the pixel you want

MAGIC-SII Analysis – Our measurement

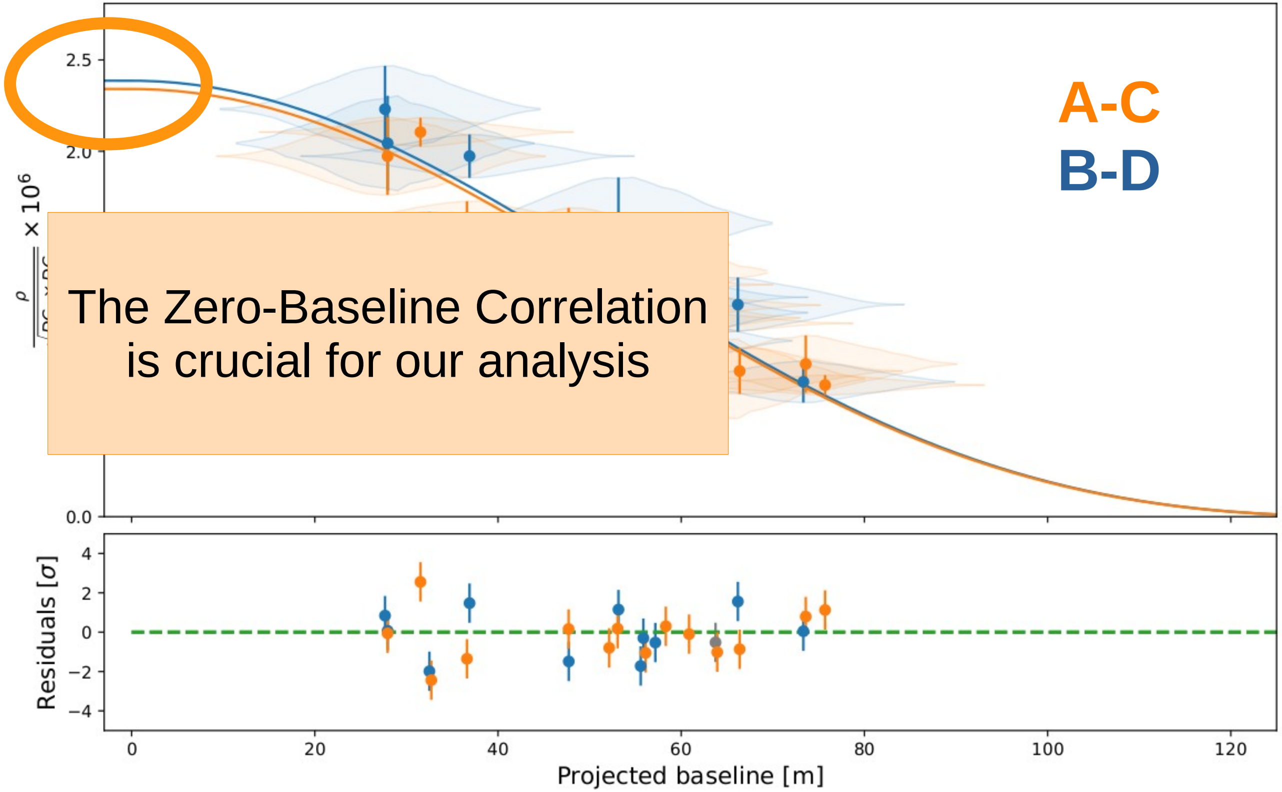
- Only have two telescopes: Adhara provides best brightness + UV coverage



- Adhara dominates the determination of our ZBC
- How consistent is the analysis of A-C vs B-D?
- Allows to test the dependence on pixel gains, transmission, etc...

MAGIC-SII Analysis – Our measurement

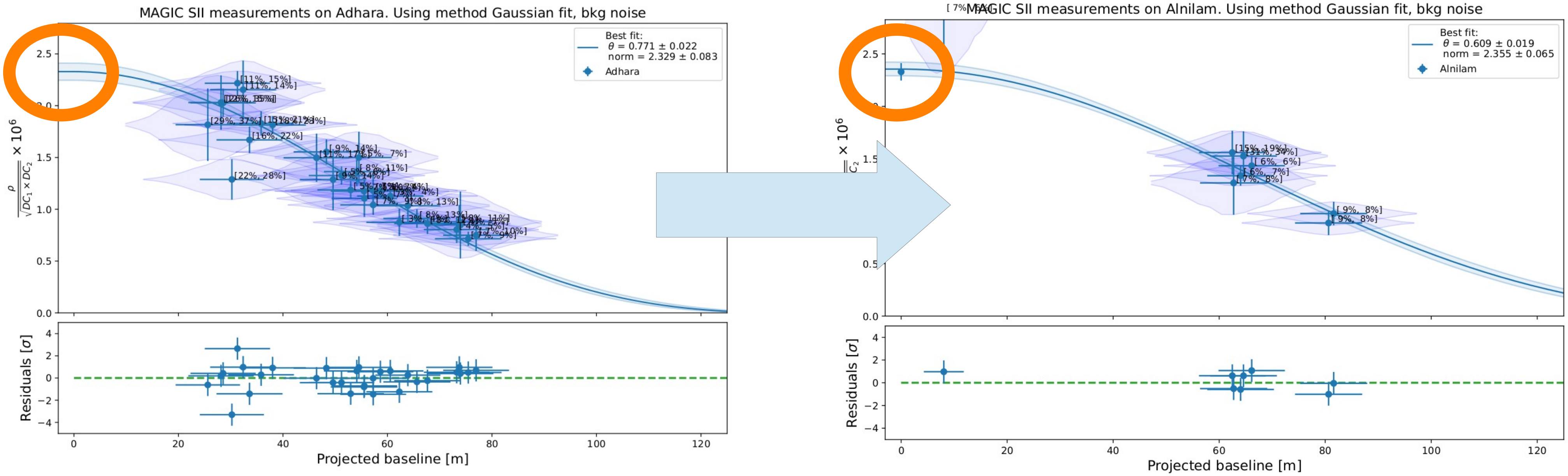
- Only have two telescopes: Adhara provides best brightness + UV coverage



- Adhara dominates the determination of our ZBC
- How consistent is the analysis of A-C vs B-D?
- Allows to test the dependence on pixel gains, transmission, etc...

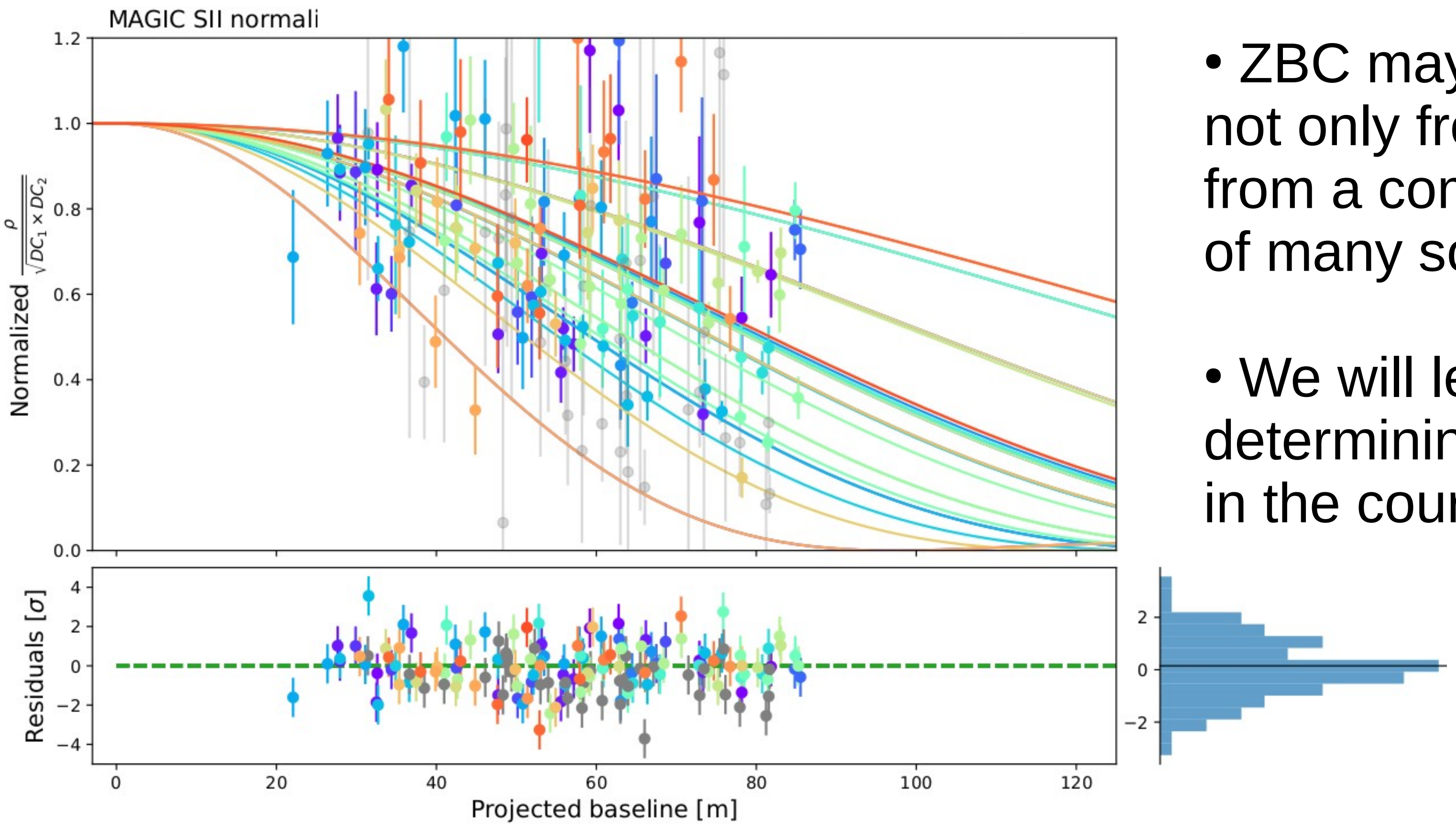
MAGIC-SII: The Zero-Baseline Correlation

- It is (supposed to be) a **constant of our system**. Determining it with decent confidence, allows performing angular diameter measurements on stars with little data



MAGIC-SII: Combining all measurements

- Combined analysis of all sources: statistical residuals



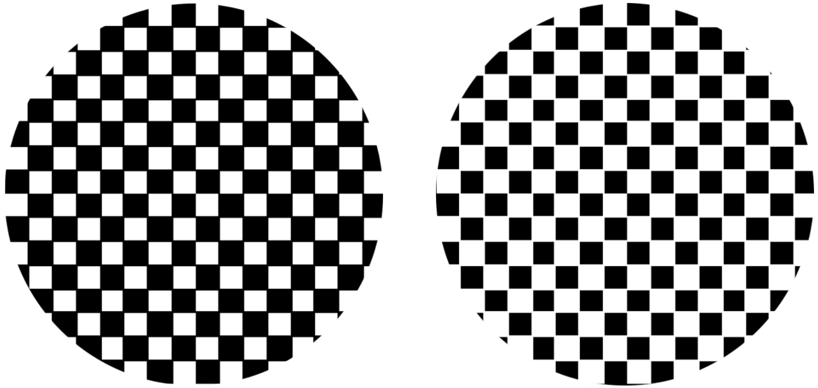
- ZBC may be determined not only from 1 source, also from a combined analysis of many sources

- We will learn about determining the ZBC later in the course

MAGIC-SII: The Zero-Baseline Correlation

- It is (supposed to be) a **constant of our system**. Determining it with decent confidence, allows performing angular diameter measurements on stars with little data

- MAGIC Active Mirror Control allows a “direct” measurement of the ZBC

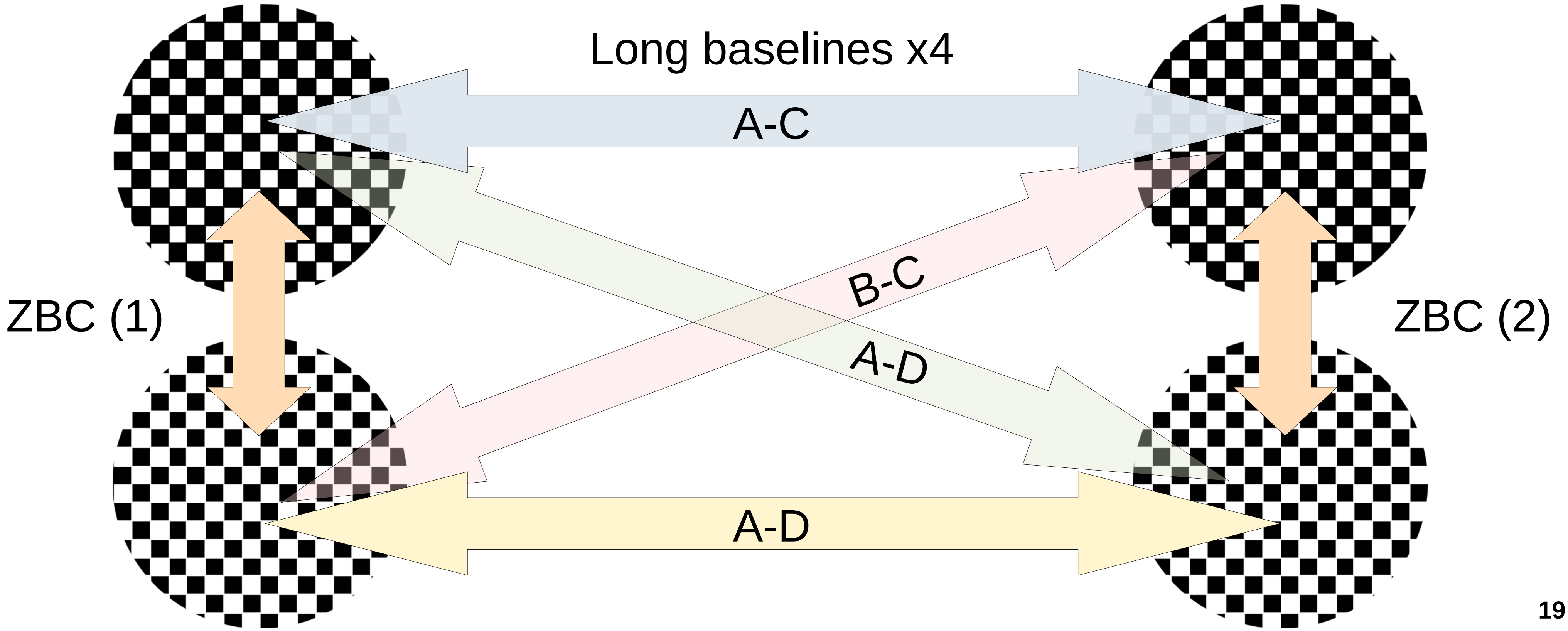


- By focussing half of our mirrors to one pixel and half to the other, we can measure (something close to the) ZBC

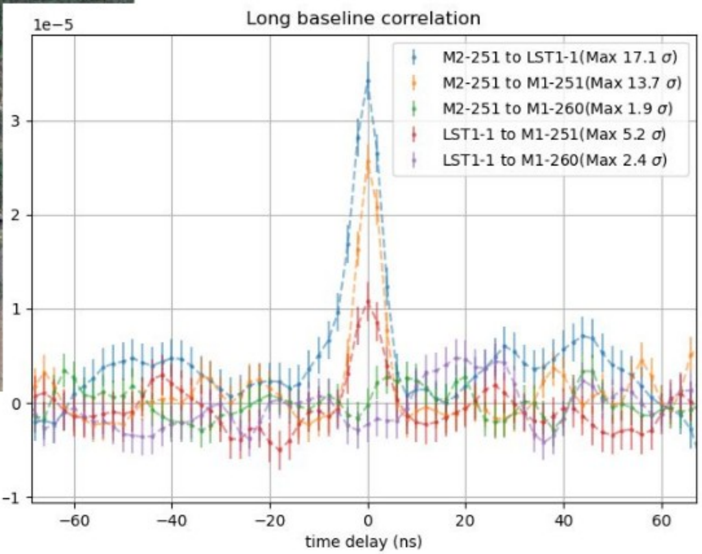
- This is something only us can do: others need to use optics: (beamsplitting mirror)

MAGIC-SII: Adhara, the princess of the fairy tail

- We routinely use 2 pixels per telescope, so we can compute many different correlation measurements:

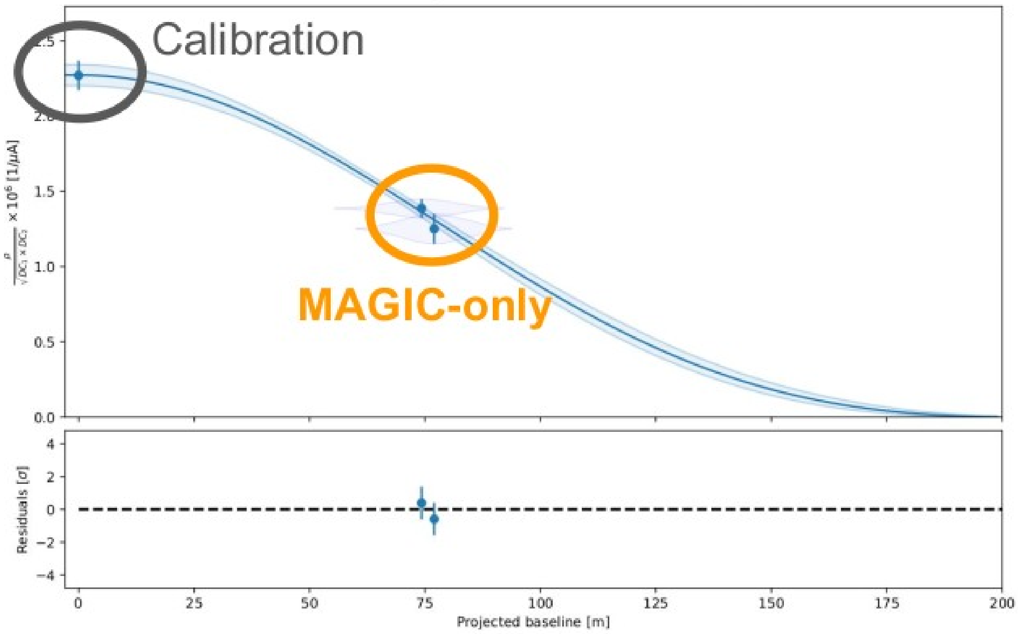


MAGIC-SII → MAGIC-LST1-SII

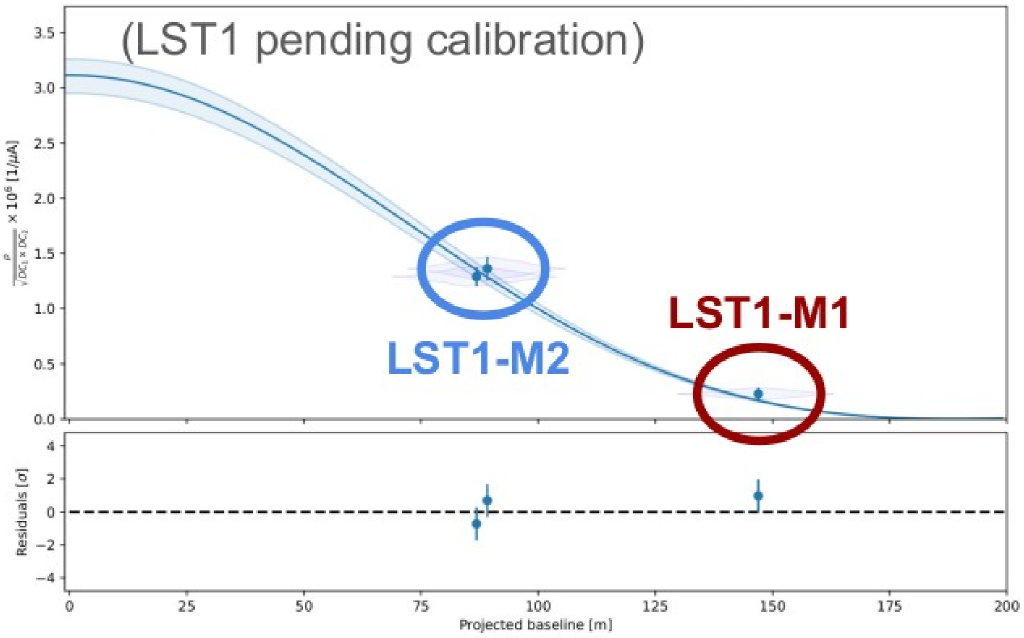


- From MAGIC, we know precisely the diameter of Mirzam
- MAGIC-LST1 correlation measurements are very consistent with MAGIC-only measurements

MAGIC-only measurement



MAGIC-LST1 measurements



IACT-SII: Analysis basics wrap up

- The library “magic_spysii” is just one of the 4 different analysis libraries that were used in the performance paper

- The usual steps of an interferometry analysis are:
    - Synchronize the interferometry raw data into your analysis folder
    - “Reduce” raw data (transform binaries into pickles, easier for python)
    - Gather all runs from a source and compute V^2 measurements
        - Compute V^2 of a calibrator (or calibrators) to compute ZBC
        - Measure the stellar diameter you want!

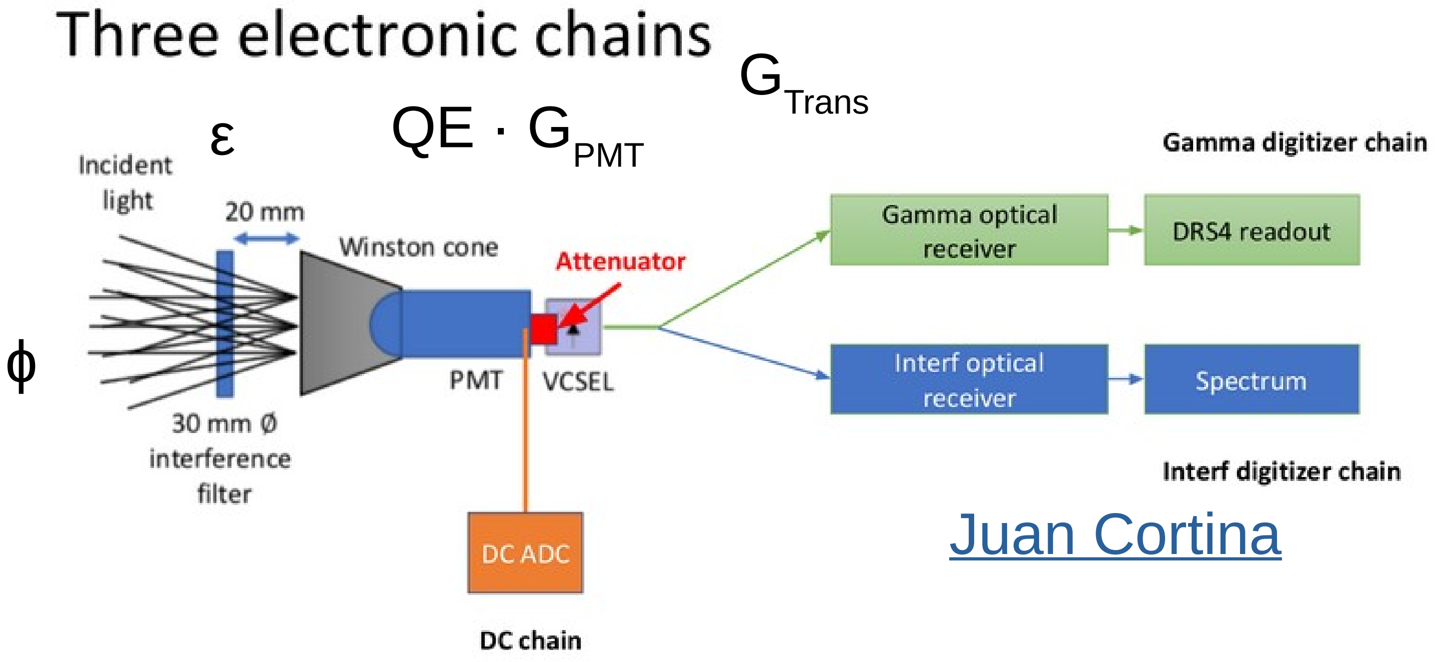
IACT-SII: How we will proceed

- We will gather all the resources that may be useful for you:
  - Useful previous interferometry presentations
  - Papers related to the science we can do
- Technically, work on the documentation of the code:
  - For the time being, working on a minimal documentation: https://tarekhc.github.io/magic_spysii/
- Weekly exercises to slowly understand interferometry data and analysis


BACKUP

MAGIC-SII systematics: Many “gains” involved

- To understand MAGIC-SII systematics, we need to understand the time evolution of all the parameters affecting SII observations:



[Juan Cortina]

ZBC: The constant of our system

- From HB&T, we know that the expected correlation:

$$\overline{c(d)} = \langle \Delta i_1(t) \Delta i_2(t) \rangle = e^2 A^2 \alpha^2 n^2 |\gamma_d(0)|^2 \Delta \nu \Delta f \qquad (4.28)$$

- After dividing by the flux, the remaining correlation should be:

$$\frac{\overline{c(d)}}{flux} \propto \frac{|\gamma_d(0)|^2}{\Delta \nu \Delta f}$$

- But as with our setup, our “flux” is the DCs (different gain than the correlation):

$$\frac{\overline{c(d)}}{\sqrt{DC^1 DC^2}} \propto \frac{|\gamma_d(0)|^2}{\sqrt{G^1{}_{DC} G^2{}_{DC}} \Delta \nu \Delta f}$$

Any time evolution in the DC gain will be a **systematic**