Friedrich-Alexander-Universität
Erlangen-Nürnberg

Erlangen Centre for Astroparticle Physics

FAU

# Intensity interferometry with the H.E.S.S. telescopes

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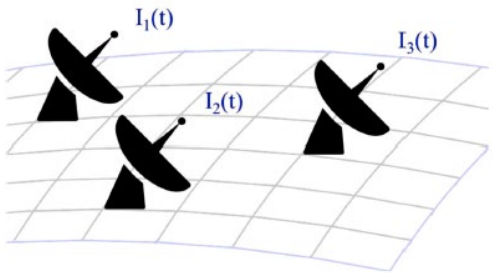
Future Prospects of Intensity Interferometry,
30 October 2024

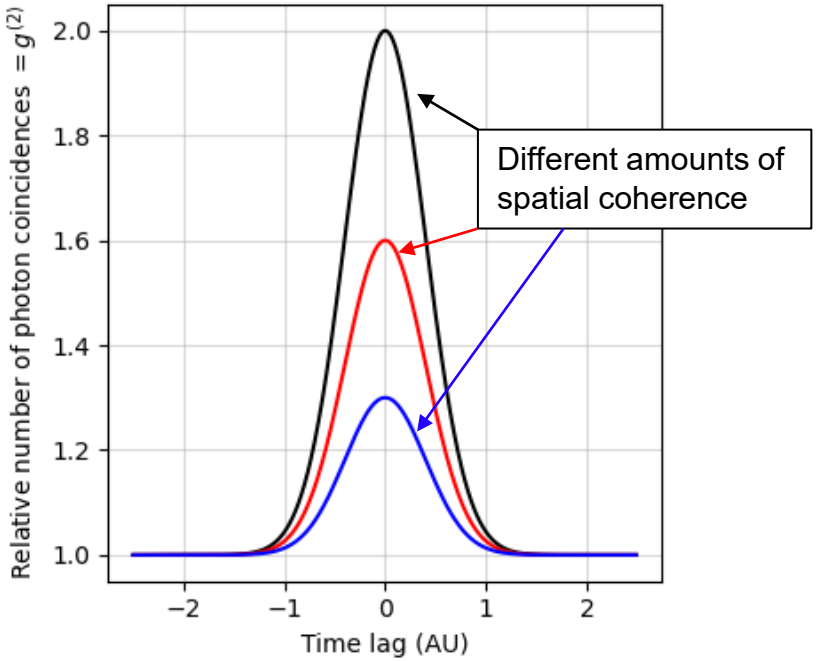
# The concept of stellar intensity interferometry

**Intensity Interferometry**

- Exploiting second-order correlations of light
- Recording photon stream in different telescopes
- ➢ No optical connections between telescopes
- ➢ Offline correlation possible
- ➢ **Require large telescopes, but no high optical quality**



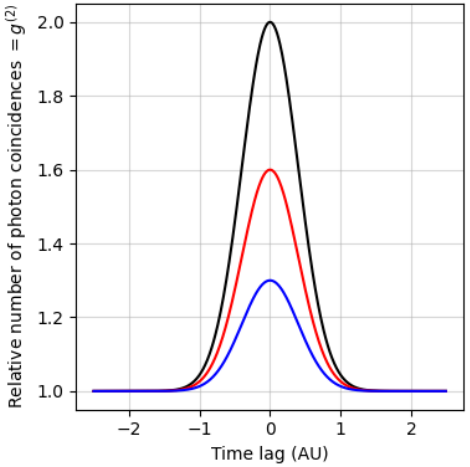

*Dravins, Dainis, and Colin Carlile. "Kilometer-baseline optical intensity interferometry for stellar surface observations."*



# The concept of stellar intensity interferometry

- Intensity interferometry: exploiting second-order correlations of light

$$g^{(2)} - 1 \propto \langle \Delta I_1 \Delta I_2 \rangle \propto |FT\,[I\,(x,y)]|^2$$



# The concept of stellar intensity interferometry

- Intensity interferometry: exploiting second-order correlations of light

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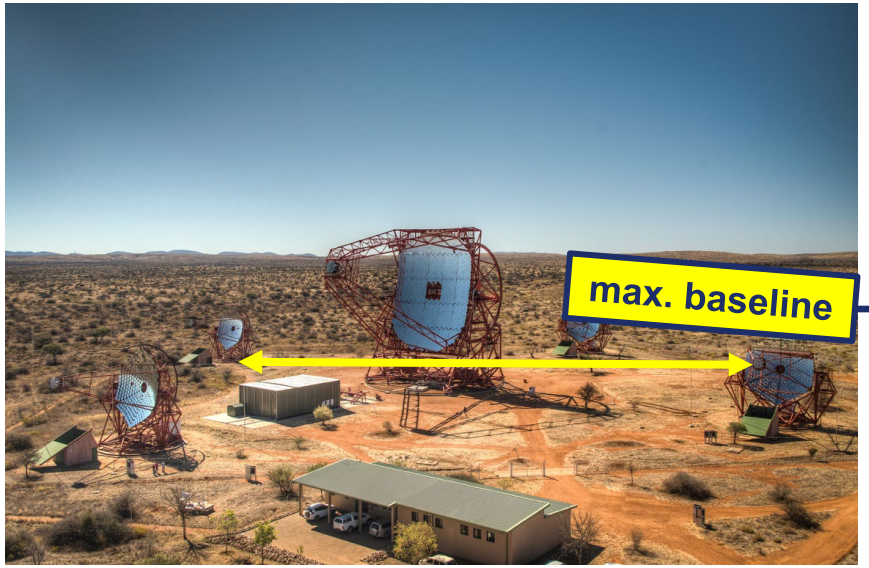
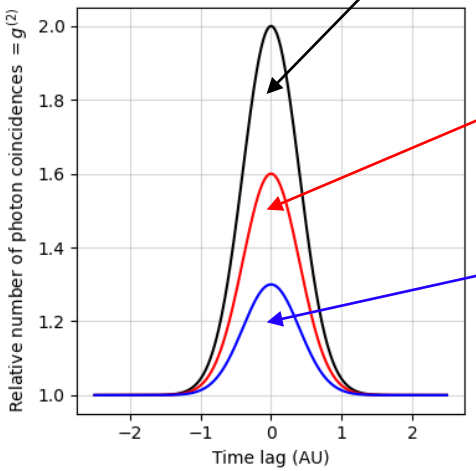
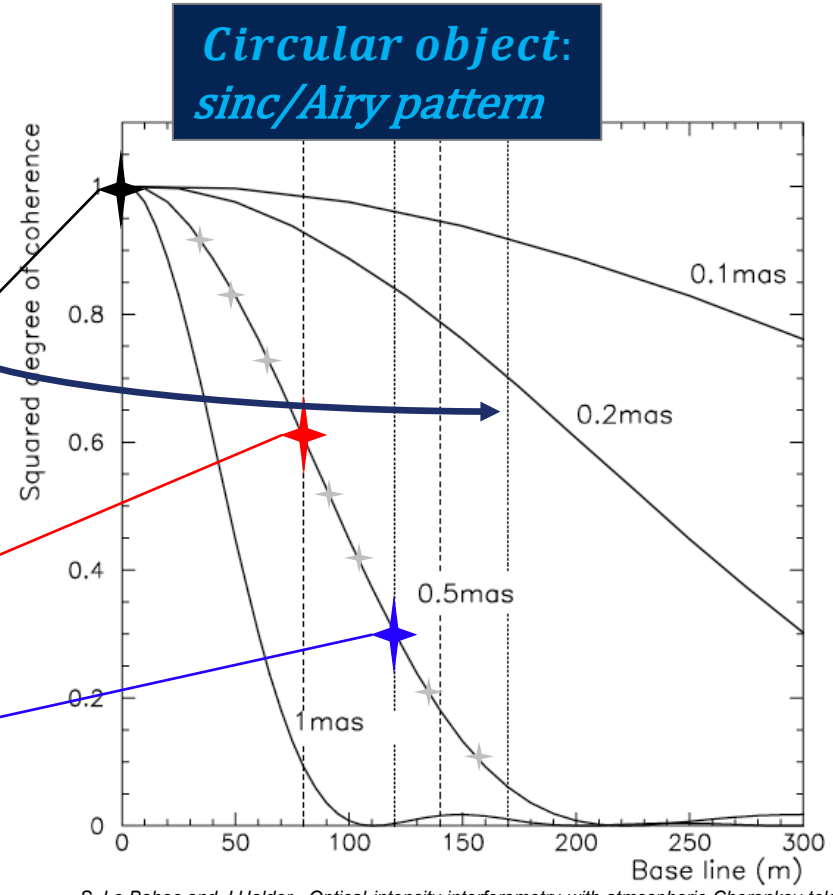
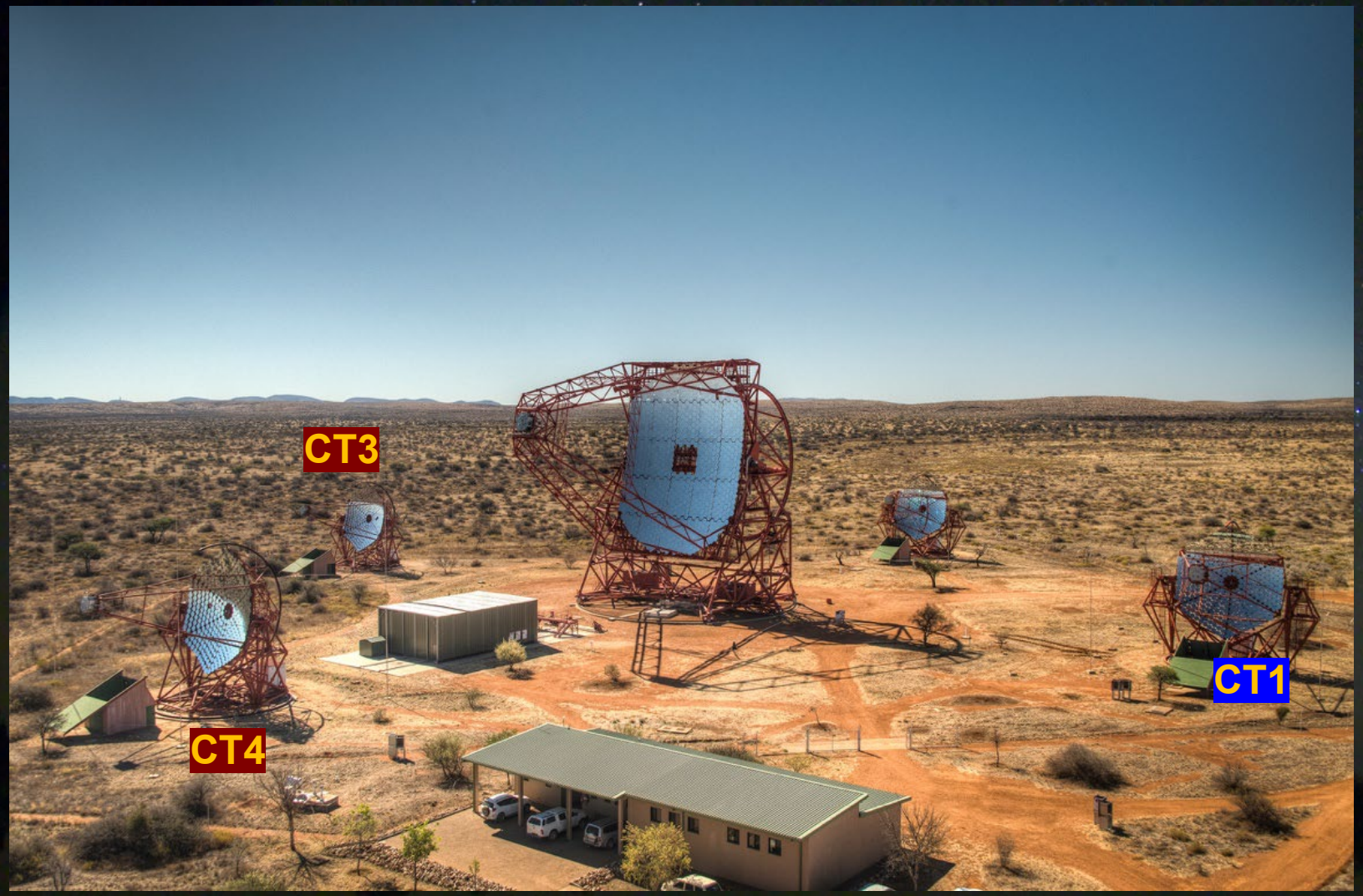


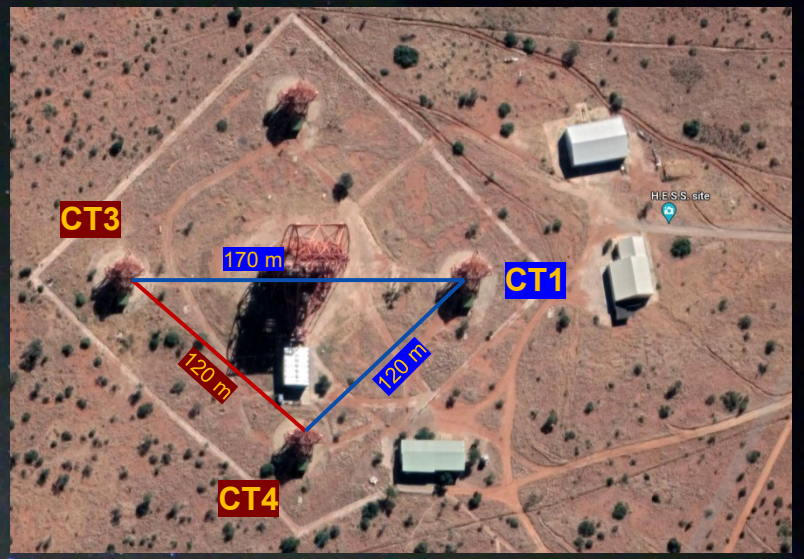




*S. Le Bohec and J.Holder. „Optical intensity interferometry with atmospheric Cherenkov telescope arrays“*

# The H.E.S.S. intensity interferometer

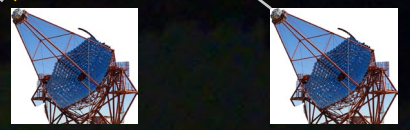


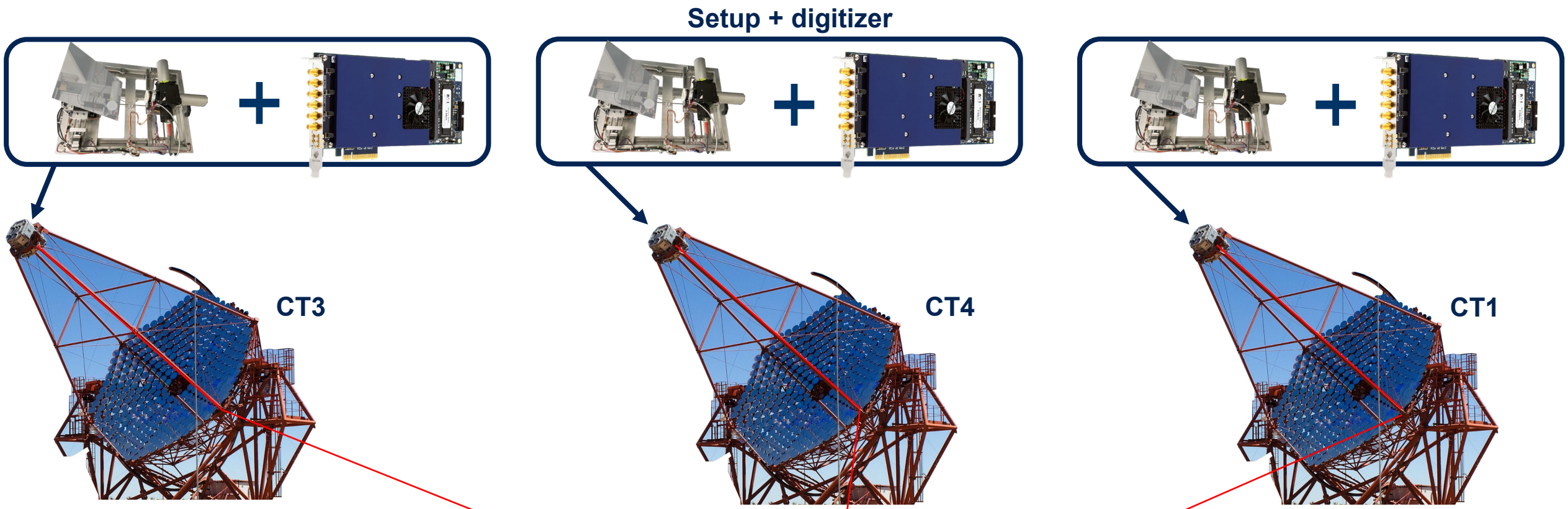

**2022** April 8 to April 23

**2023** April 25 to May 12

Actual baseline is a projection



# Measurement setup

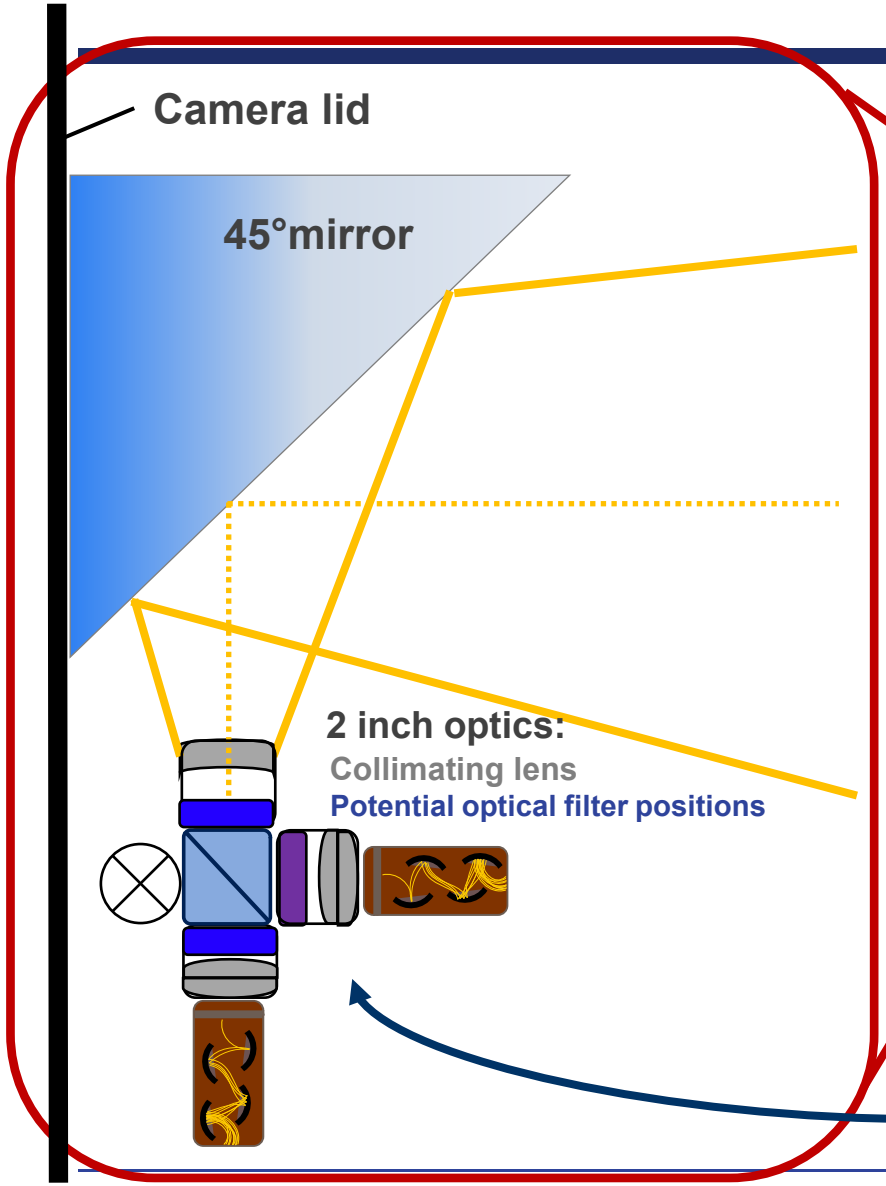


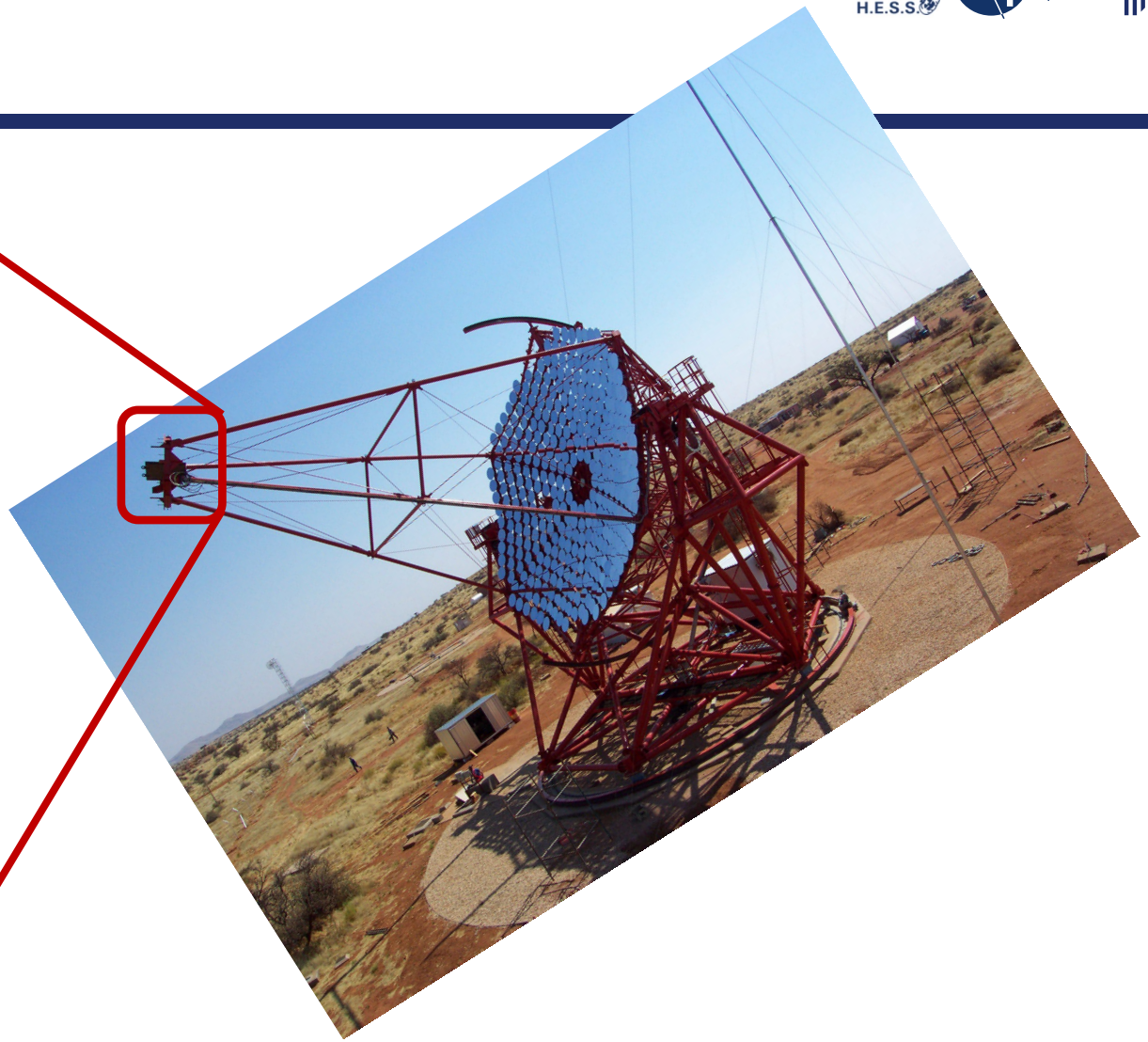

- Digitize in focal plane
- Offline correlation and analysis after measurement

→ Lots of storage → online correlation more beneficial → store raw data for noise analysis

# Measurement setup

## Mechanical setup

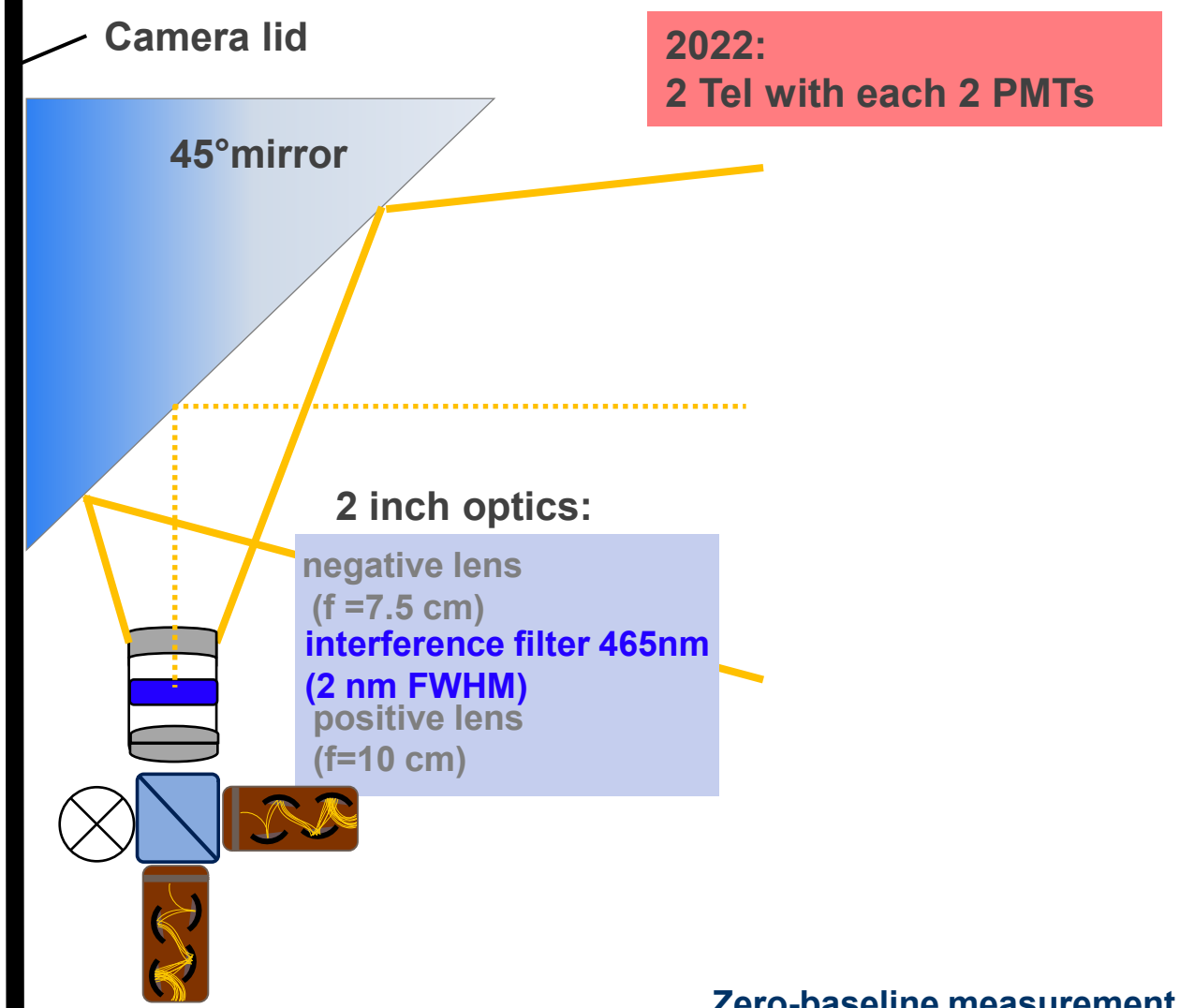


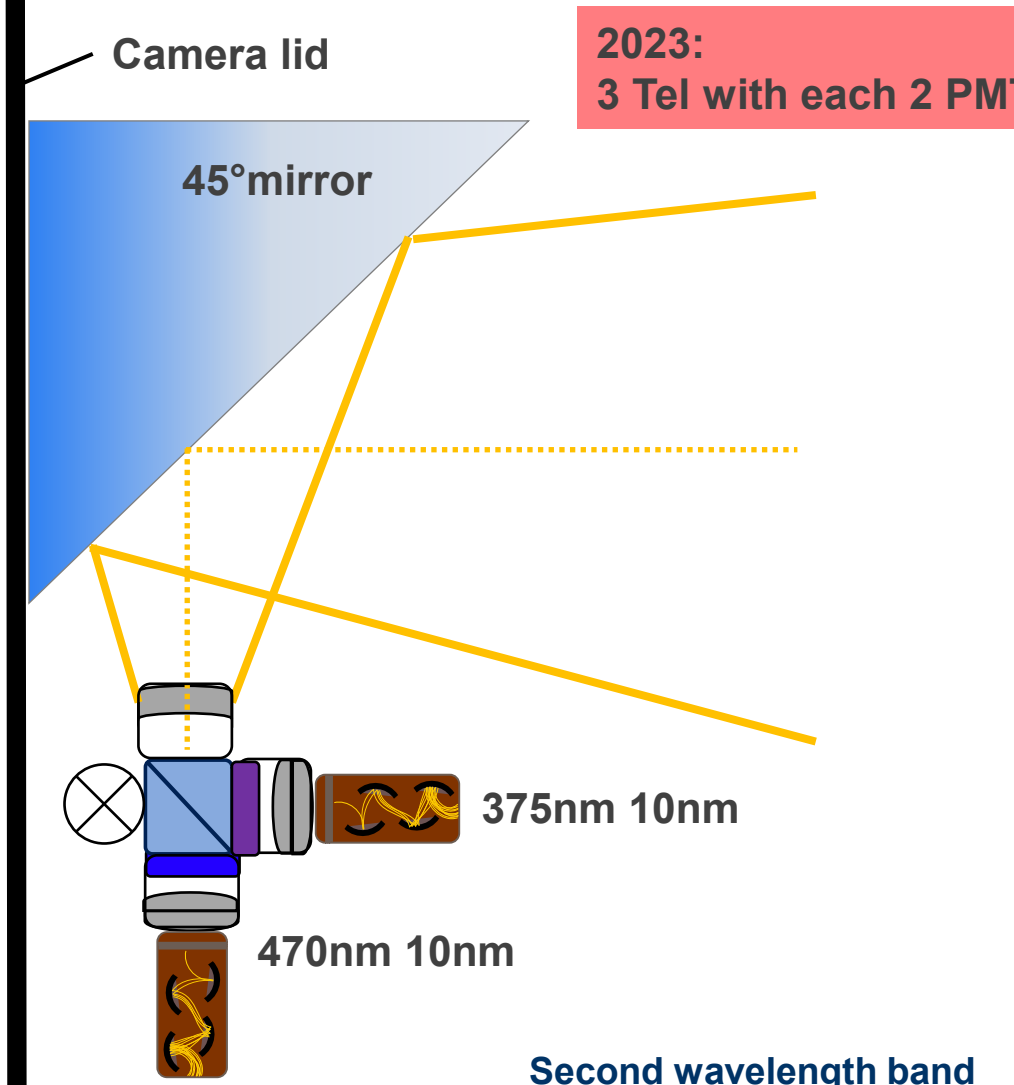
Either zero-baseline measurement or second wavelength band

# Measurement setup

## Optical configuration



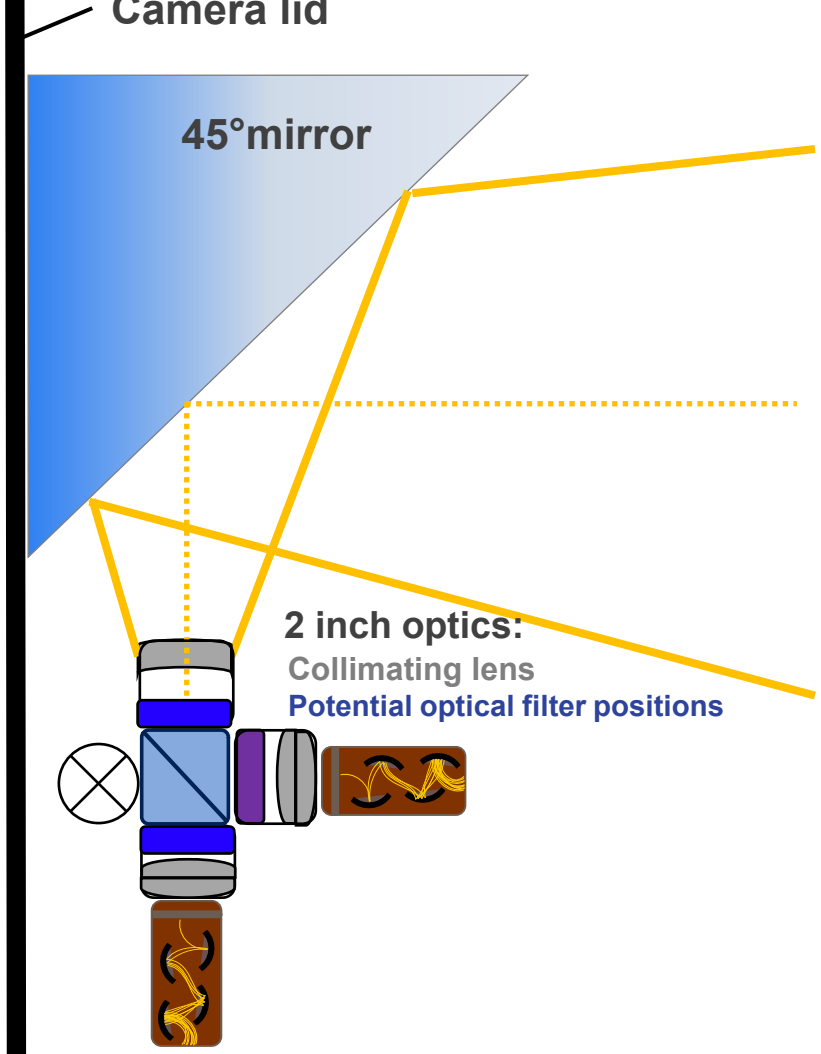

**Zero-baseline measurement**

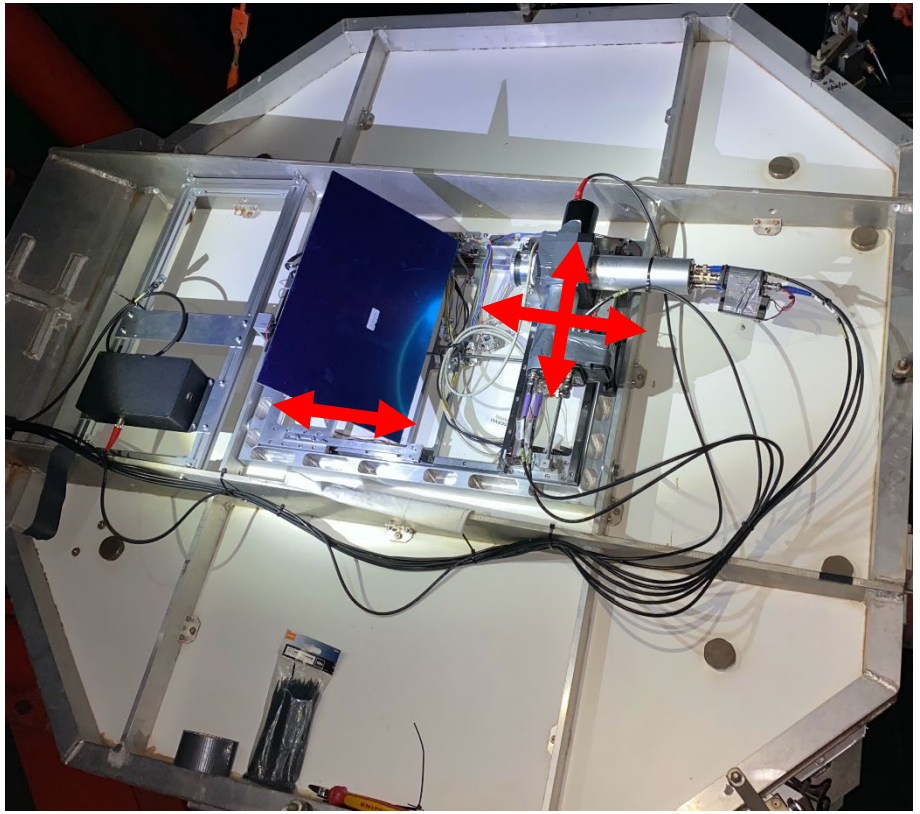



**Second wavelength band**

# Measurement setup

## Mechanical setup



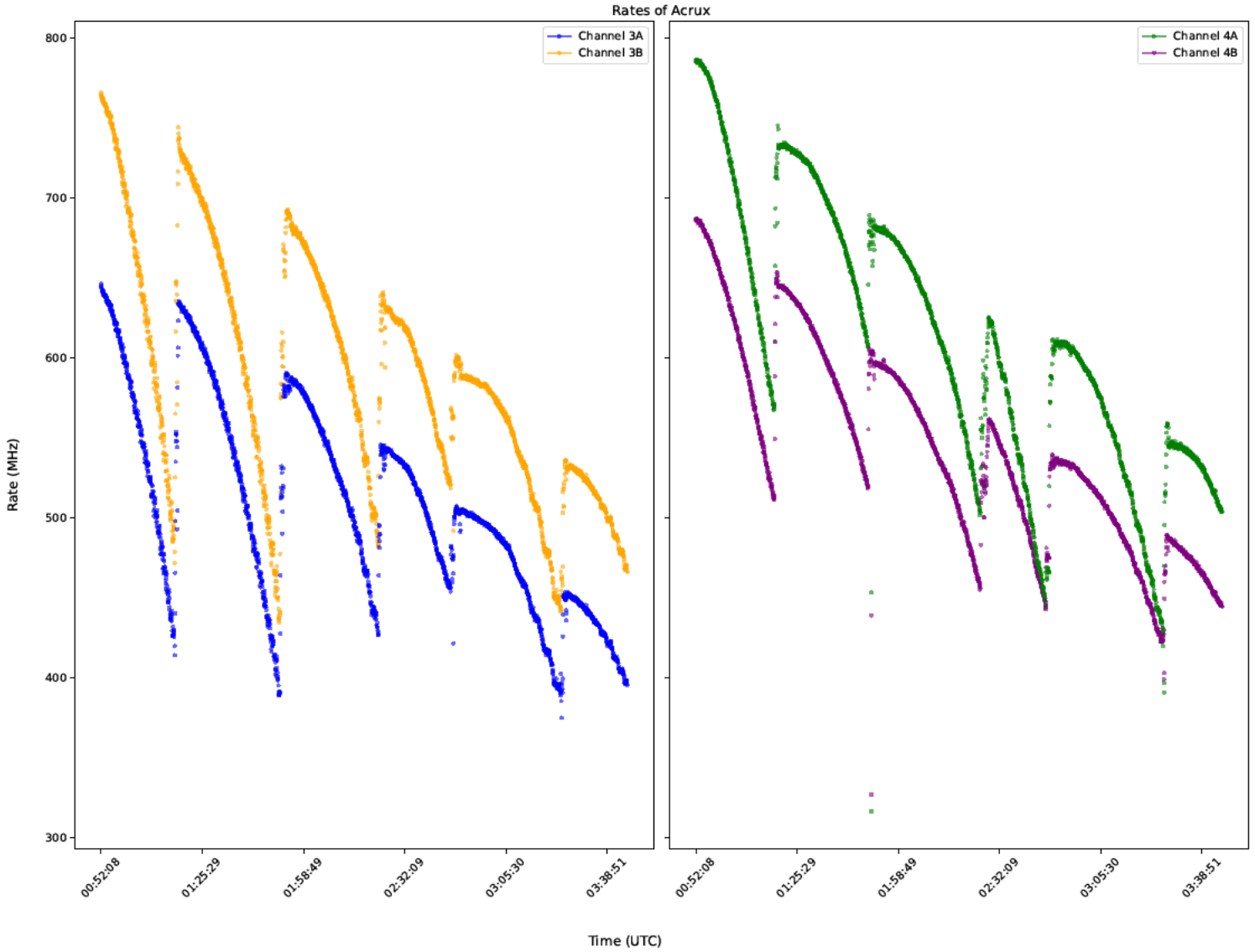
Mounted onto the lid

→ Exposed to nature and weather (sheltered in a hut)

→ See marks from dust on rails

→ Built more robust and with some protection

# Adjusting rates of stars

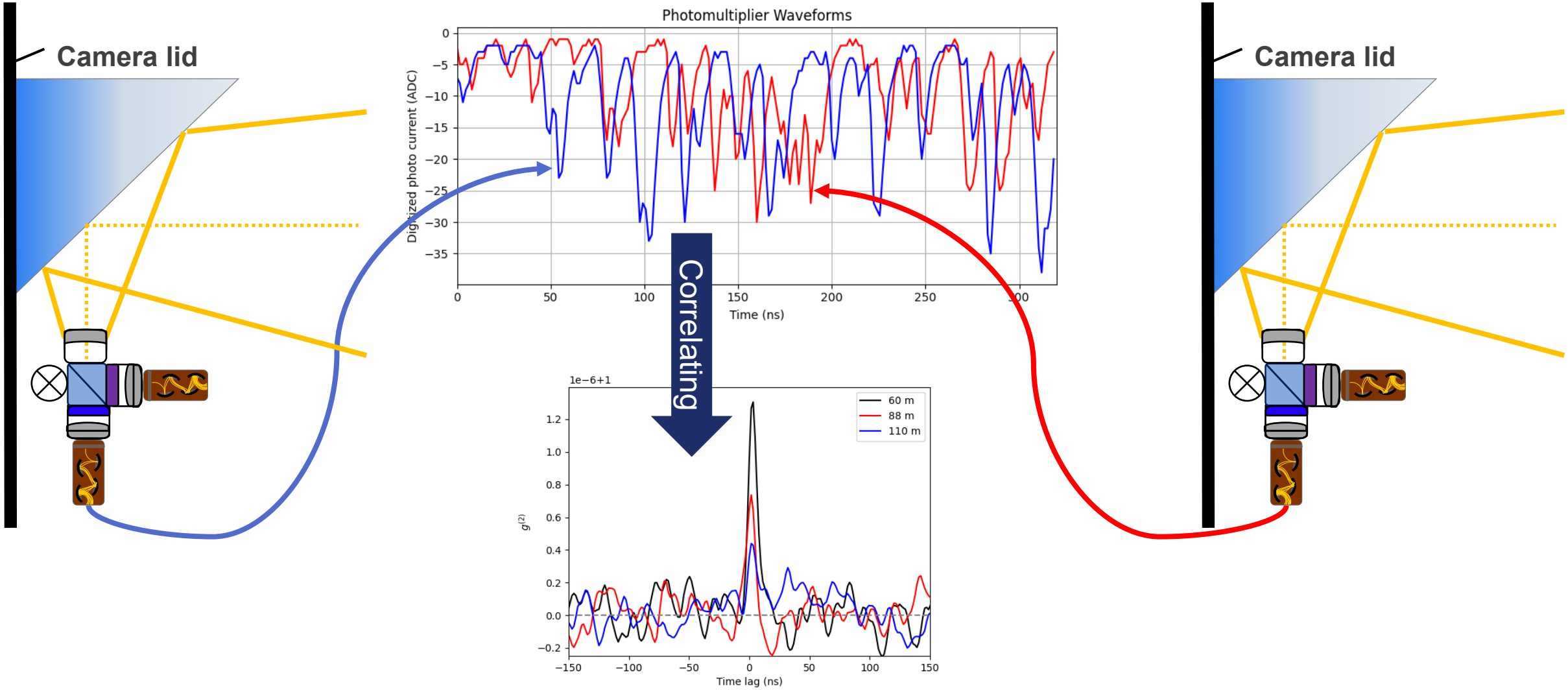



- Example of rates vs time for Acrux over one night for all 4 channels in both telescopes
- In general rates depend on altitude of the star due to absorption in the atmosphere
- For setting stars (decrease of altitude) rates drop continuously over time
- Now: manual adjustment

→ Future: automatic adjustment when rates drop below certain %

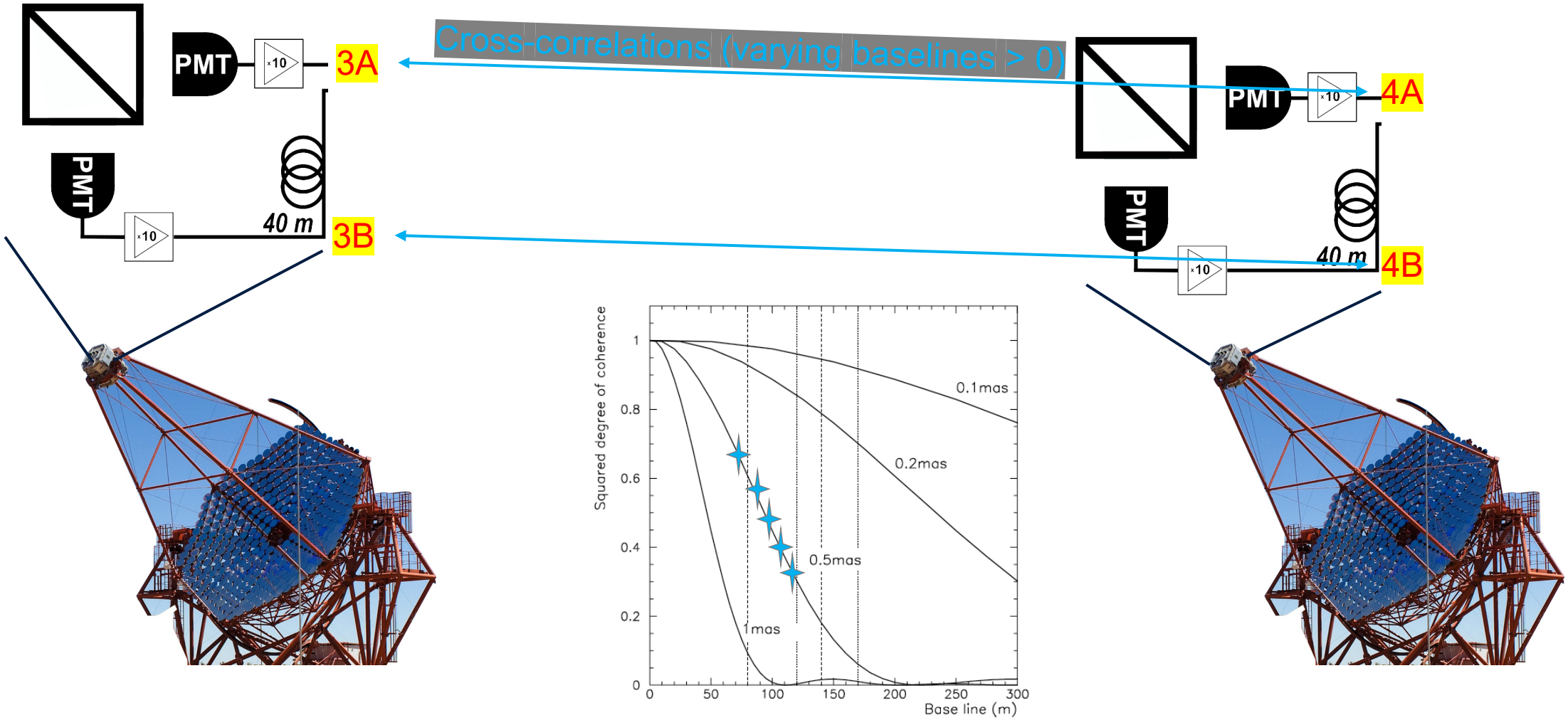
# Analysis

## Correlation between two channels



# Analysis

## Correlation channels – 6 correlations

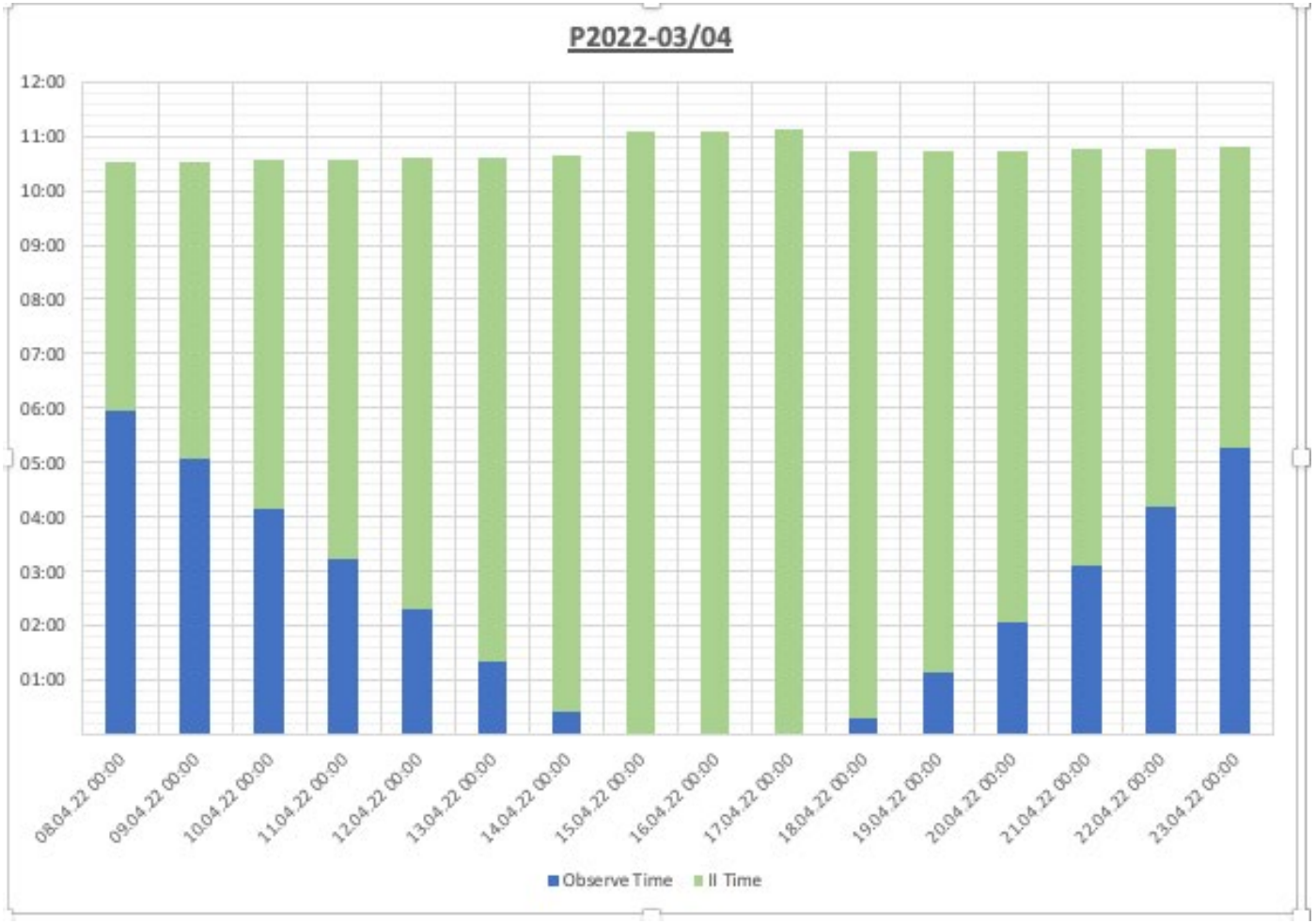


# Measurement schedule

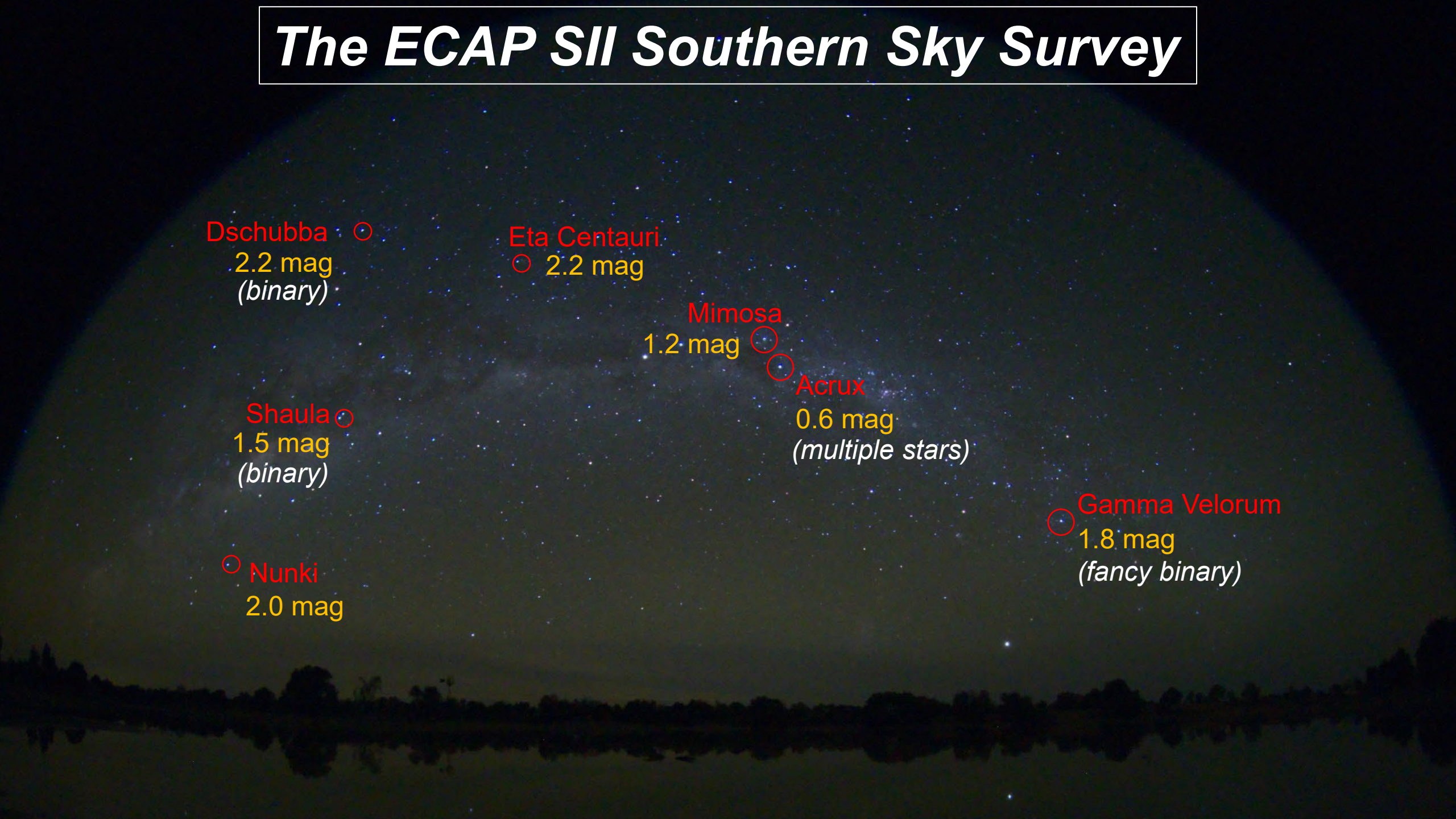
## When do we measure?

- Adjust measurement time to gamma ray observations
- Intensity Interferometry during full moon
- Small field of view → insensitive to straylight of moon

- Fast switch between gamma ray observations and II due to structure

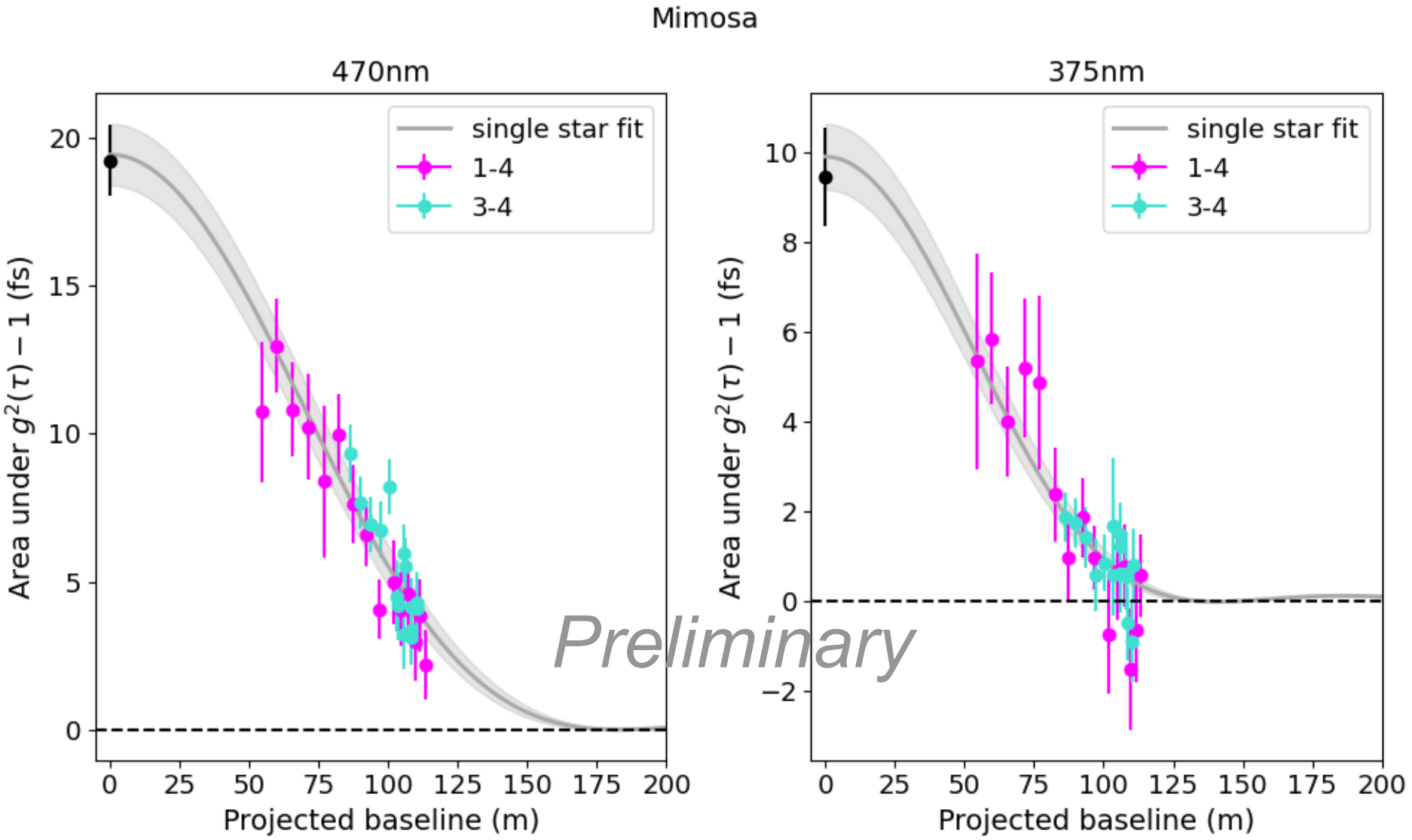


# The ECAP SII Southern Sky Survey



# Results of the 2023 campaign

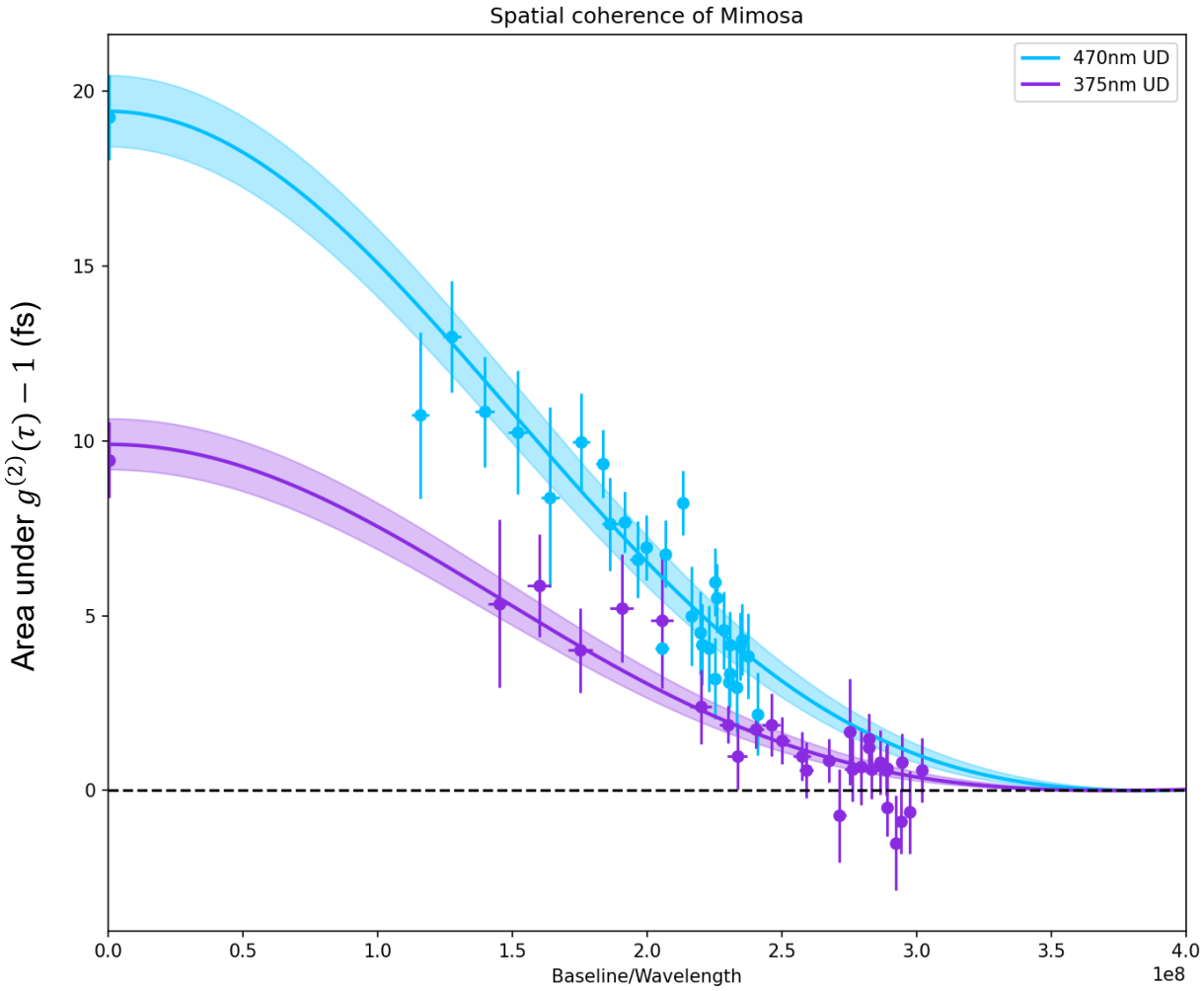
## Mimosa – two wavebands



# Results of the 2023 campaign

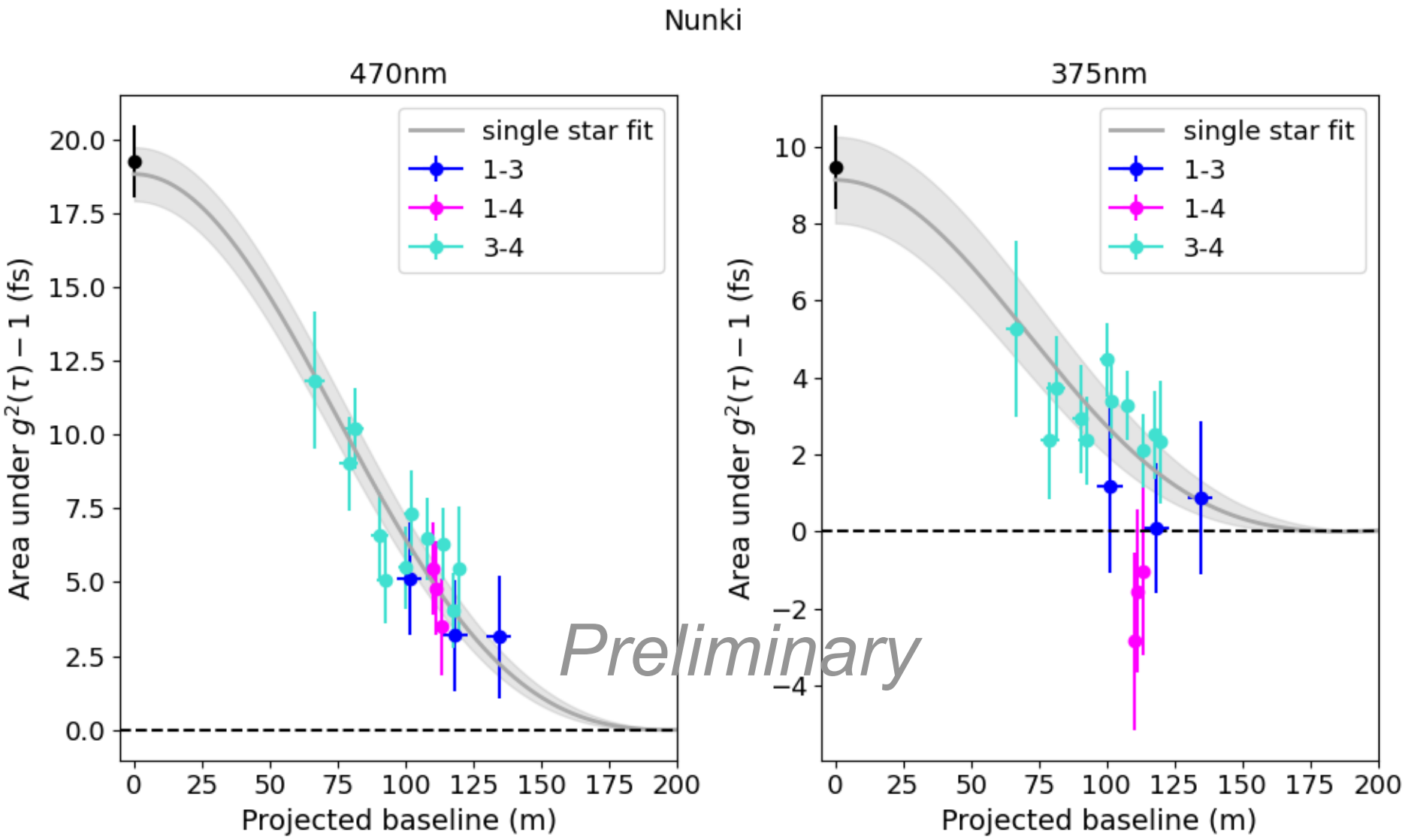
## Mimosa – two wavebands

- Squared visibility scales linearly with wavelength
- Two colors effectively extend baseline range



# Results of the 2023 campaign

## Nunki – two wavebands



# Results of the 2023 campaign

## Zero-baseline correlation value

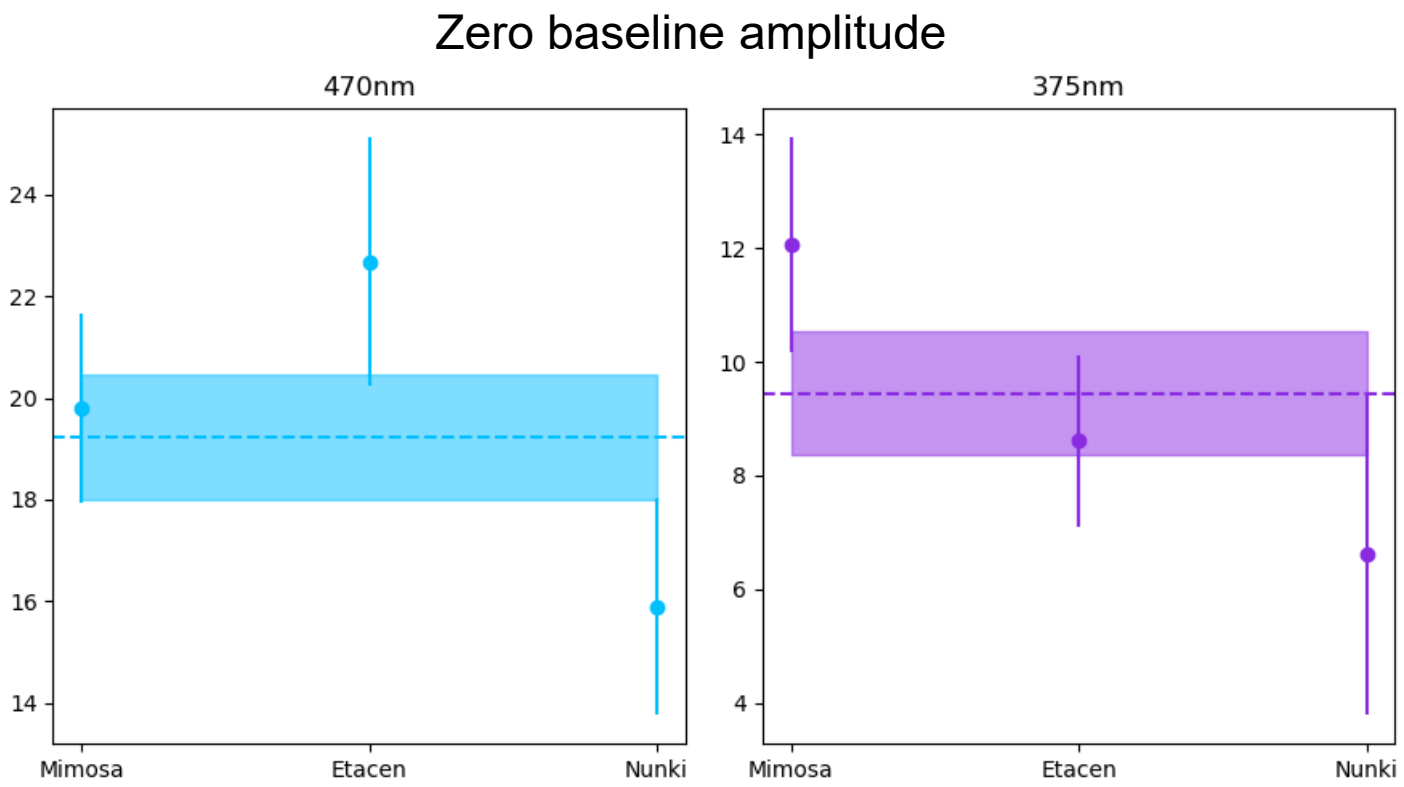
Correlation at zero baseline = fixed parameter of our instrument

→ Set as fixed data point

→ Theory approx 31 fs and 19 fs

For each color channel:

- zero baseline amplitude computed via UD fit
- Weighted average
- Insert value as data point into squared visibility curves and re-fit UD model



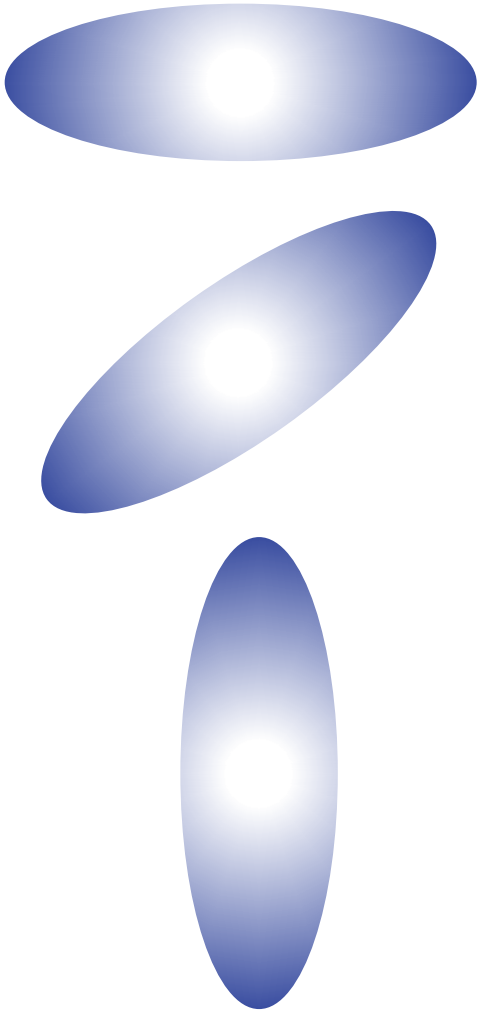

→ Calibration source

# Stellar astrophysics

- Differential angular diameter in different wavelengths provides better understanding for limb darkening studies
- Rapid rotators → gravity darkening → increases wavelength dependency of $\Phi_{UD}$
- Extension to more telescopes (CTA)

  → broader span of uv coverage

  → determine position angle of stars
- Not much data about stars in the southern hemisphere!




Thank you for listening!

# Measurement schedule

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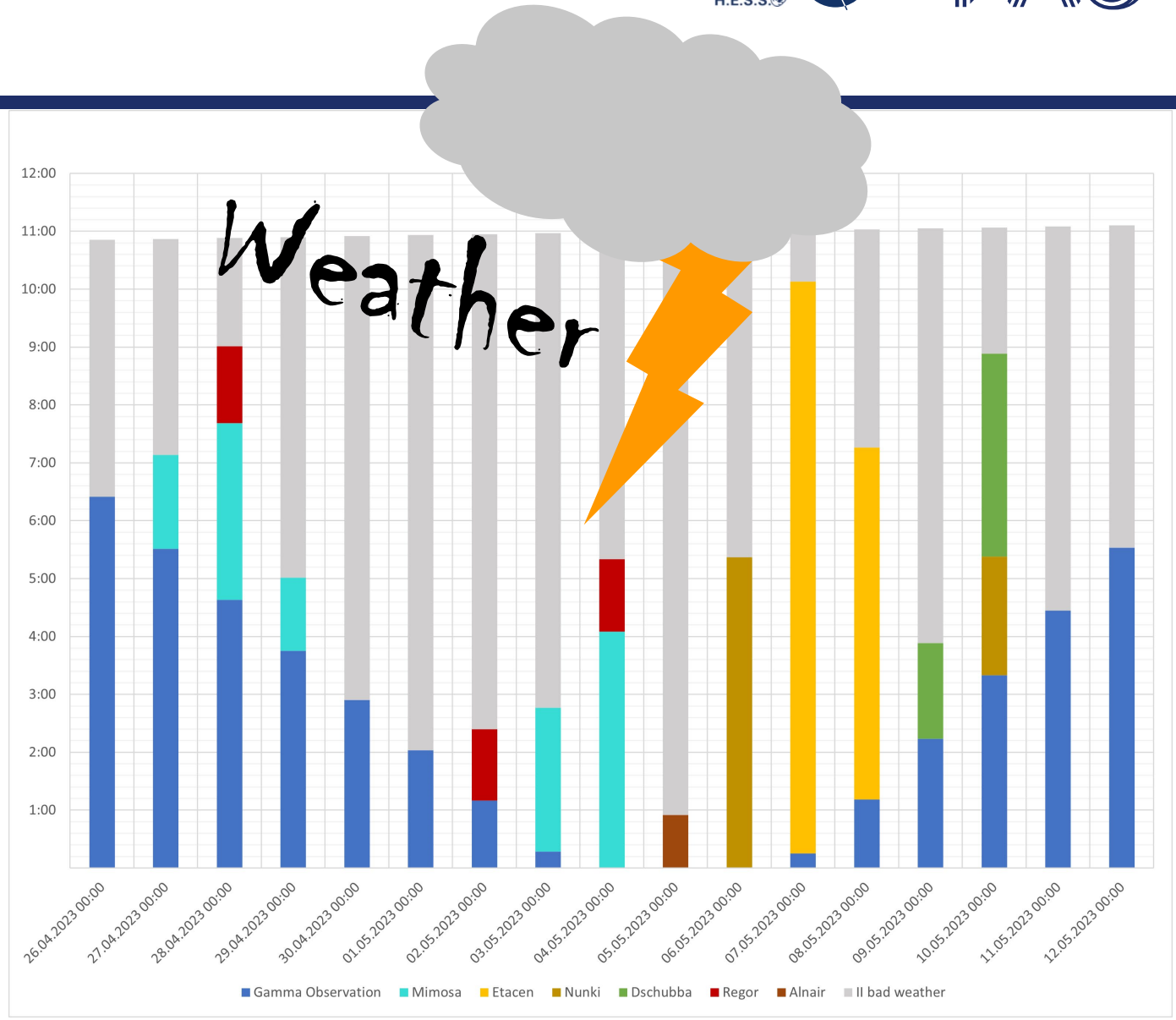
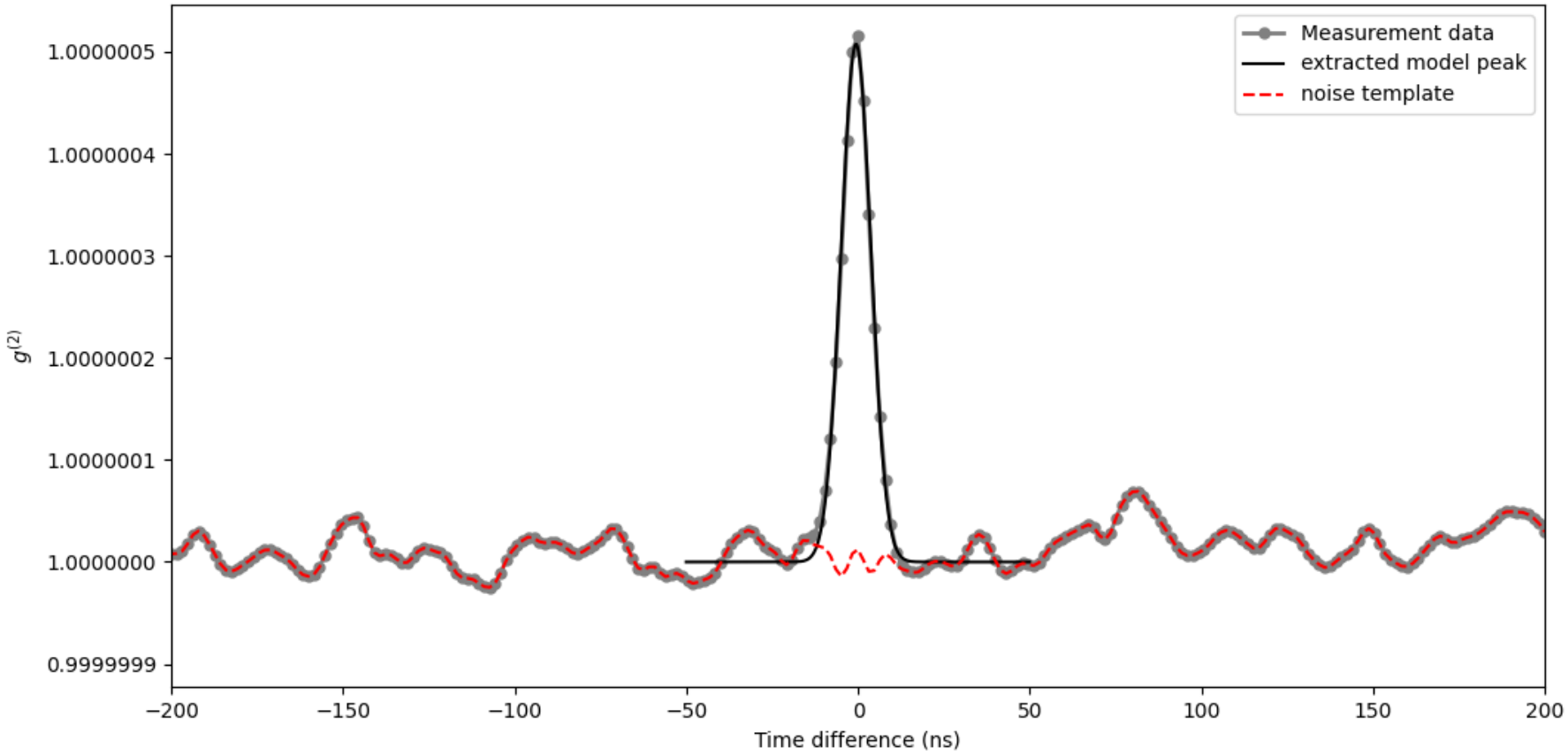
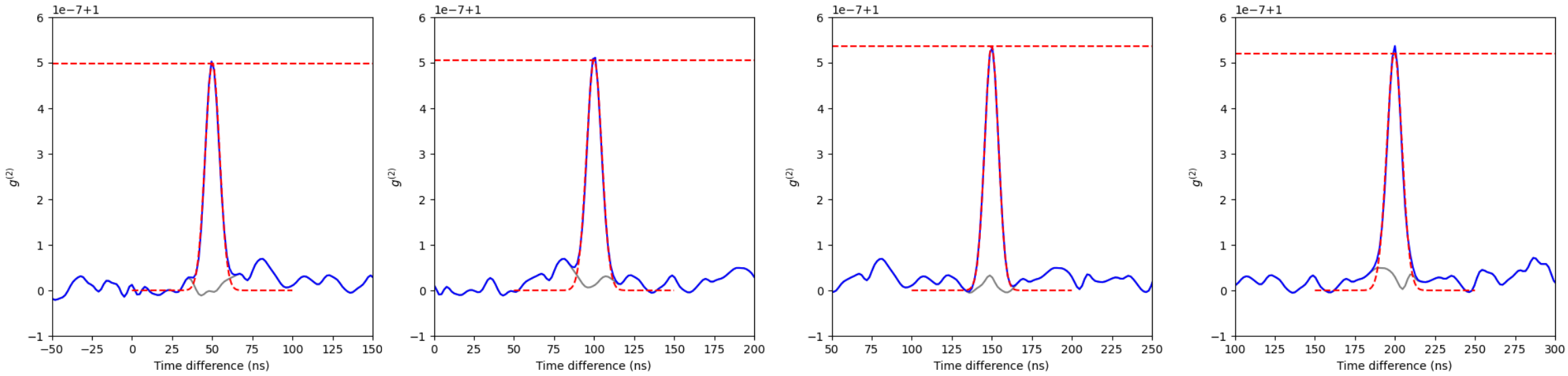


# Influence of (photon) noise to the correlation peak



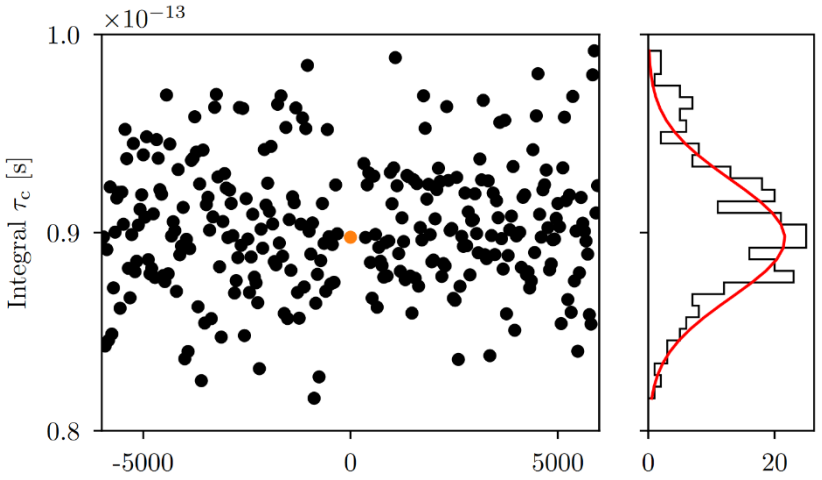
# Influence of (photon) noise to the correlation peak

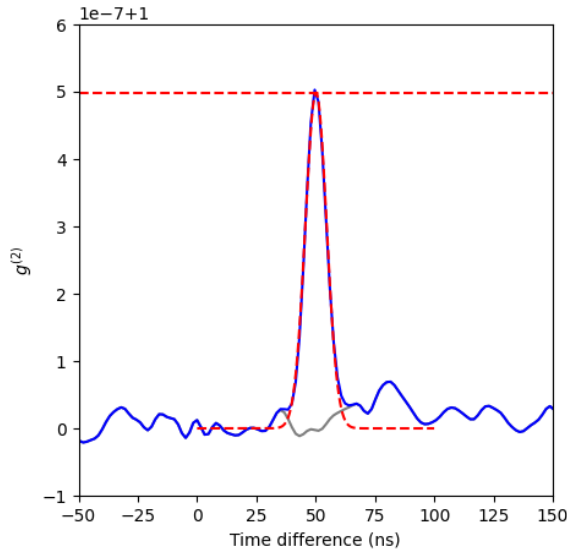
- The amplitude of the fit is influenced by the underlying noise, and so is the peak integral

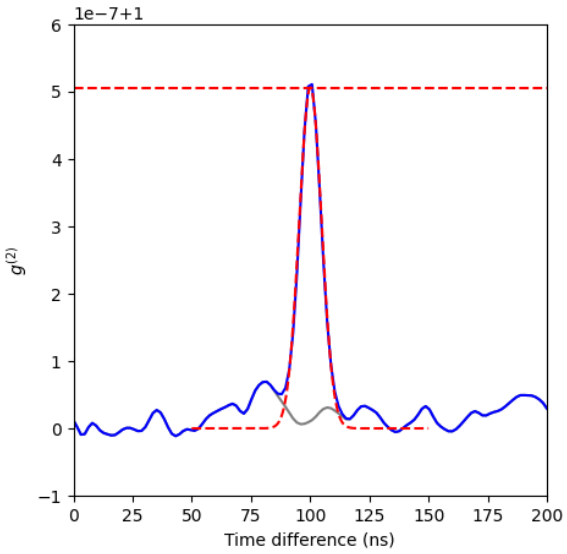


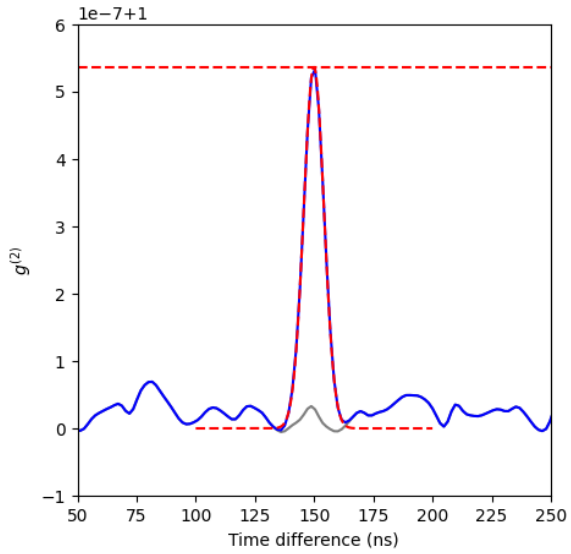
# Influence of (photon) noise to the correlation peak

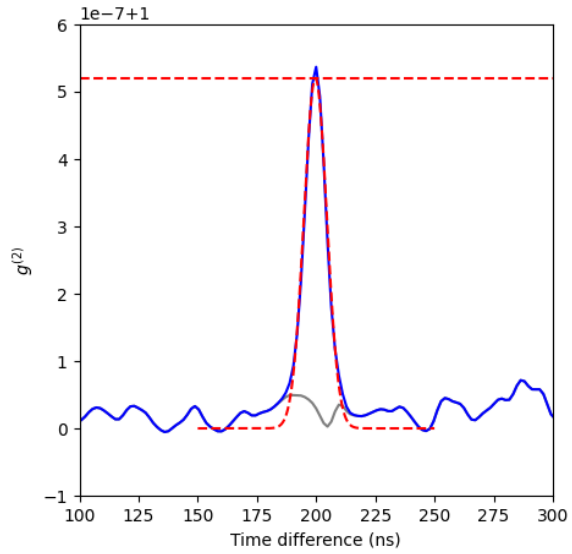
- The amplitude of the fit is influenced by the underlying noise, and so is the peak integral
- The sigma of the distribution is considered the error on the measurement



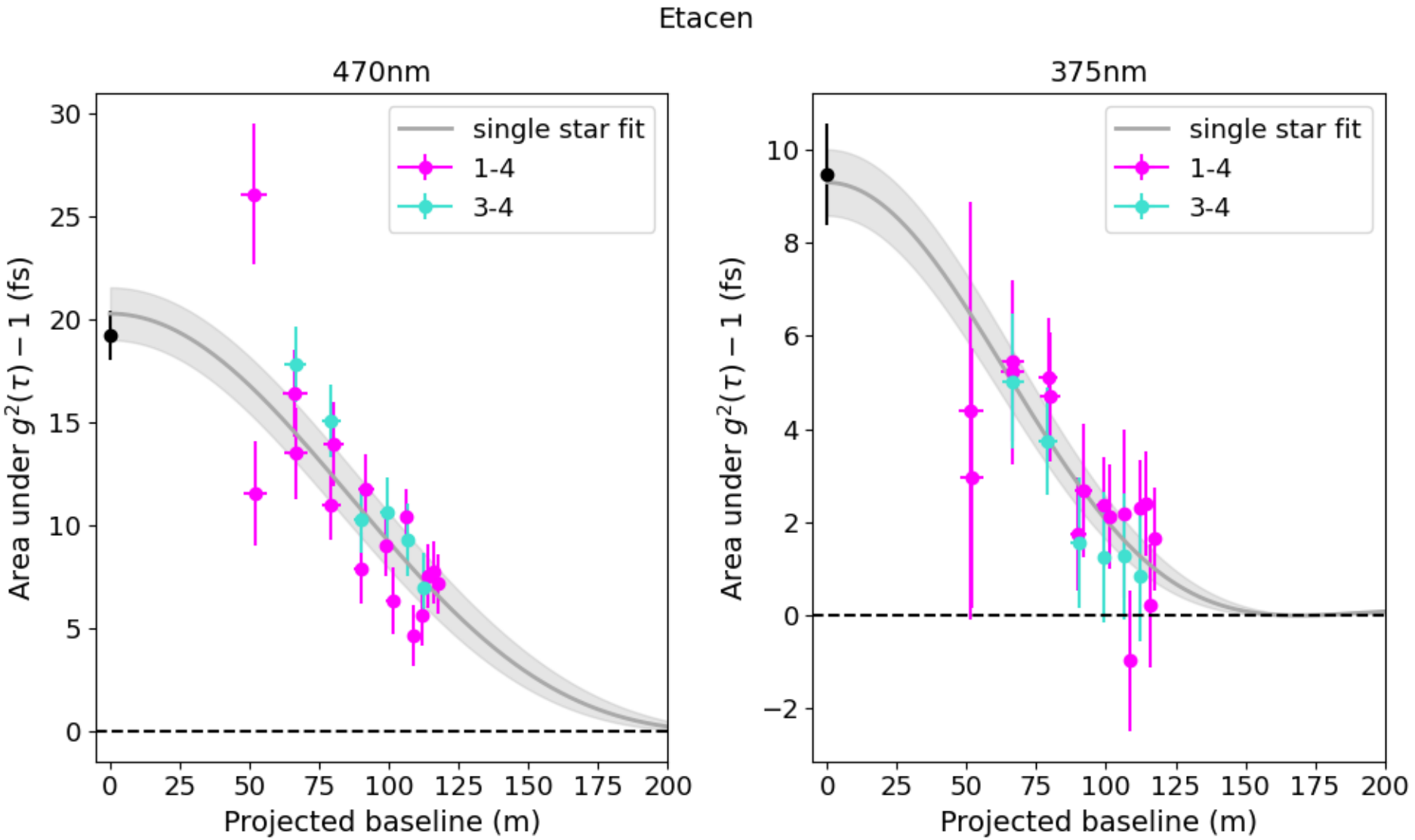



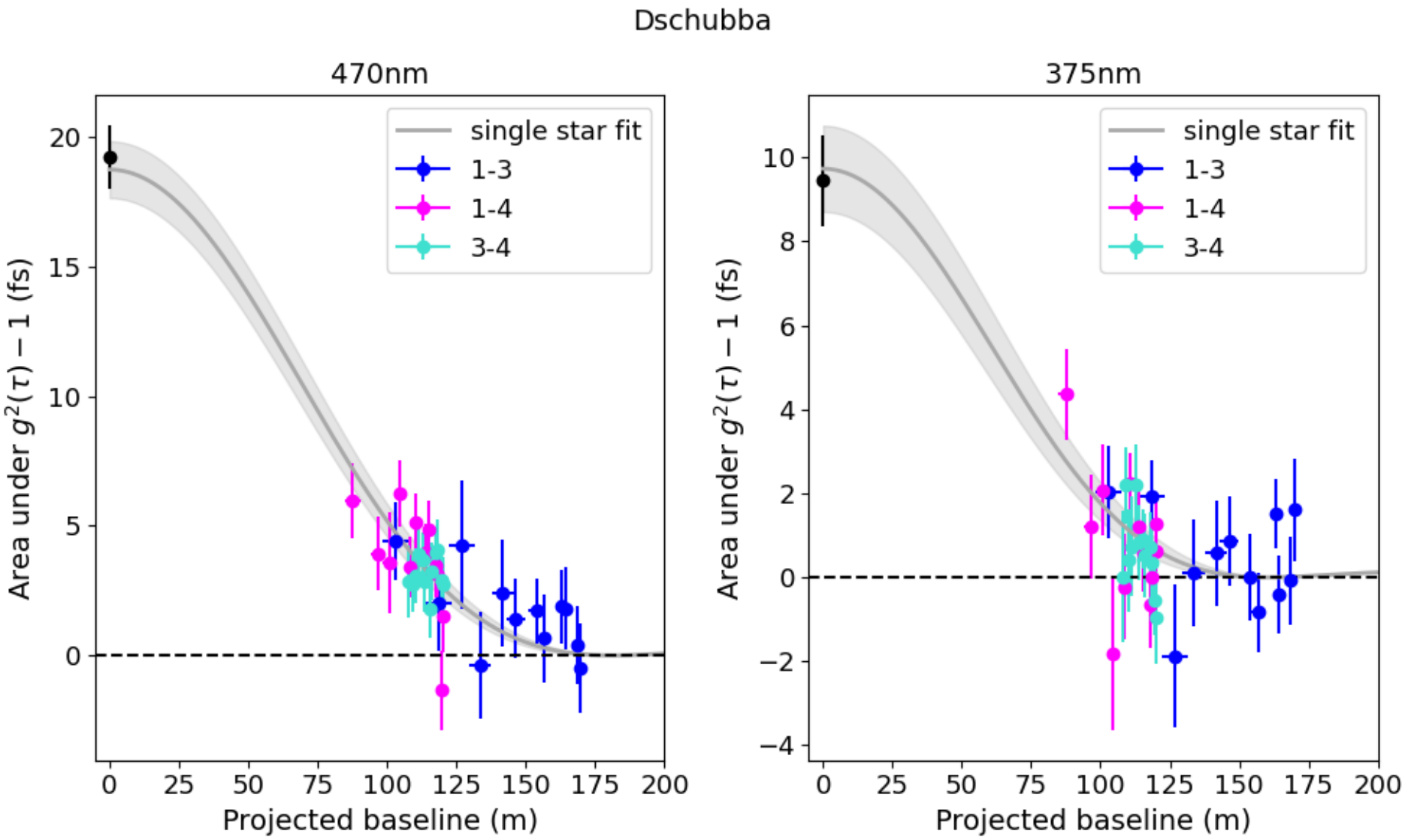
# Results of the 2023 campaign

## Eta Centauri

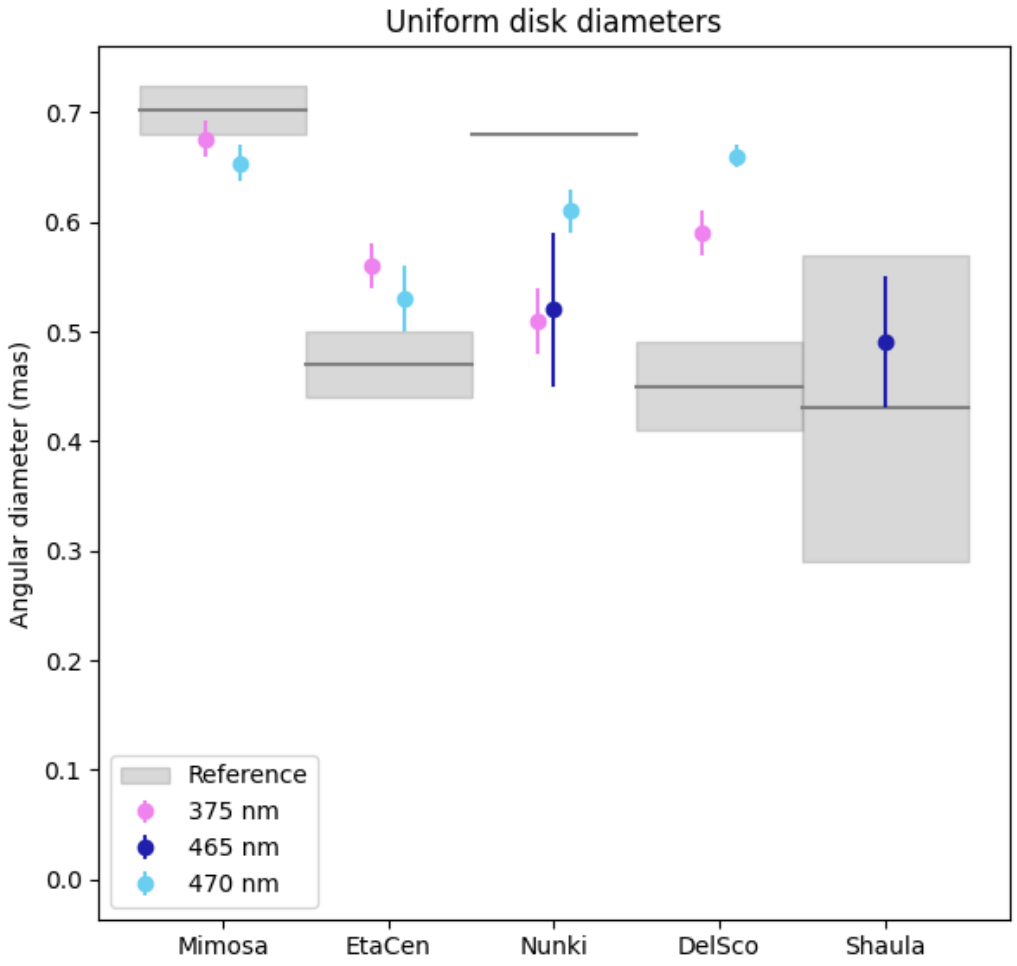


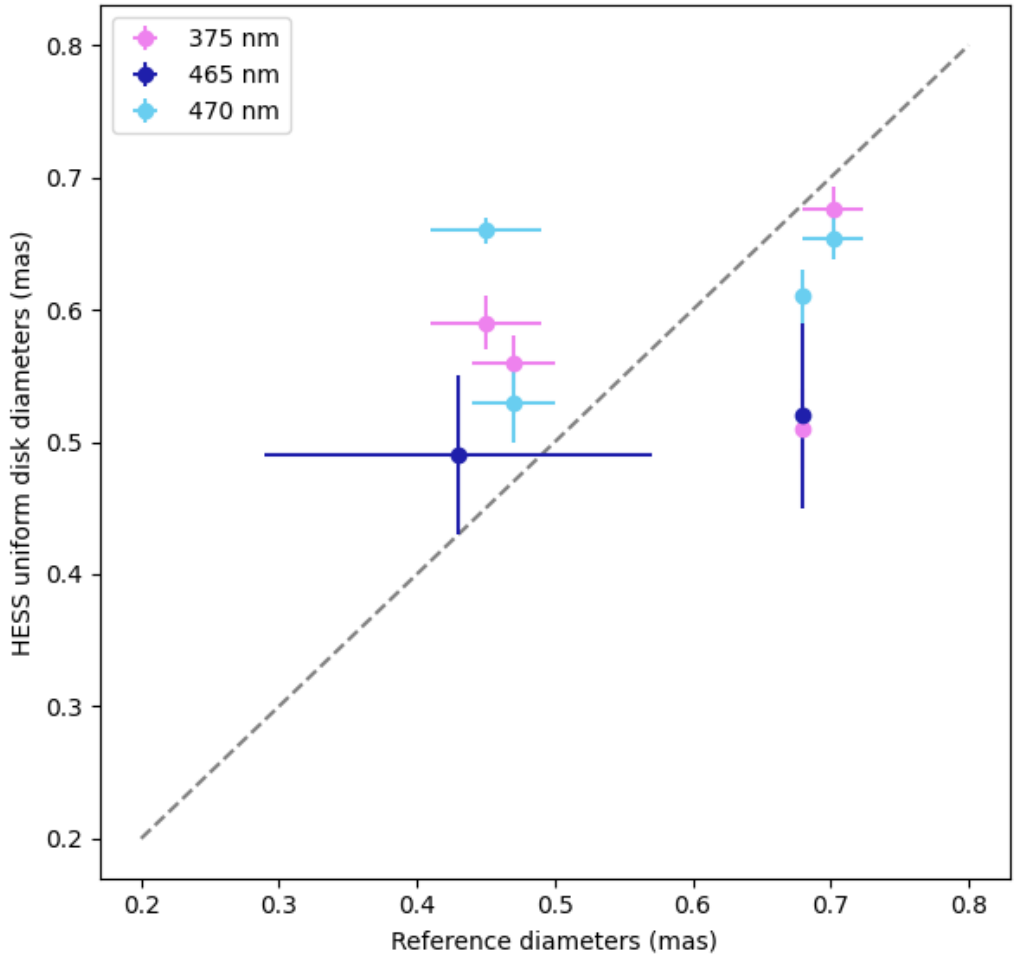
# Results of the 2023 campaign

## Dschubba



# Data comparison



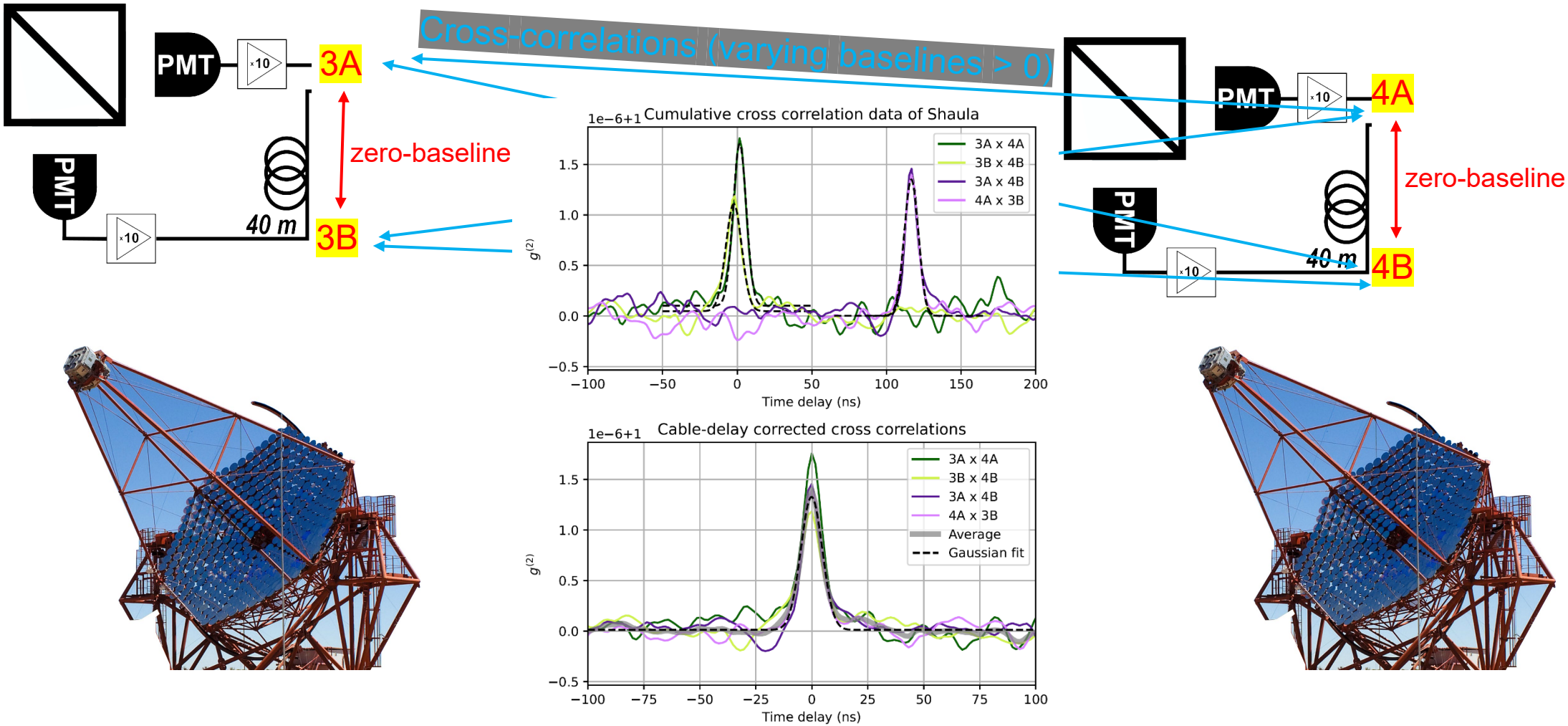
# Measurement setup – data transfer

Camera back plane


server room

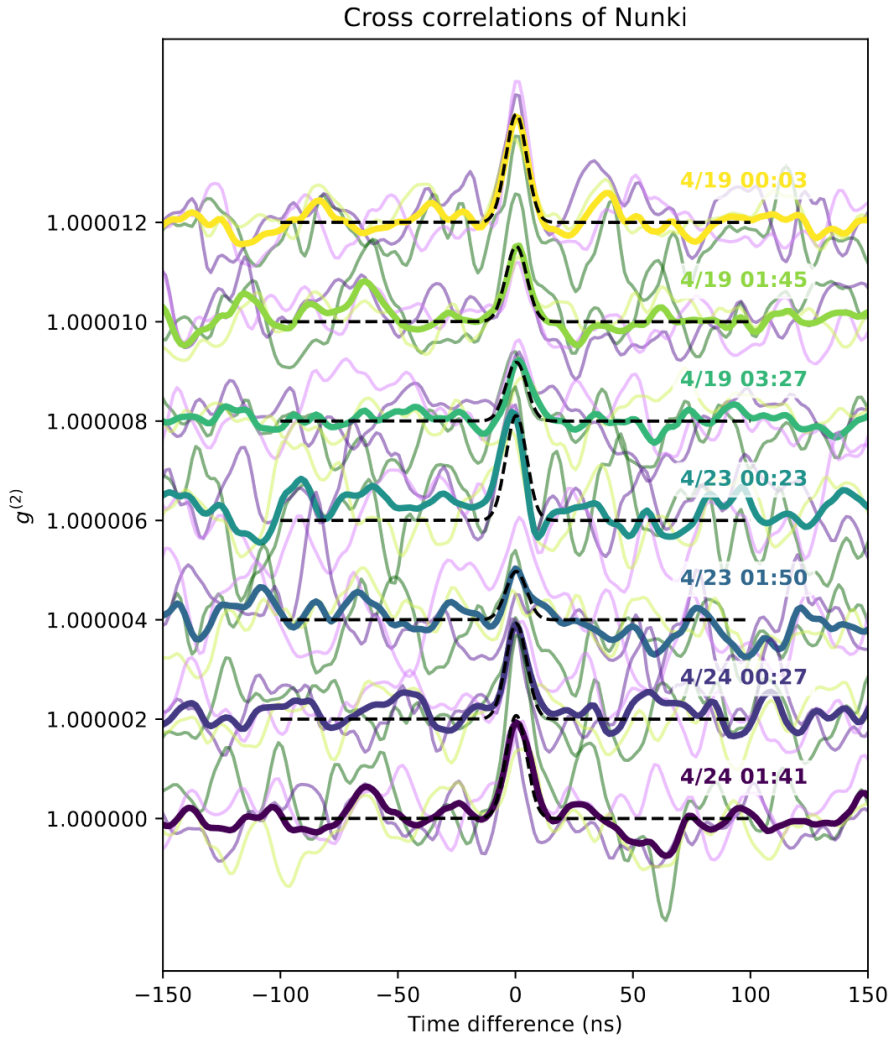
# Analysis

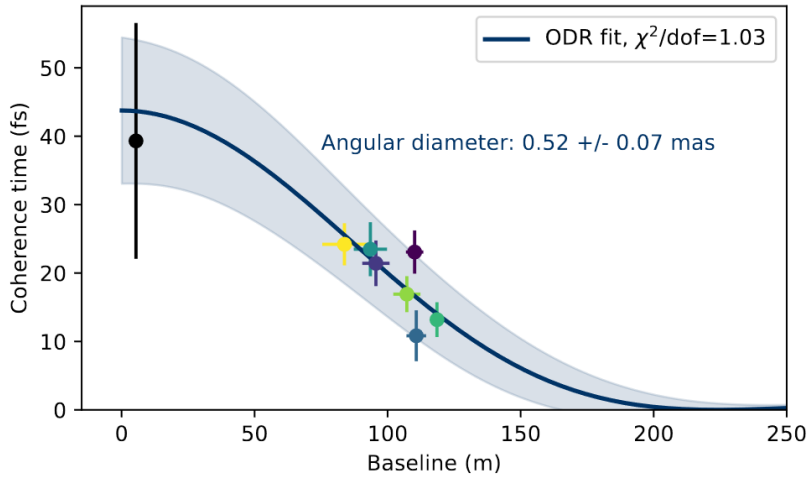
## Cross correlations – coherence loss

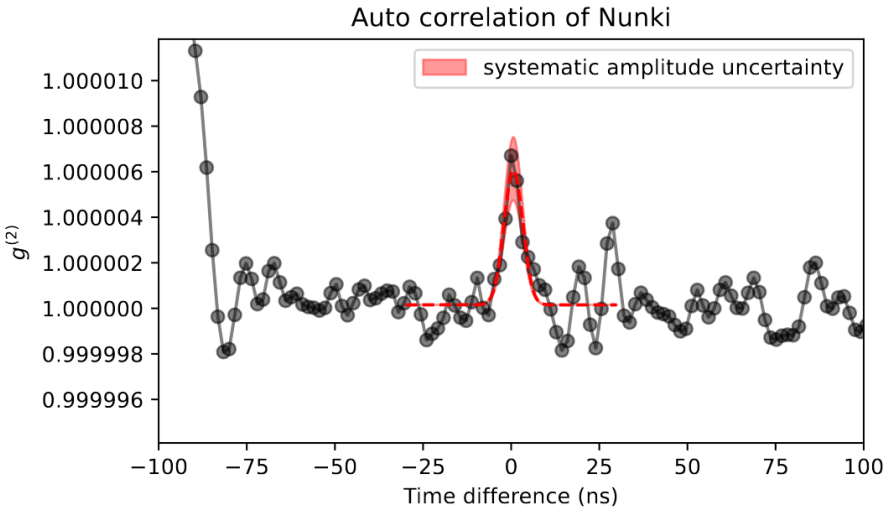


# Results of the 2022 campaign

## Nunki – one waveband with zero-baseline value

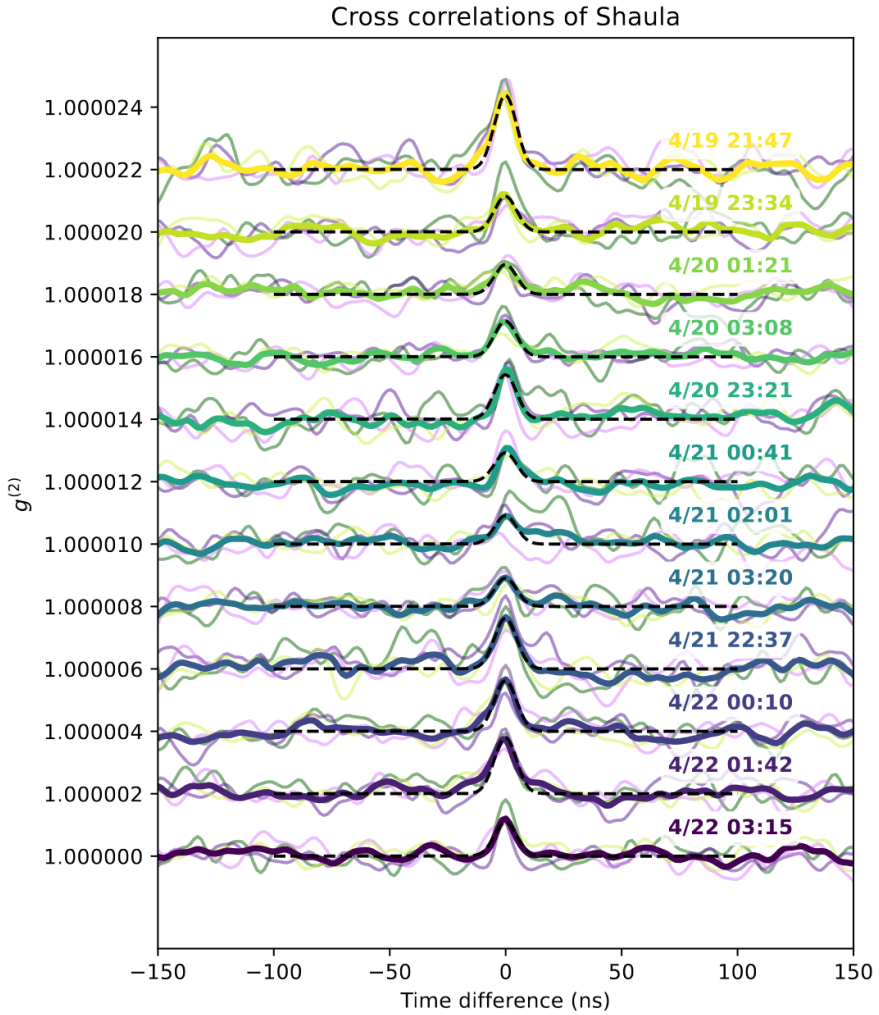


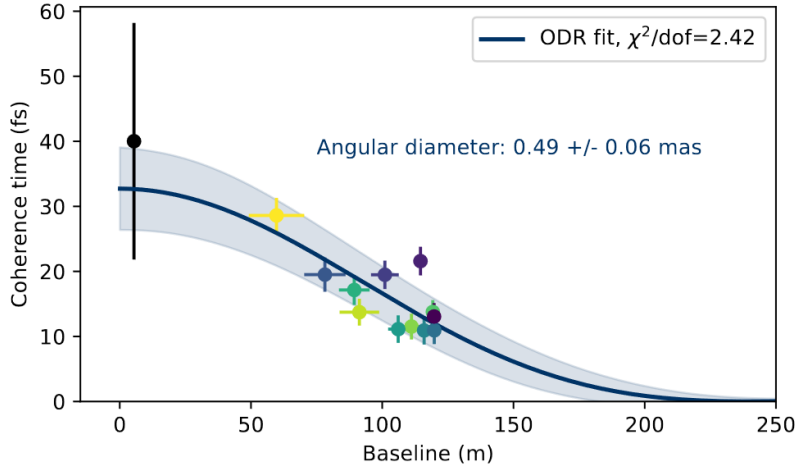



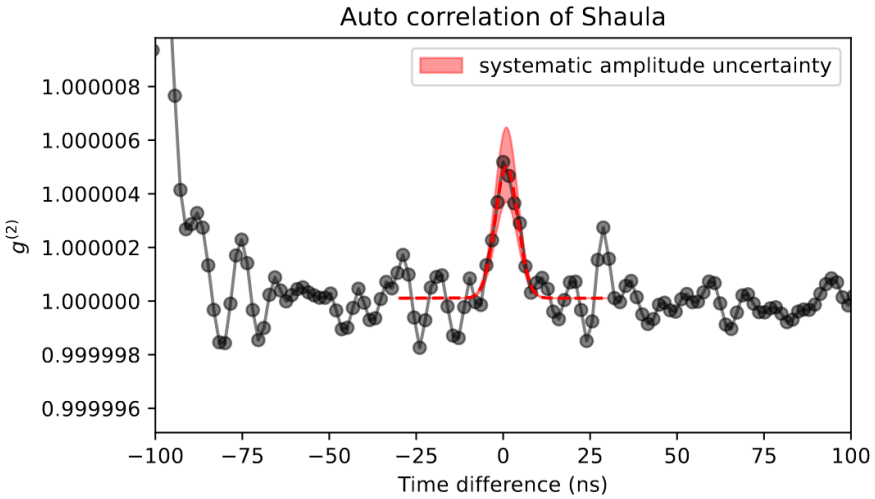



# Results of the 2022 campaign

## Shaula – one waveband with zero-baseline value



# Night Sky Background (NSB) check