Fast Photon Counting Stellar Intensity Interferometry: Prospects for the ASTRI Mini-Array

A. Spolon[1], M. Fiori[1], L. Zampieri[1], L. Lessio[1], L. Paoletti[1], C. Pernechele[1]
and the ASTRI Project
[1]INAF - Astronomical Observatory of Padova, Italia

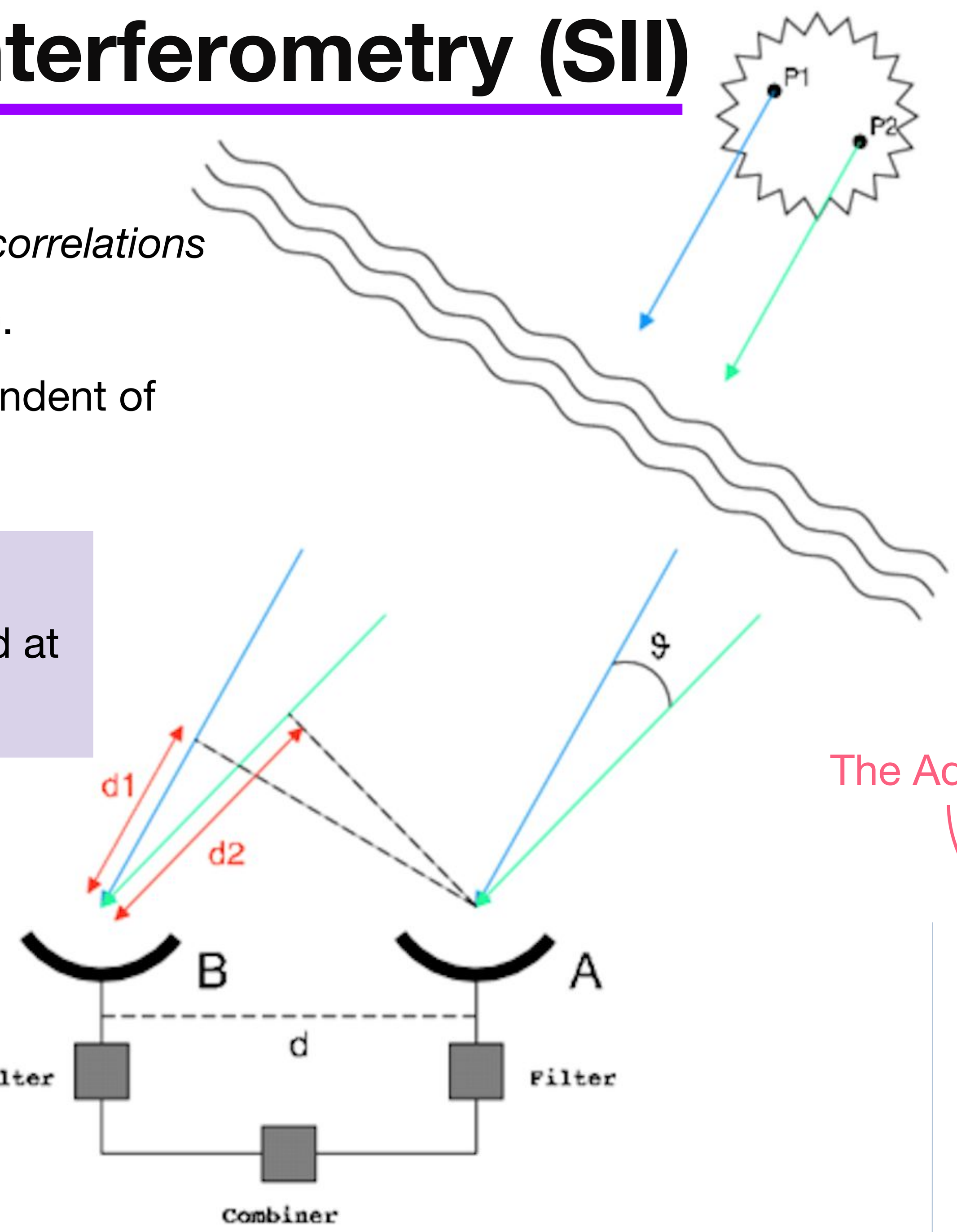
Funded by the European Union NextGenerationEU

Stellar Intensity Interferometry (SII)

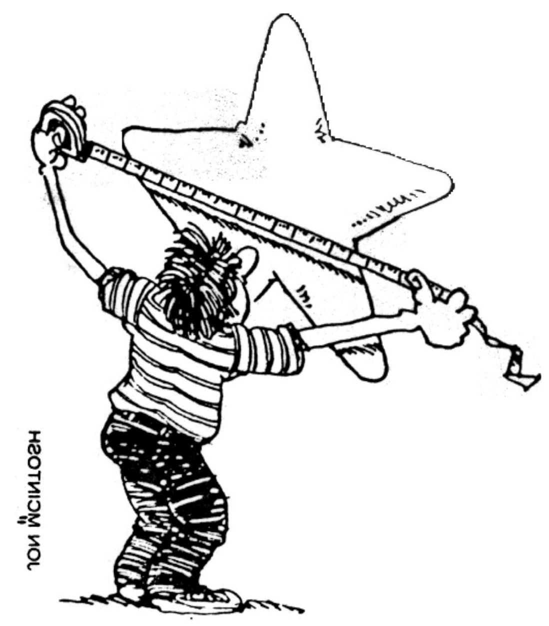
How it works?

Intensity interferometry evaluates the *correlations between pairs of point sources* (P_1, P_2).
Each point radiates light and is independent of each other.

SII in based on correlation of the light intensity fluctuations of a star detected at two or more telescopes.



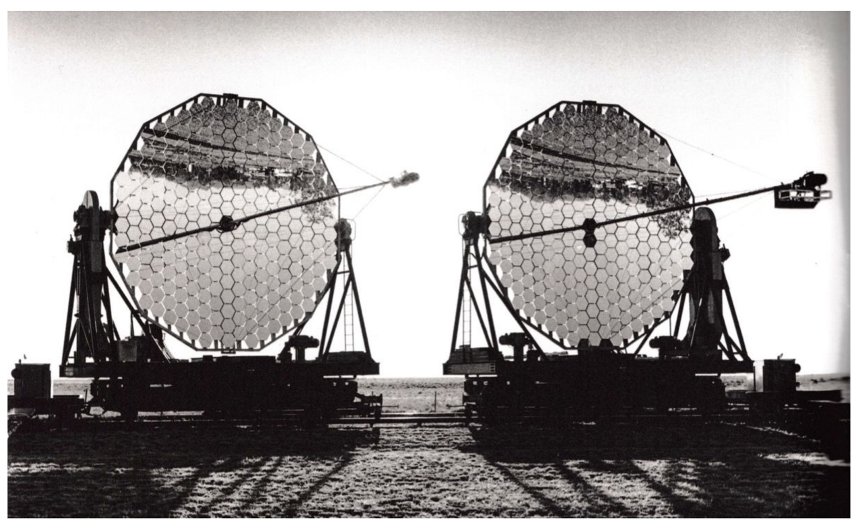
Working principle of an intensity interferometer. From [1].



What can we measure?

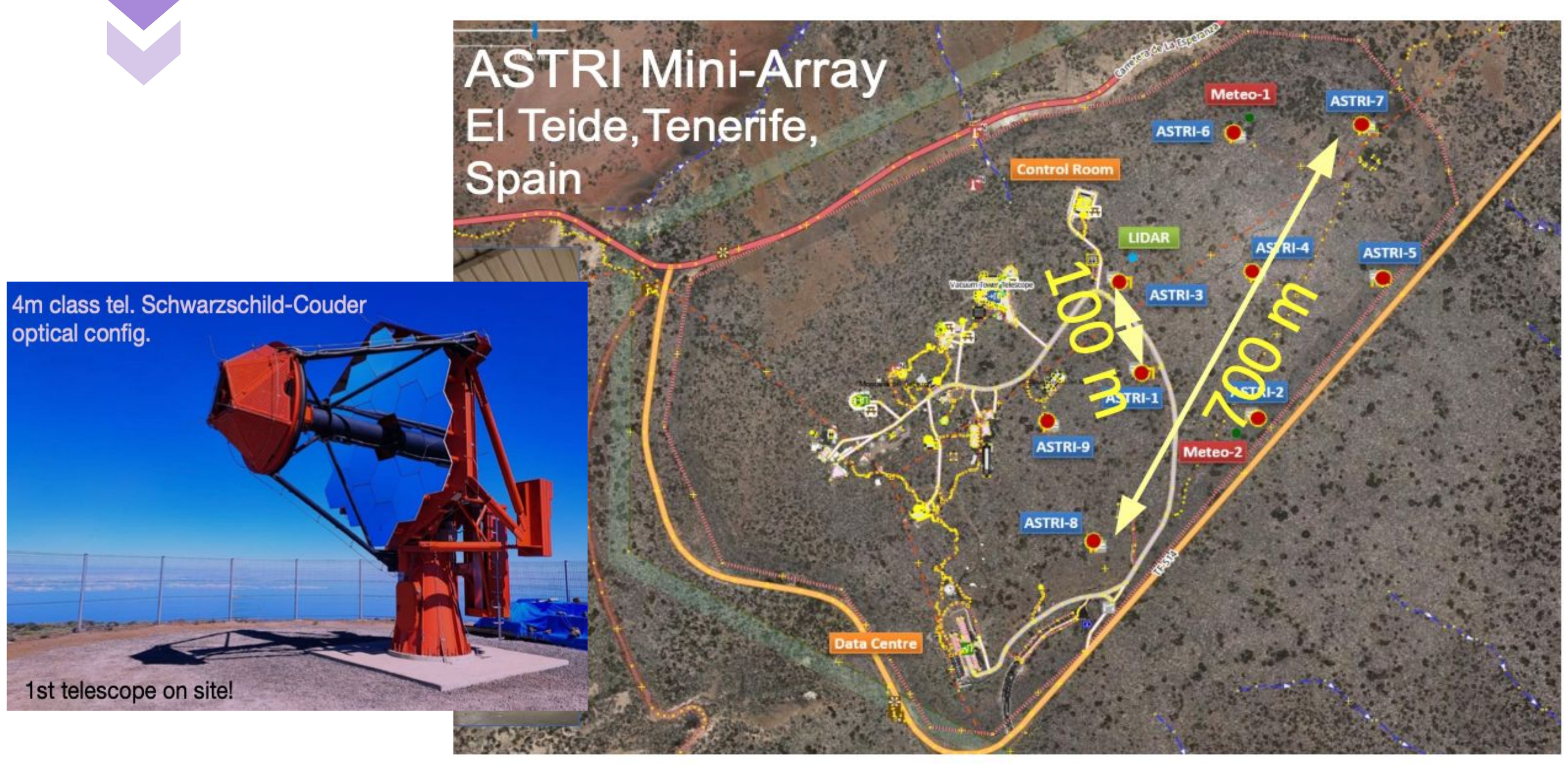
Radius and surface structures of bright and hot stars (O/B → F/G type).

SII was pioneered by **Brown & Twiss** in Narrabri, Australia [2]. They made the first direct astronomical measure of stellar radii via SII.


The two Narrabri SII telescopes.

Operating simultaneously ARRAY of large area telescopes
+ connecting them electronically → renewed interest for SII
→ Tool for imaging obs. in optical band
(~long-baseline radio interferometric array).

ASTRI Mini-Array



9 Imaging Atmospheric Cherenkov Telescopes [3] to:

- study gamma-ray sources at very high energy (TeV)
- **perform optical SII observations** → ASTRI SII Instrument (SI^3)

Goal: using the **long multiple baselines (36)** of all 9 telescopes to do image reconstruction with resolution of **~100 μas.** [4]

SI^3 => optical widow (1-8 nm filter; centered at 420-500 nm).

Methods

Photon-Counting Intensity Interferometry

Counting coincidences in photon arrival times measured at 2 telescopes and exploit the quantum properties of the light emitted from a star.

2nd order (discrete) degree of coherence of a star [5]

Measures the degree of correlation of its lights. Depends on telescopes separations *d* and the relative delay τ between them.

$$g^{(2)}(\tau, d) = \frac{N_{XY} N}{N_X N_Y}$$

N_X, N_Y = # photons detected at telescopes X and Y in time T
N_{XY} = # simultaneous detection in bin *dt*
N = # intervals (T/*dt*)

The Aqueye/Iqueye team!
Scan me!

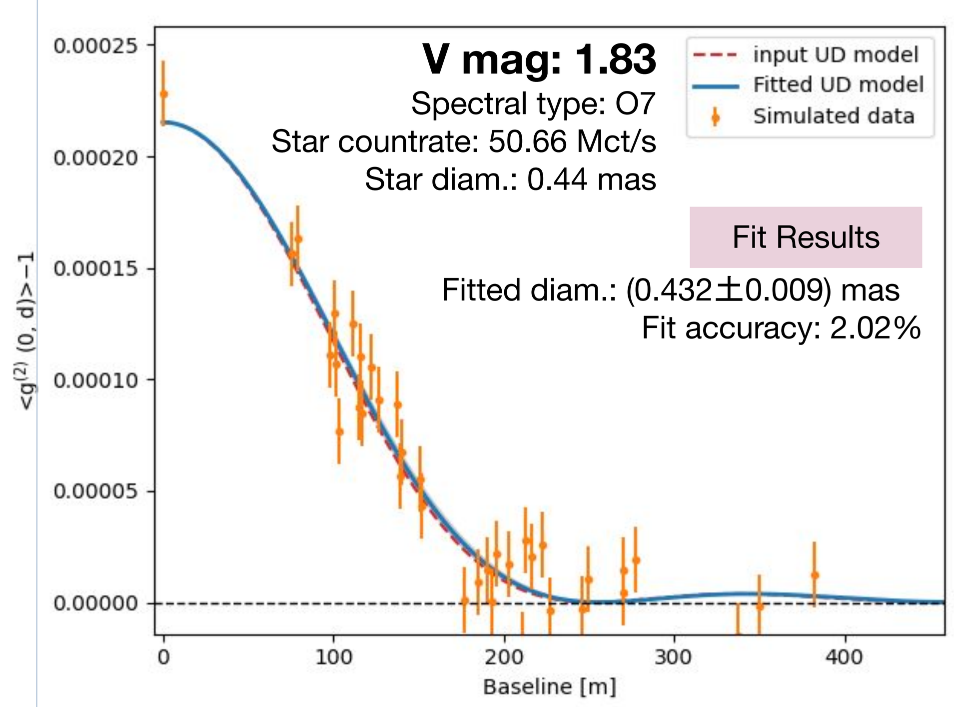
ASIAGO SII experiment

1.22m Galilelo (IFI+Iqueye) + 1.82m Copernico (Aqueye+) Telescopes @Asiago (Italy)

- First measurements of the correlation of the arrival times of photons from a star counting coincidences in post-processing.
- Validating the feasibility of this type of measurements on a km baseline

ASTRI SII Simulations

Simulated g$^{(2)}$ measurements of two different stars with an uniform disk.



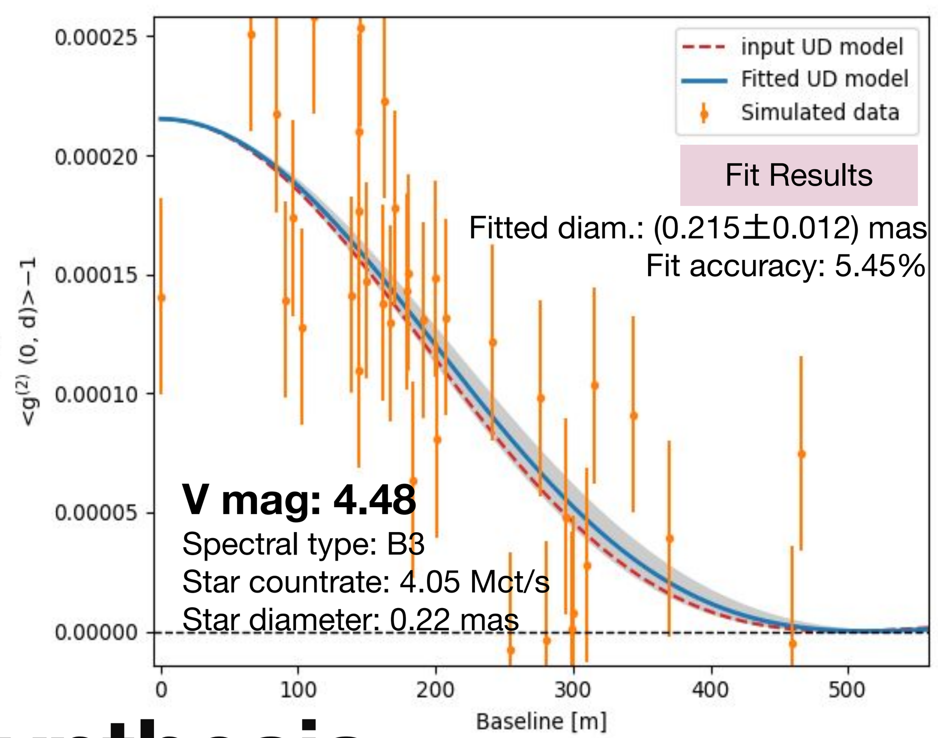
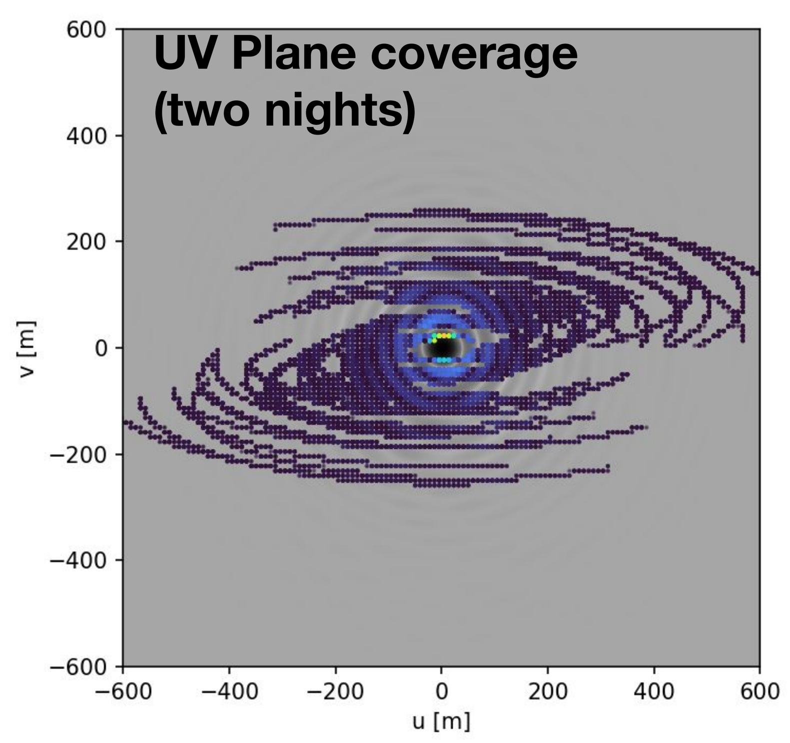
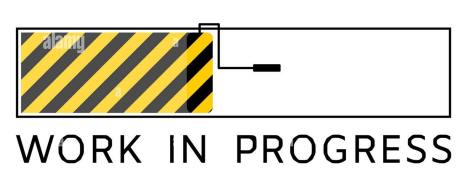
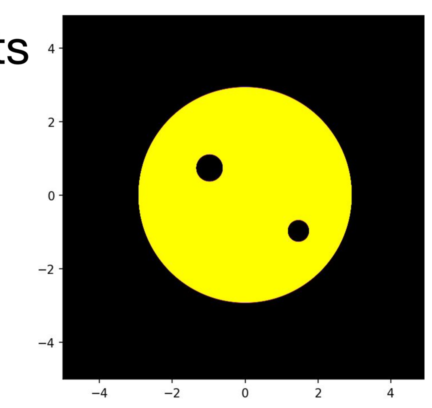


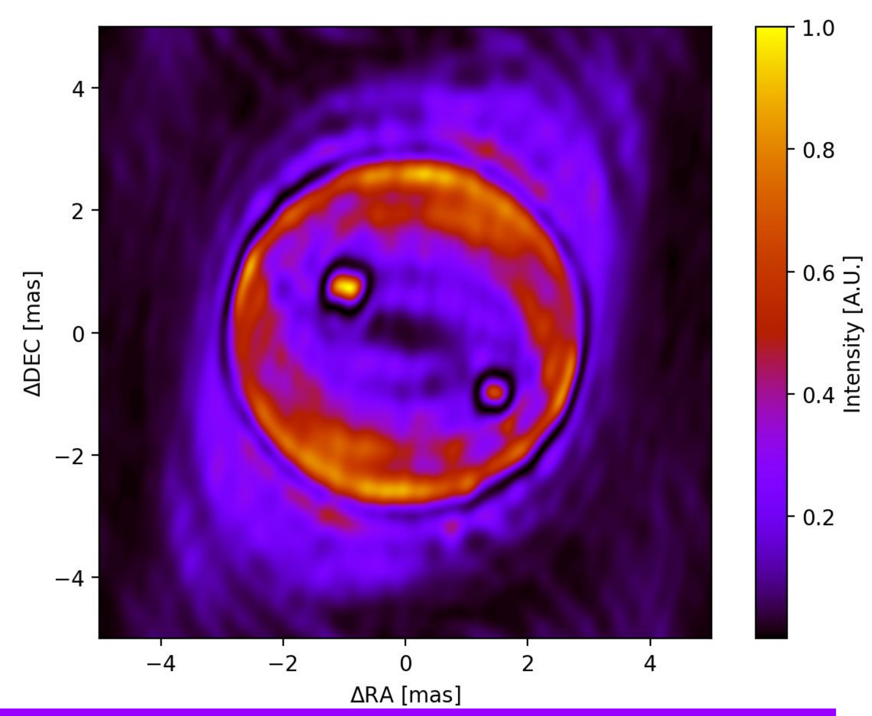
Image Synthesis



Simulated A-type star +dark spots







References

1. Foellmi C., 2009, A&A, 507, 1719.
2. Brown, R. H. & Twiss, R. Q. 1957, Proc. R. Soc. London Ser. A, 242, 300
3. Scuderi et al. 2022, JHEAp, 35, 52
4. Zampieri L., et al., 2022, SPIE Conference Series, Vol. 12183
5. Zampieri L., et al., 2021, MNRAS, 506, 1585