Towards Image Synthesis with Photon Counting Stellar Intensity Interferometry

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ASTRI Mini-Array

Stellar Intensity Interferometry (SII)

How it works?

Fast correlated variability is produced by pairs of point at the source (P_1, P_2).

Each point radiates and is independent of each other.

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

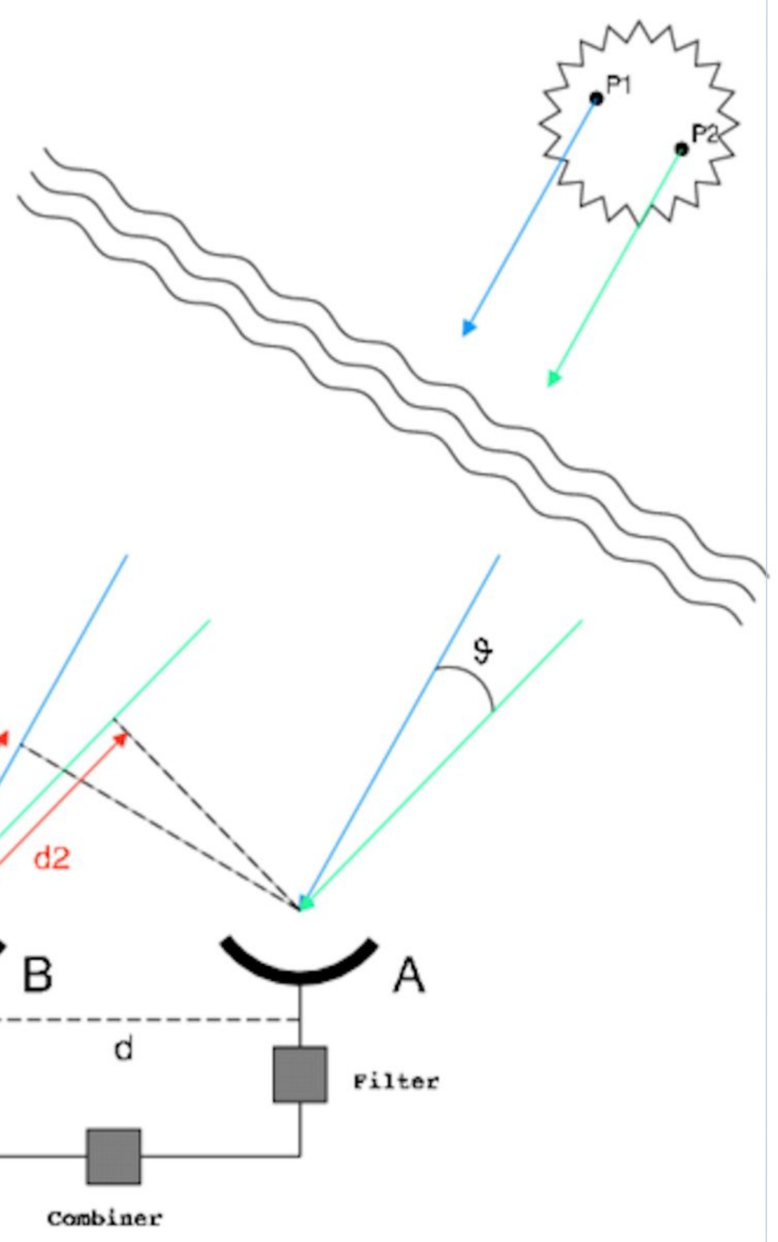


Fig.1: Working principle of an intensity interferometer. From [1].

What can we measure?

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

The first Intensity Interferometer

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

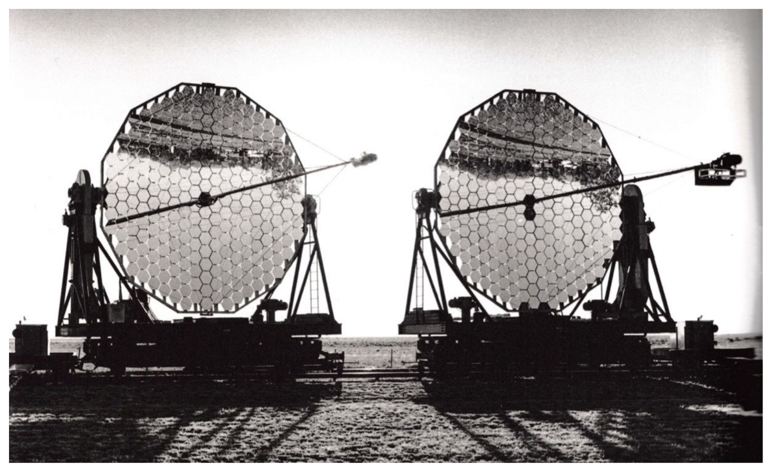


Fig.2: The two Narrabri SII telescopes.

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).

METHODS

Photon-Counting Intensity Interferometry

Counting coincidences in photon arrival times measured at 2 telescopes and exploiting 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)

ASIAGO SII experiment — TEST

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

The Aqueye/Iqueye team! Scan me!

Goal

- 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

IMAGES Synthesis

1st Optimization of the available pipelines for the treatment of the time series acquired at extremely high count rates with the entire array.

2nd Development of efficient and innovative algorithms for the cross-correlation of the arrival times in large time series.

3rd Implementation of a dedicated pipeline for the synthesis of images starting from the interferometric data and the data related to the instrumental simulations.

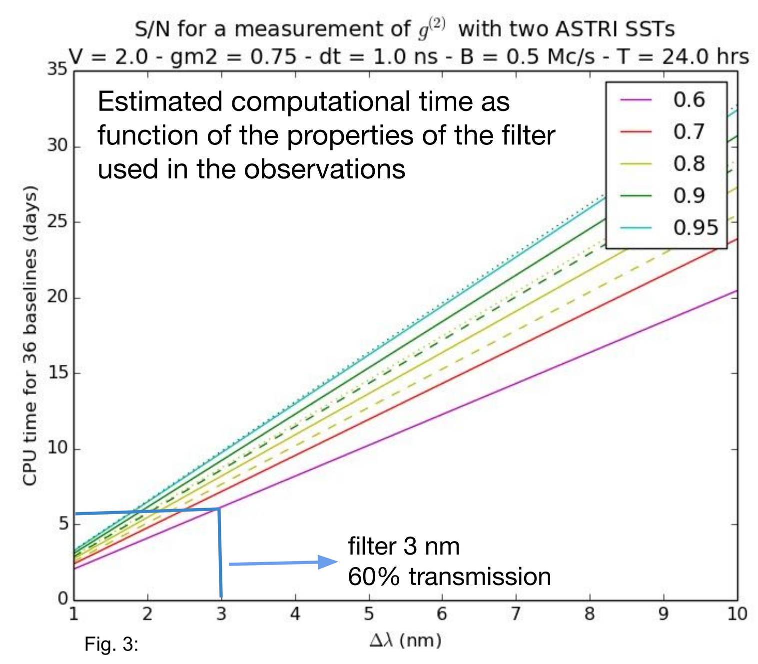
Computational Time to analyze SII data

To analyze 1 hr of data (36 baseline):

10^4 hr (CPU time) →

10^4/2000 core = 5 hr

→ 5*24 hr (real data) = 5 days



ASTRI Mini Array [3]

9 Imaging Atmospheric Cherenkov Telescopes 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 window (1-8 nm centered at 420-500 nm).

Resources Request

Parallelize and accelerate algorithms with CUDA.

Start from **multiples CPUs** (2000 CPU cores: 1 hr data)

→ code optimized (100 hr of data)

→ **GPUs** (to accelerate the computing time: 20x).

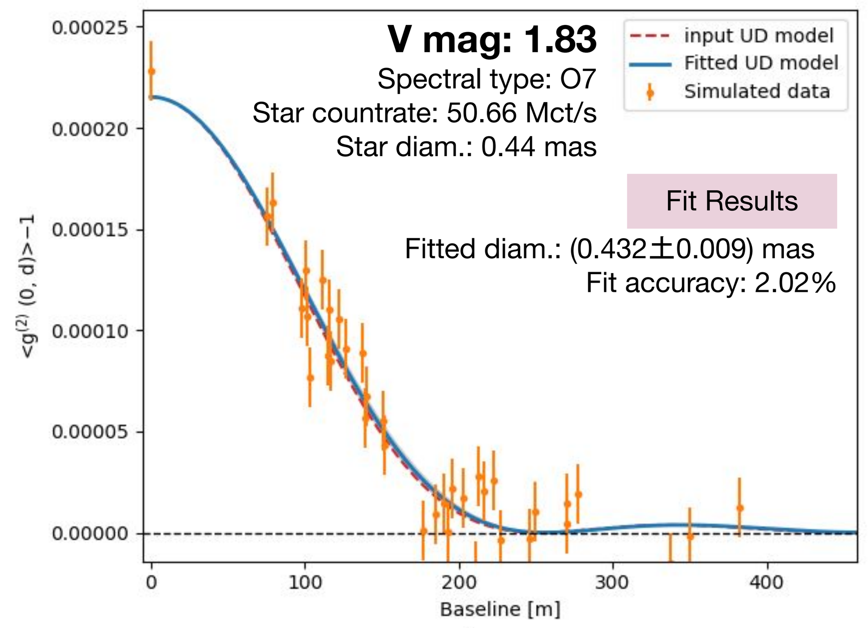
4 Leonardo Booster GPUs (1 hr data in 1 hr).

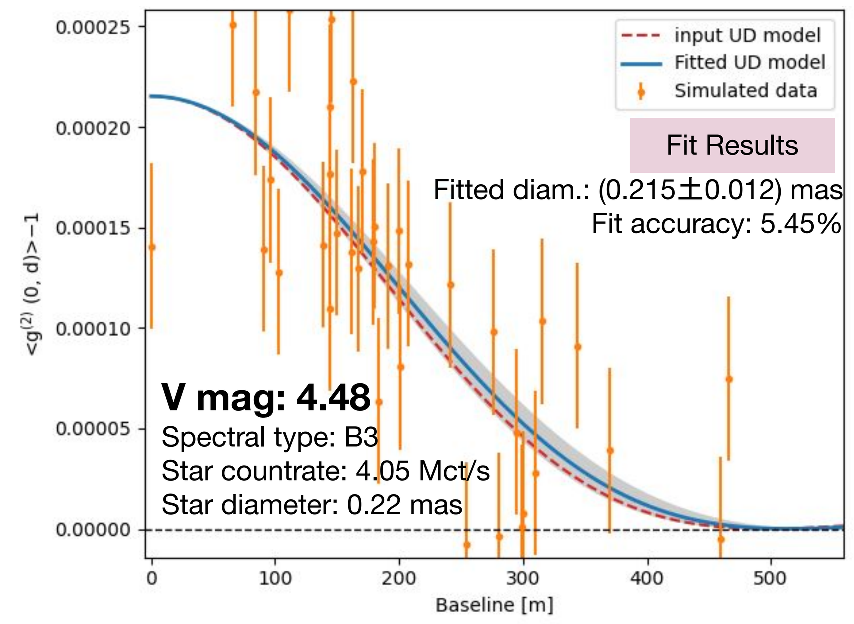
	CPUs	GPUs
Tot. cores hr	5×10^6	5×10^5
2024	70%	30%
2025	30%	70%

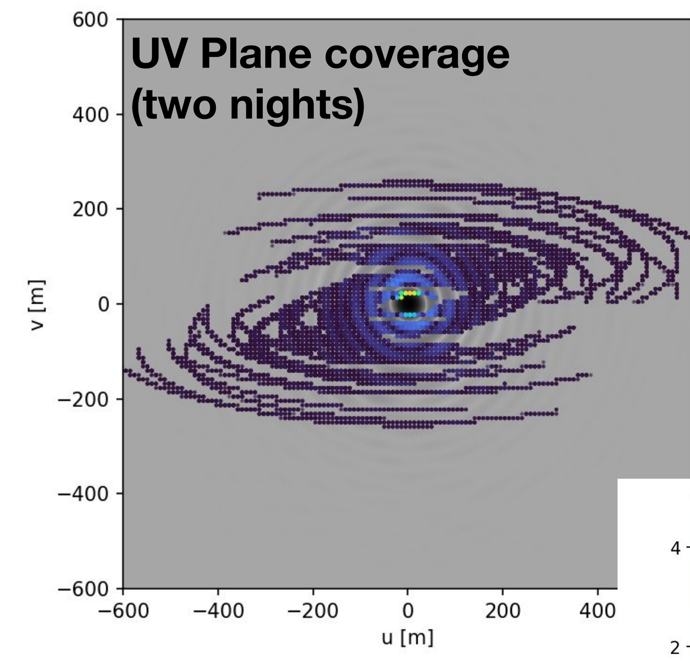
Table: Prospects for use of Resources.

ASTRI SII SIMULATIONS

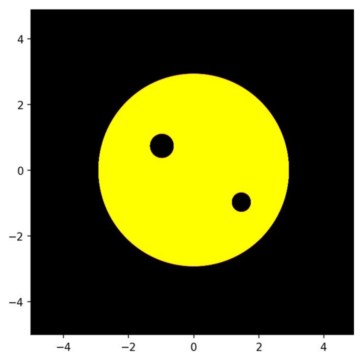
Simulated $g^{(2)}$ measurements of two different stars with an uniform disk.

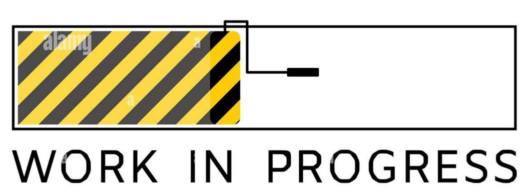


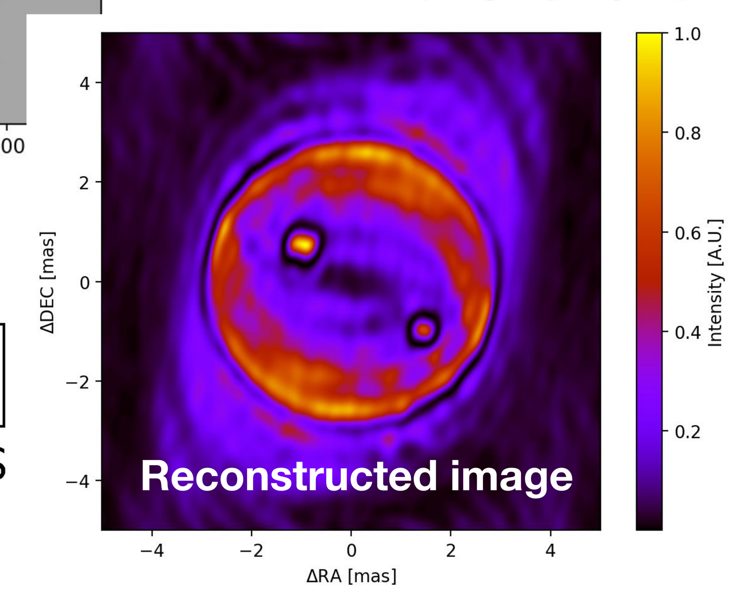




Simulated A-type star +dark spots







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