Reviving Stellar Intensity Interferometry with the Cherenkov Telescope Array:

Laboratory simulation of stellar observations

Tiphaine Lagadec - Lund Observatory, Sweden
lagadec.tiphaine@gmail.com

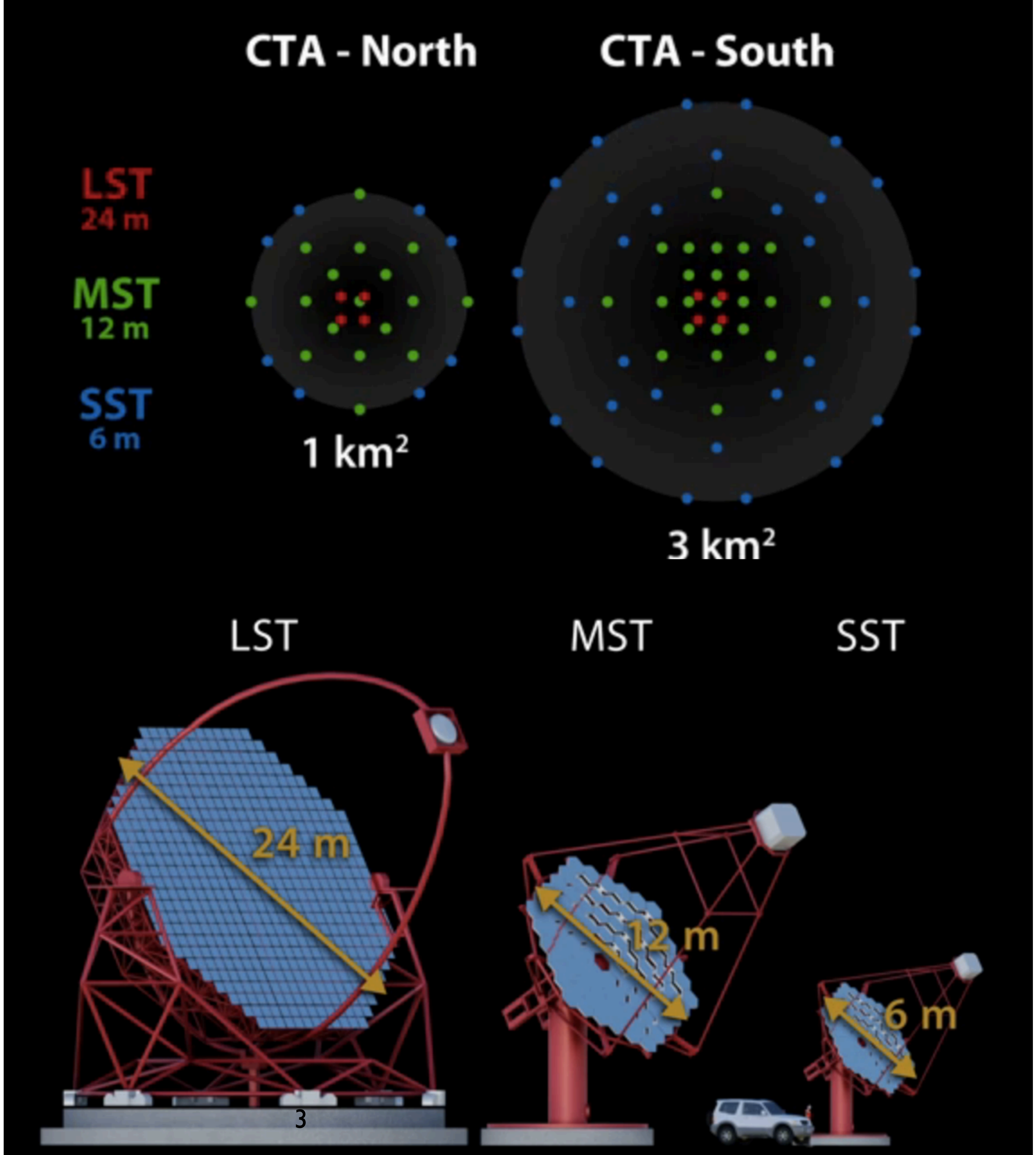
Content

- *A long held dream...*
- *Experimental simulations*
- *Method*
  How to make an artificial star in the lab?
  The detectors
  The correlation
- *Results*
  1D angular measurements
  2D angular maps
  2D binary star
- *Pending issues*

2 arrays
→ Full sky coverage

km baseline
→ ~μas resolution

many baselines
→ covers uv-plane



End-to-end experimental simulation of SII

To be simulated:

- Multiple baselines
- Complex stellar structures

To be tested:

- Digital correlators
- Semiconductor detectors

Overall aim:

Demonstrate the procedure of SII with CTA

- Retrieve correlations between pairs of telescopes
- Retrieve signatures of complex stellar structures
- Retrieve images

The method
How to make a star in the lab?

Requirements:

- Small angular diameter
- Complex structures
- Bright and hot
- Chaotic thermal light (Gaussian amplitude distribution)

The method
How to make a star in the lab?

Requirements:

- Small angular diameter

Illuminated pinholes

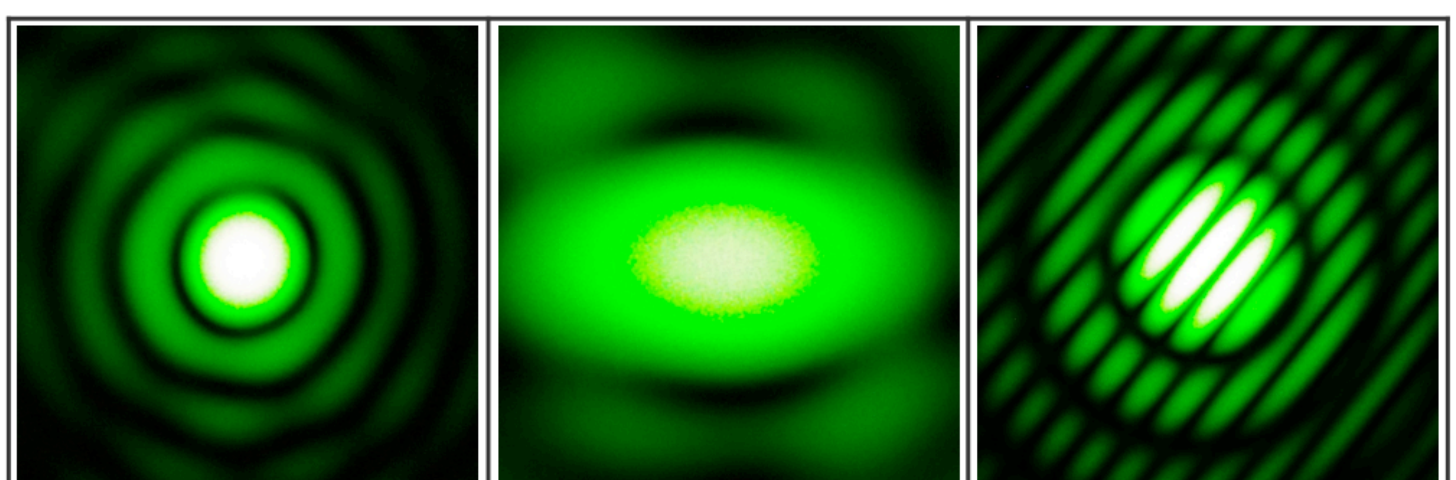
100 µm pinhole @ 23 m ⇒ 1 arcsecond star

The method
How to make a star in the lab?

Requirements:

- ~~Small angular diameter~~
- Complex structures

Pinholes come in different shapes and sizes
(round, elliptical, double aperture)
⇒ Simulating "realistic" star shapes and angular diameters



The method
How to make a star in the lab?

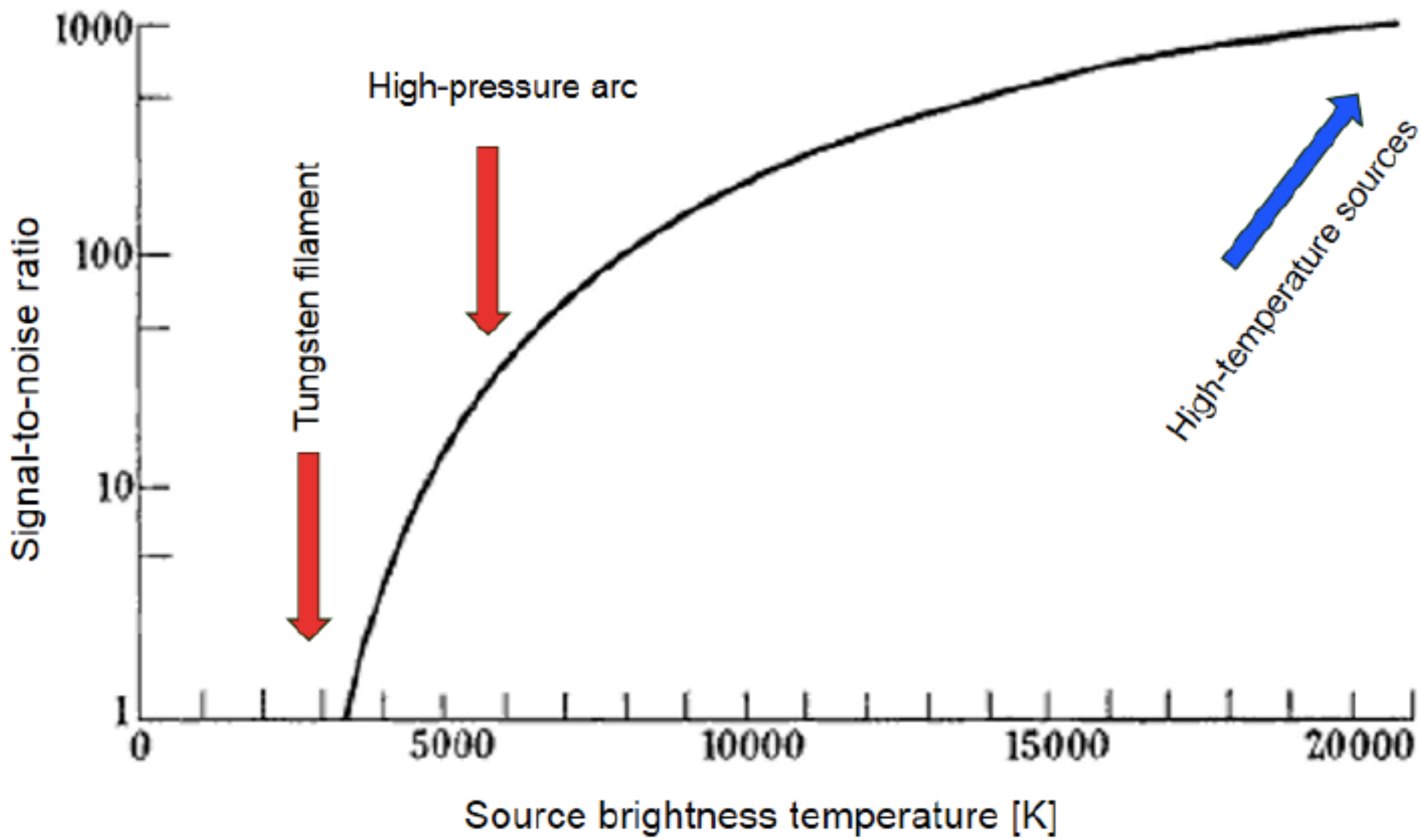
Requirements:

- ~~Small angular diameter~~
- ~~Complex structures~~
- Bright and hot

The method
How to make a star in the lab?

The problem of the temperature

SNR as a function of the source brightness temperature from R.Hanbury Brown and R.Q.Twiss:



The method
How to make a star in the lab?

Requirements:

- ~~Small angular diameter~~
- ~~Complex structures~~
- ~~Bright and hot~~

Laser radiation very bright

The method
How to make a star in the lab?

Requirements:

- ~~Small angular diameter~~
- ~~Complex structures~~
- ~~Bright and hot~~
- Chaotic thermal light (Gaussian amplitude distribution)

? Laser radiation very bright **but not thermal** !
(no intensity fluctuations in space and time)

The method
How to make a star in the lab?

Requirements:

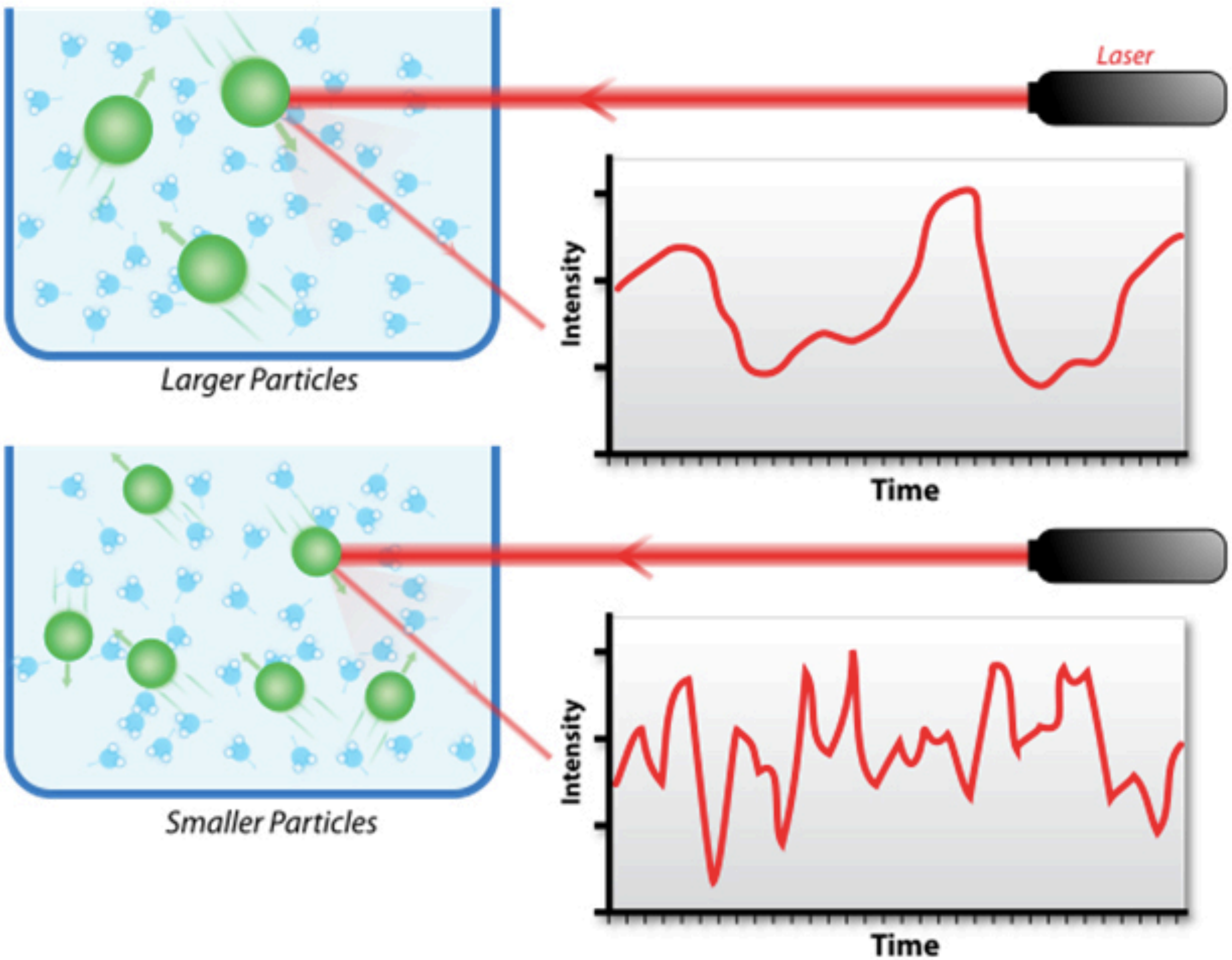
- ~~Small angular diameter~~
- ~~Complex structures~~
- ~~Bright and hot~~
- Chaotic thermal light (Gaussian amplitude distribution)

Dynamic Light Scattering (DLS):

Coherent bright radiation **scattered**
Resulting radiation is thermal and Doppler broadened

The method
How to make a star in the lab?

Dynamic Light Scattering



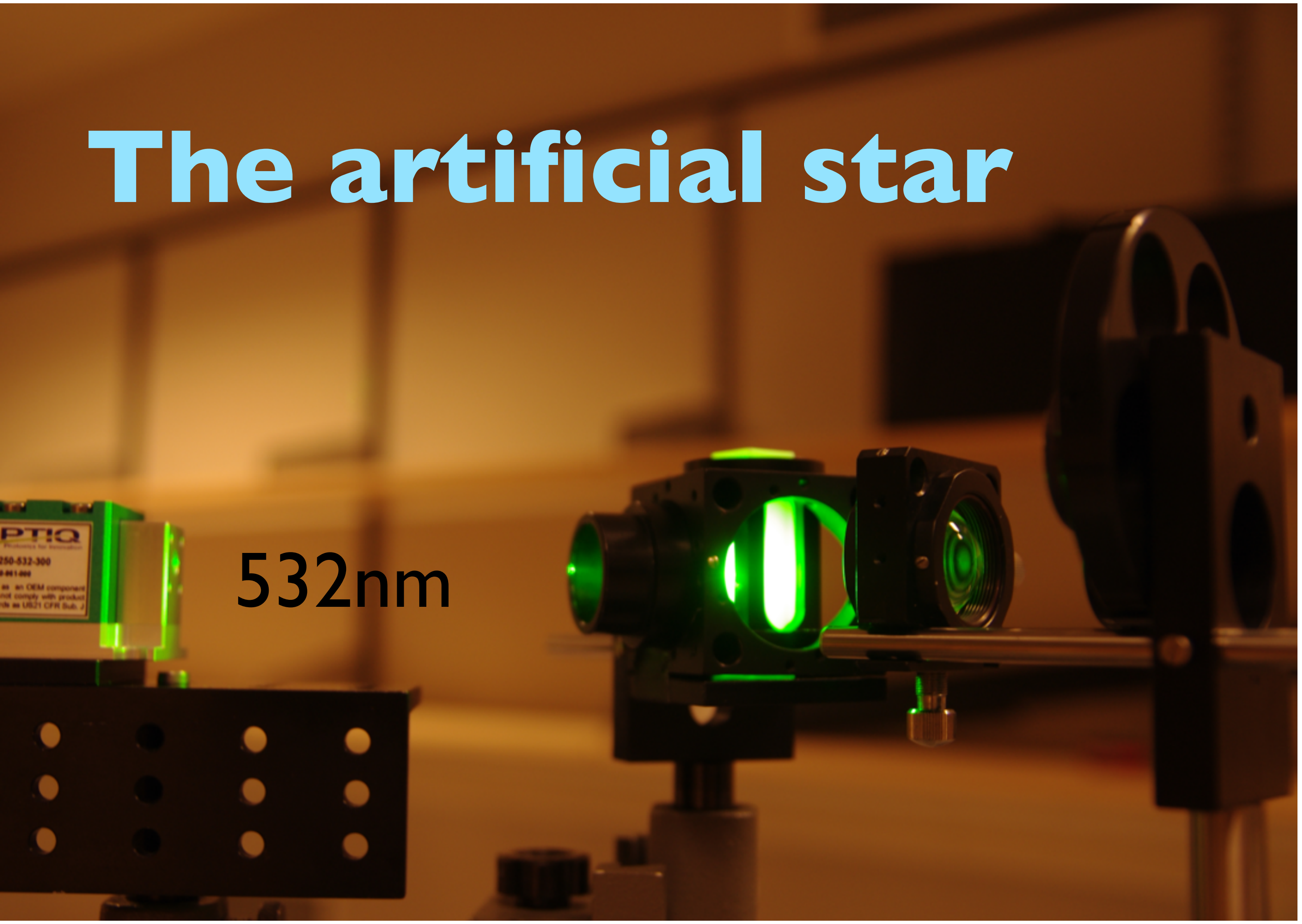
The method
How to make a star in the lab?

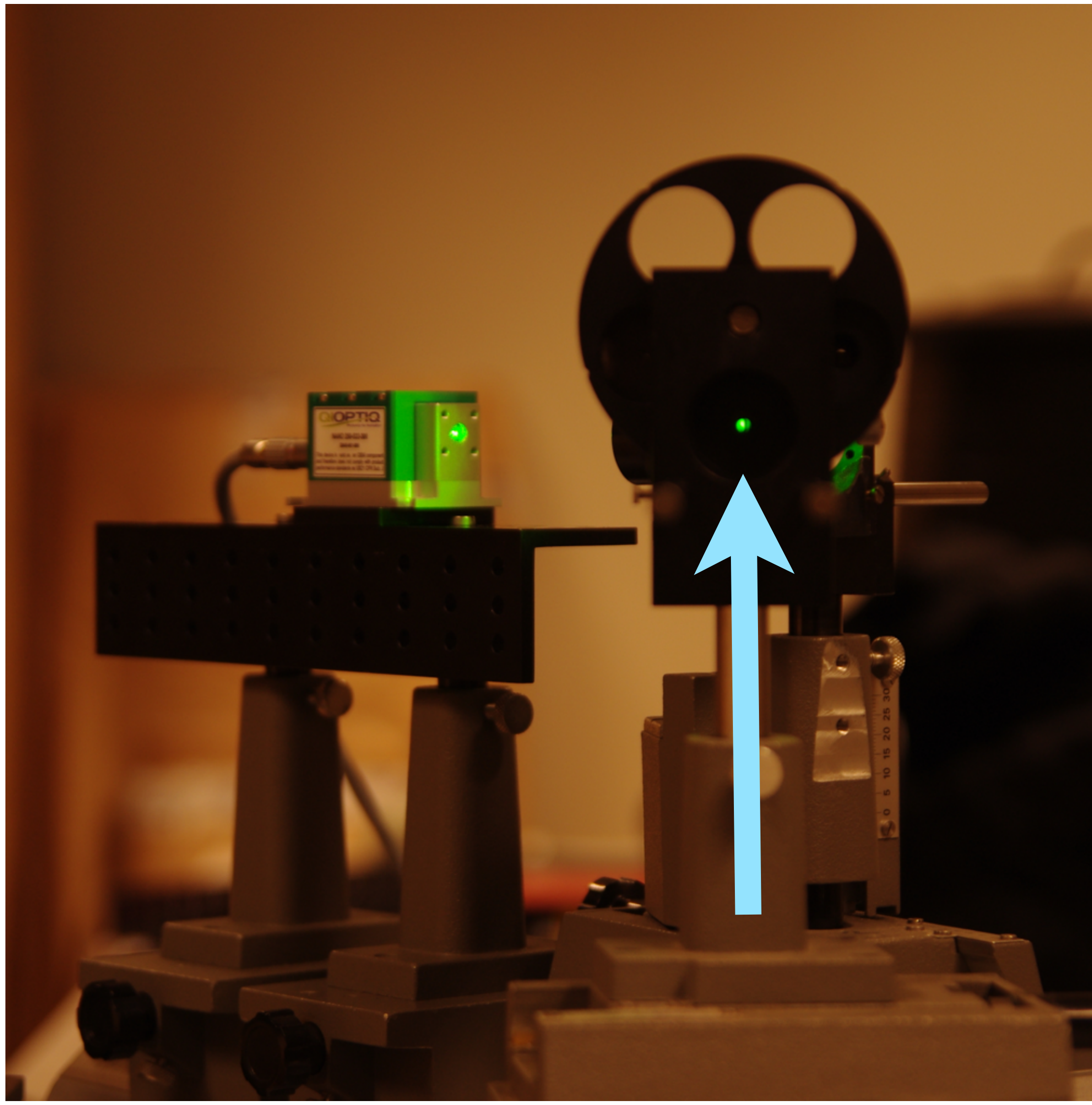
Requirements:

- ~~Small angular diameter but good photon fluxes~~
- ~~Complex structures~~
- ~~Bright and hot~~
- ~~Chaotic thermal light (Gaussian spectrum)~~

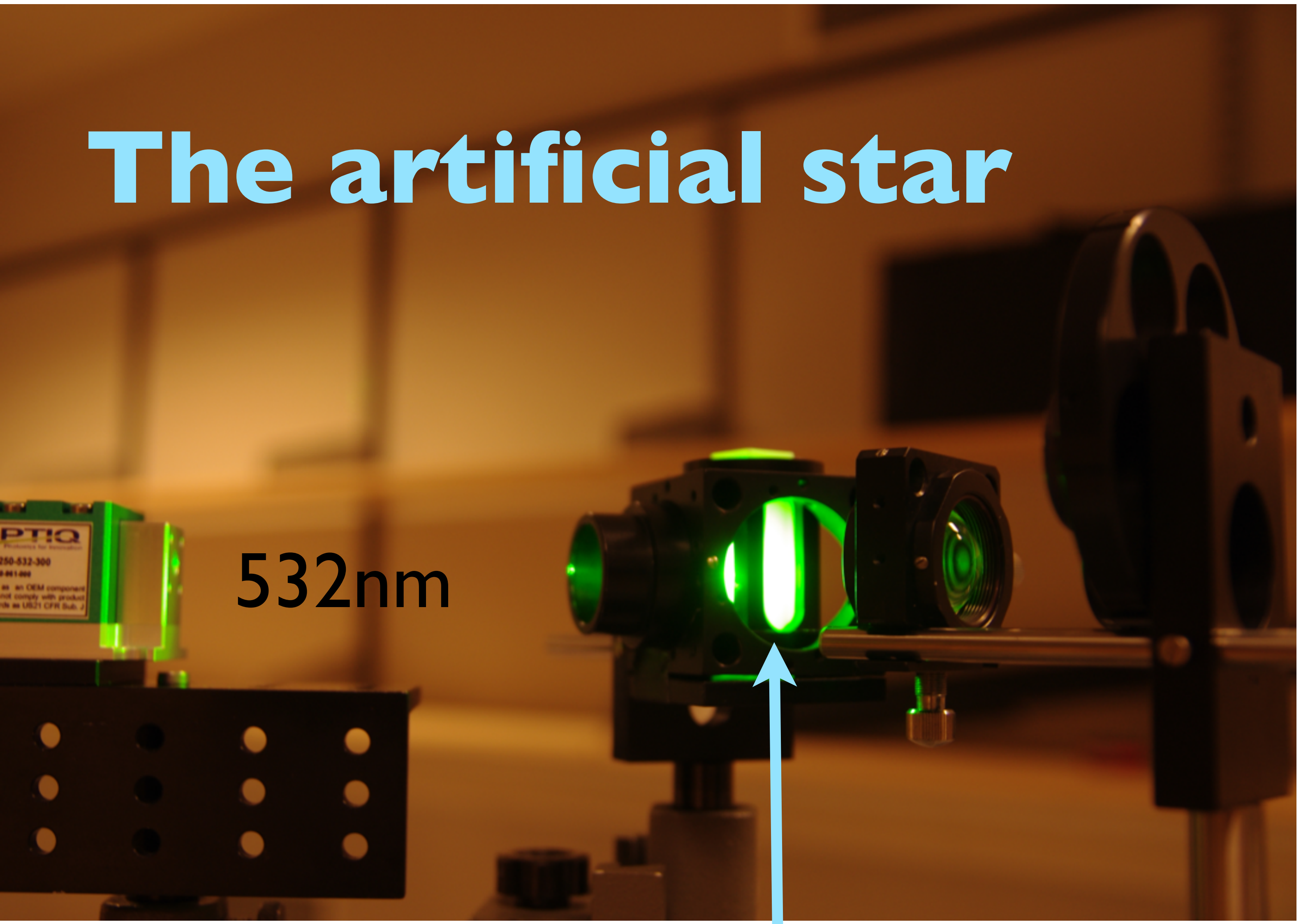
$\Rightarrow$ We have our artificial star !

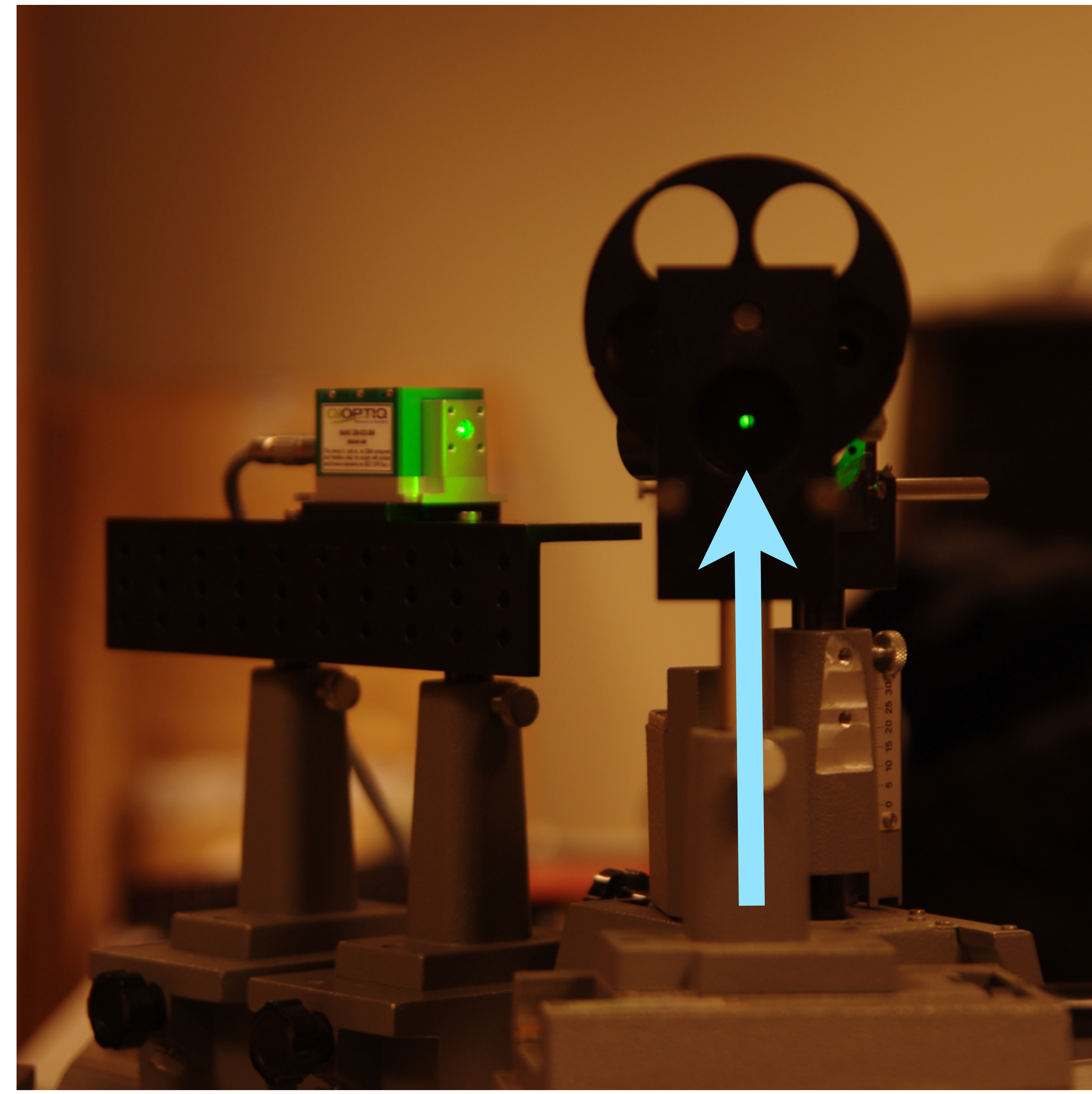
The method
How to make a star in the lab?





The method
How to make a star in the lab?





Scatterer: plastic micro-spheres or fat globules in milk

The method
How to make a star in the lab?

≈23m away

The method
The detectors

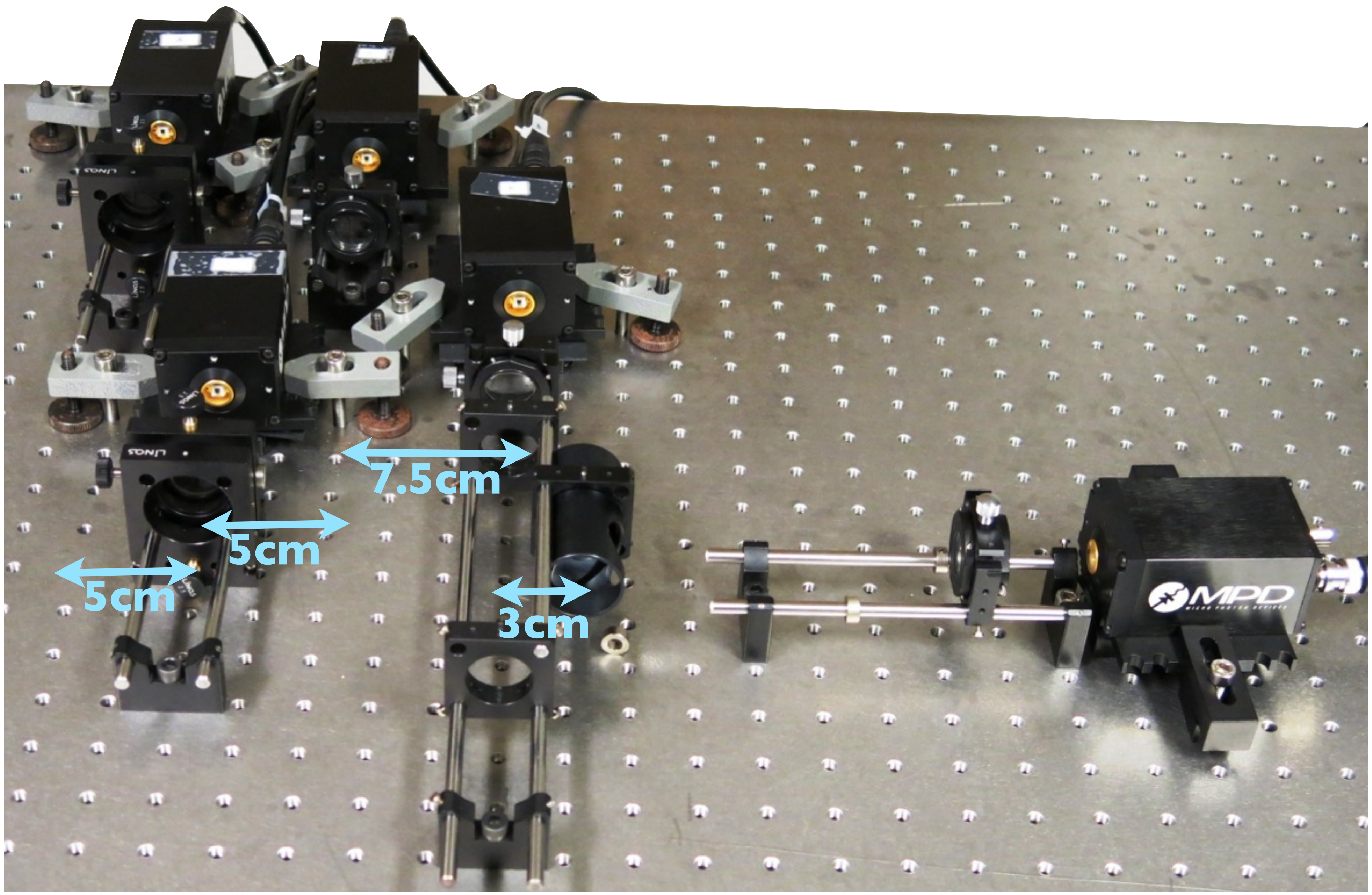
Single Photon Avalanche Diode (Geiger mode APD)

- Analogous to planned CTA detectors

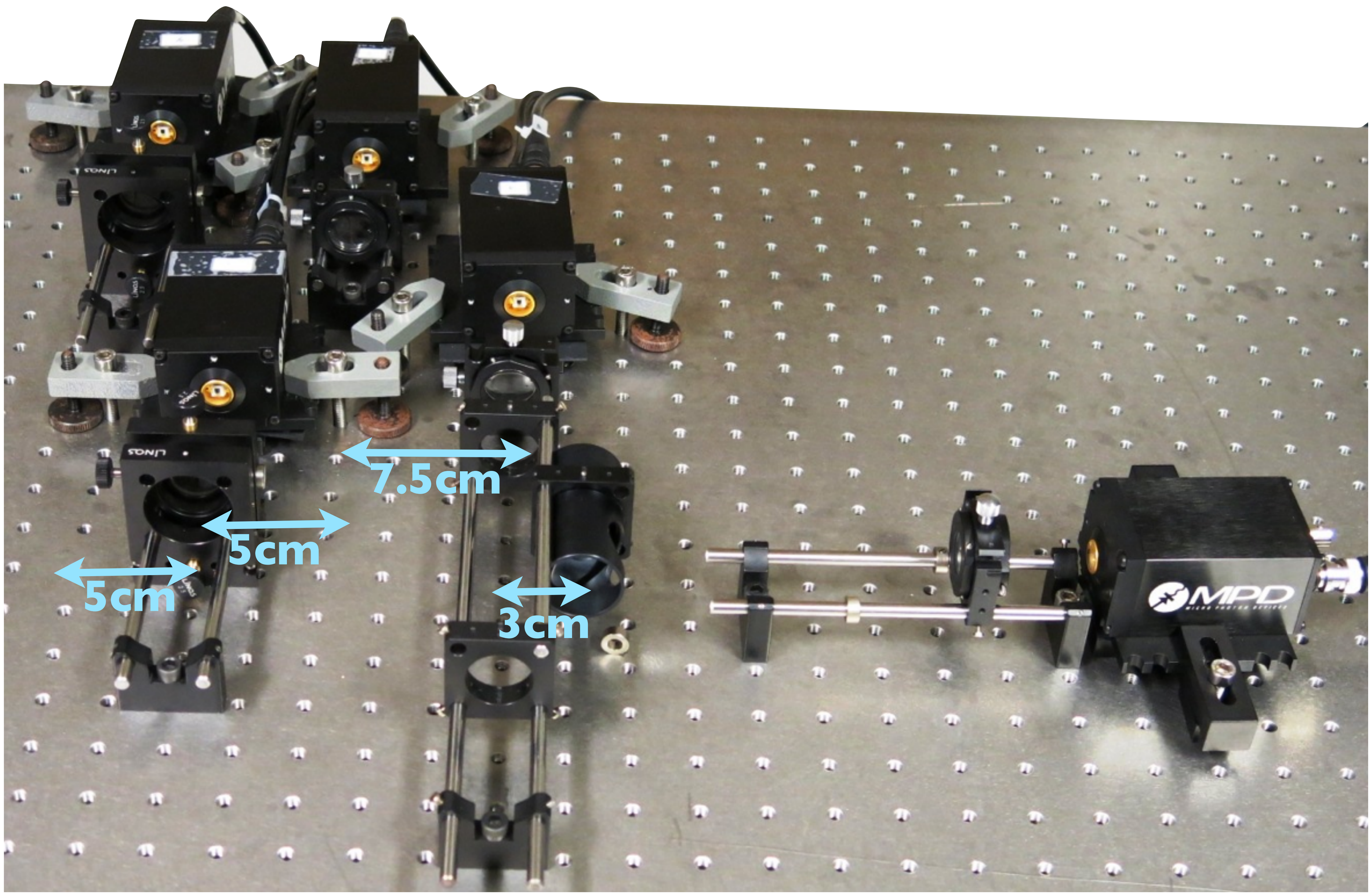
- Very high QE
- High gain
- Large bandwidth

- Compact
- Fast (~ns)
- Immune to magnetic fields

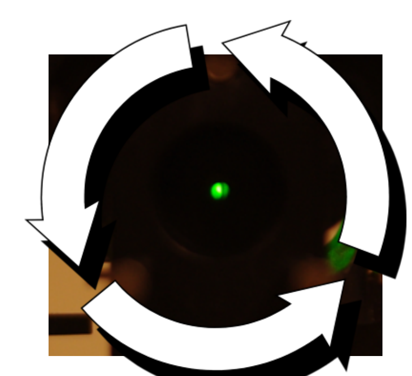
The method
A 2D telescope array in the lab



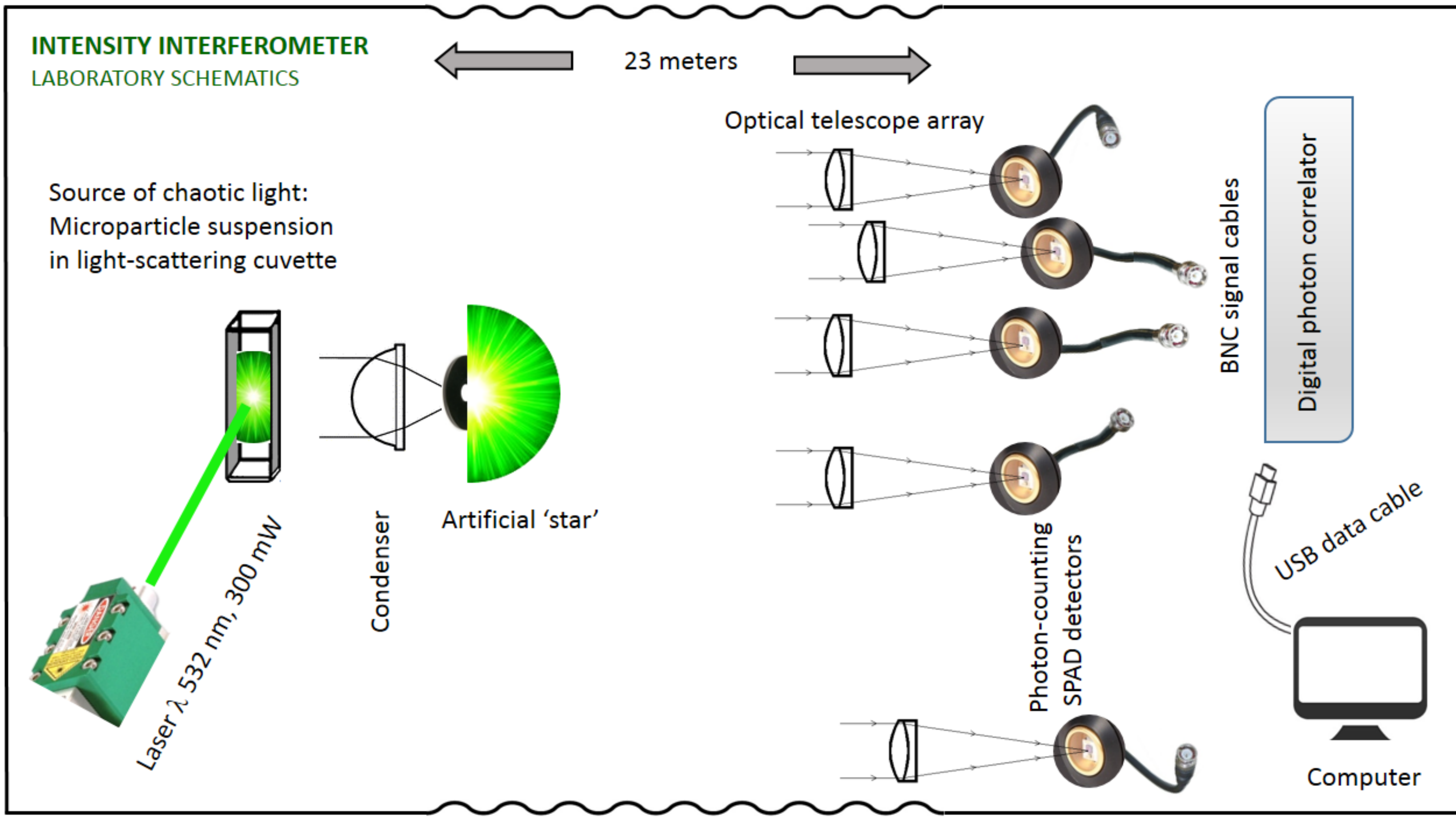
The method
A 2D telescope array in the lab



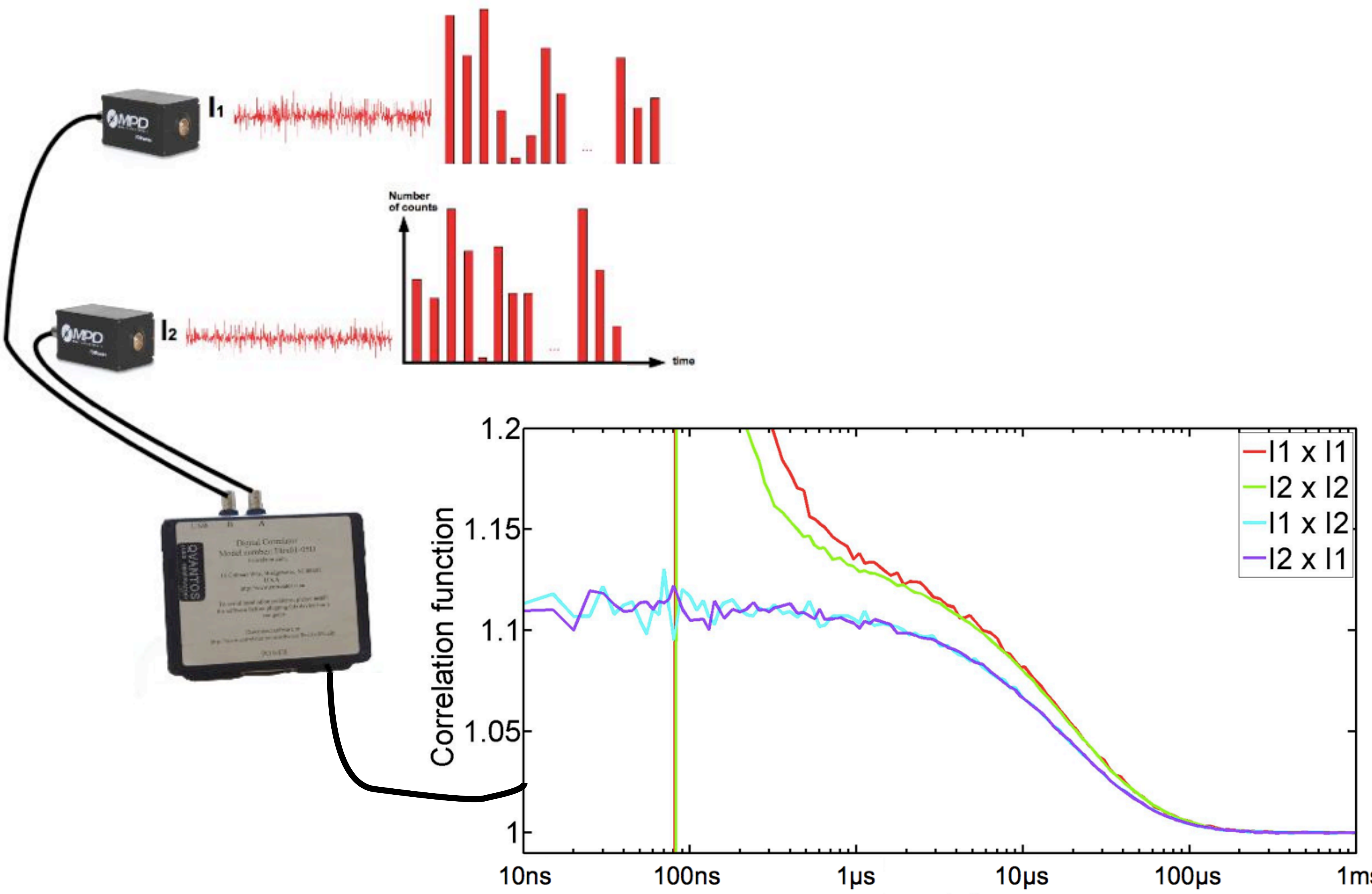
Rotating source angle enables 2D-array



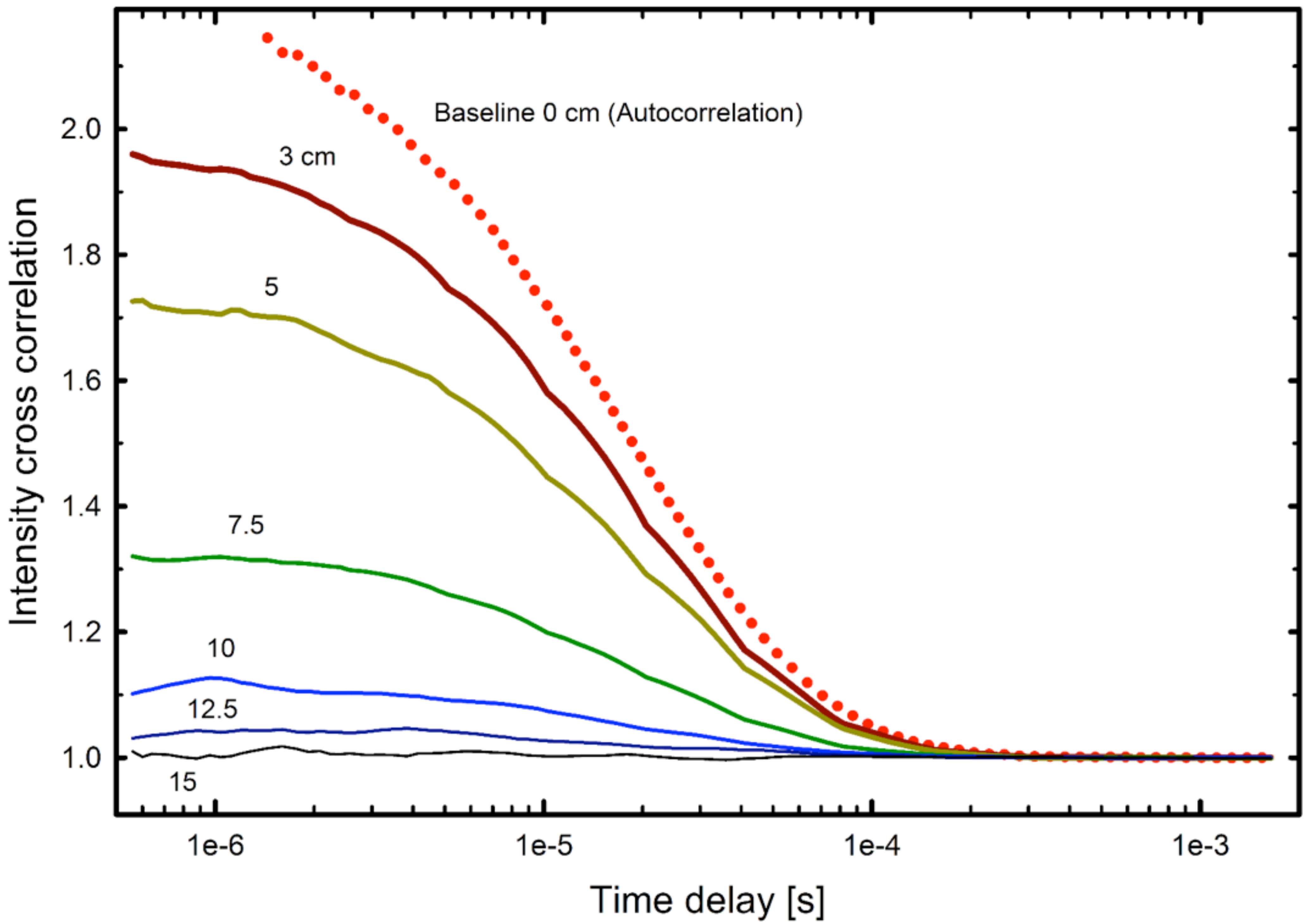
The method
The set-up



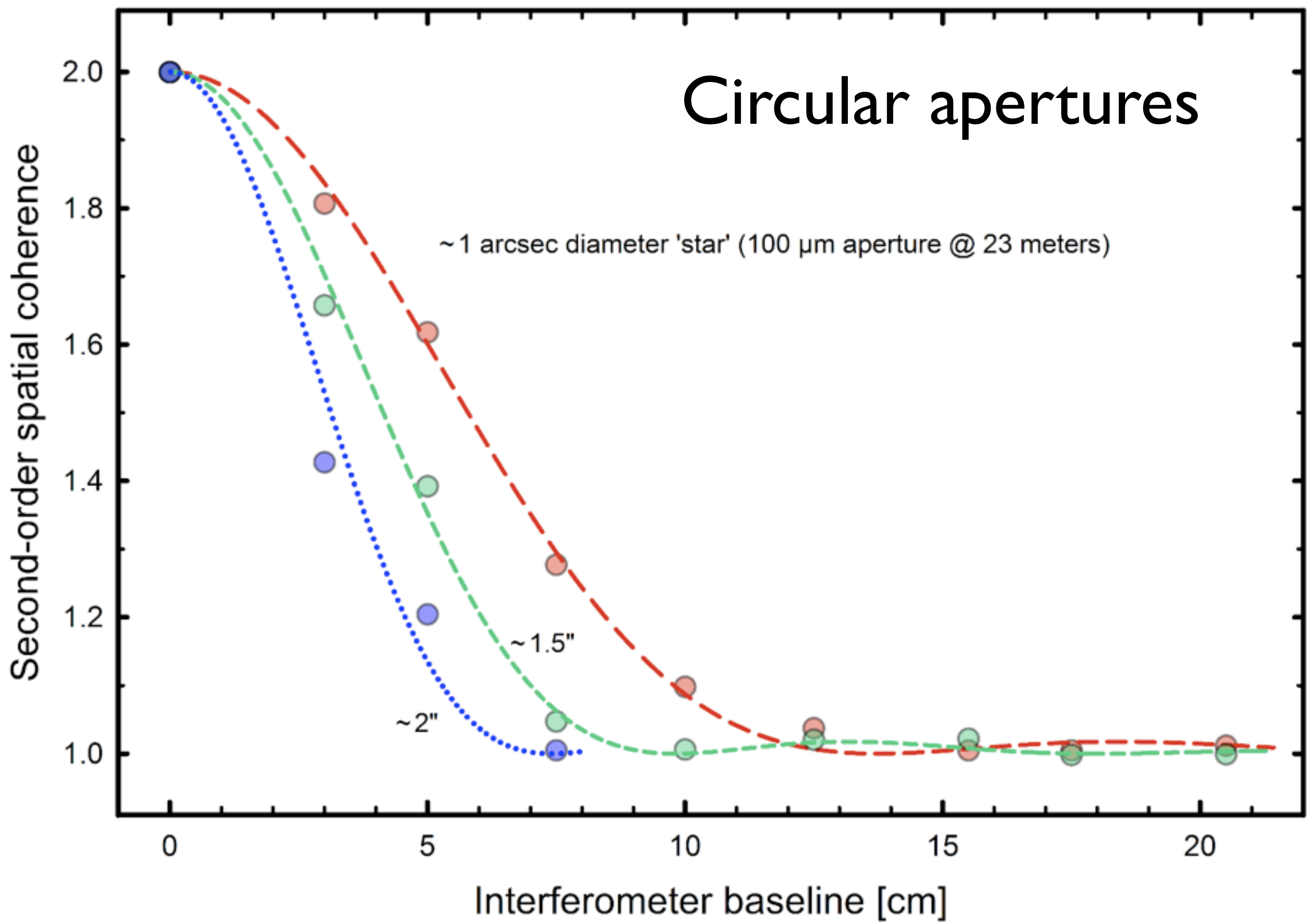
The method
The correlation



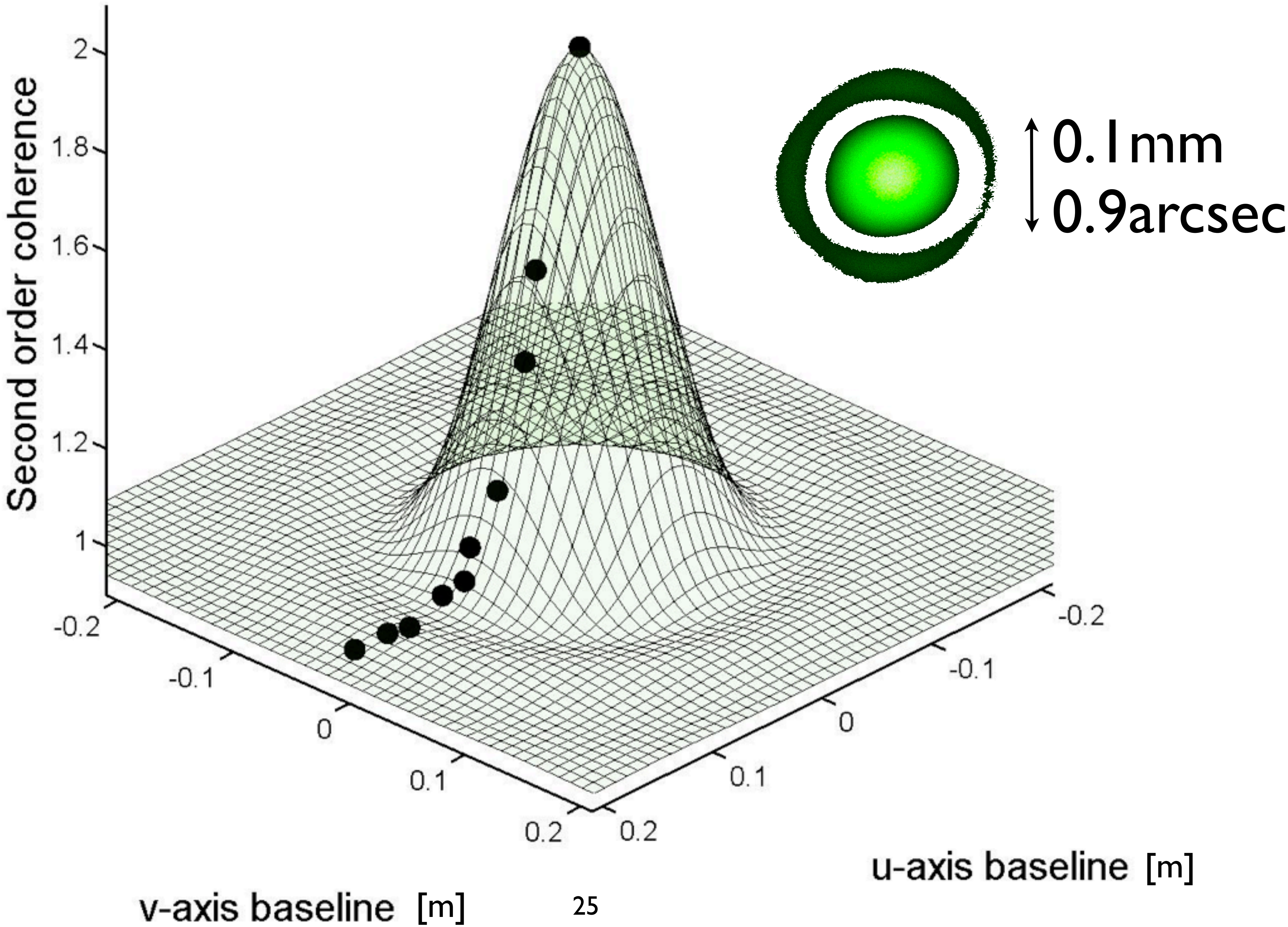
The results
1D angular diameter



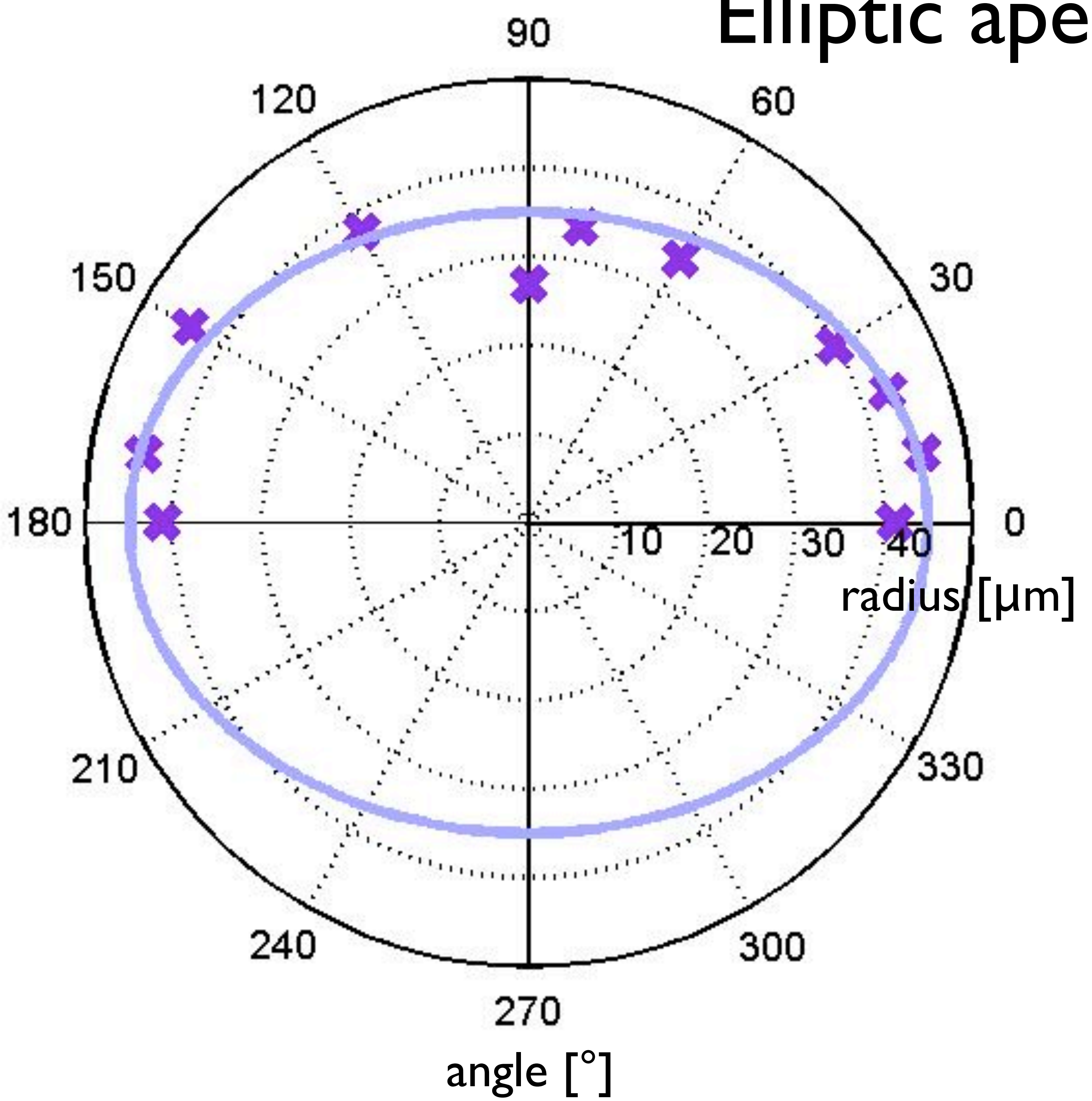
The results
1D angular diameter



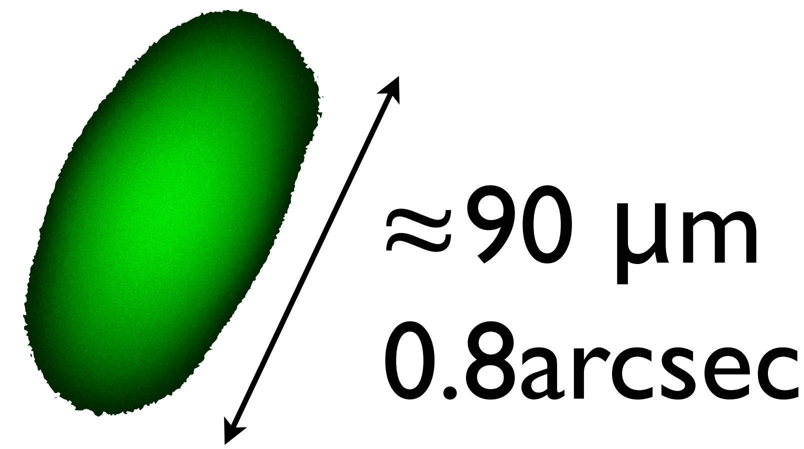
The results
1D angular diameter

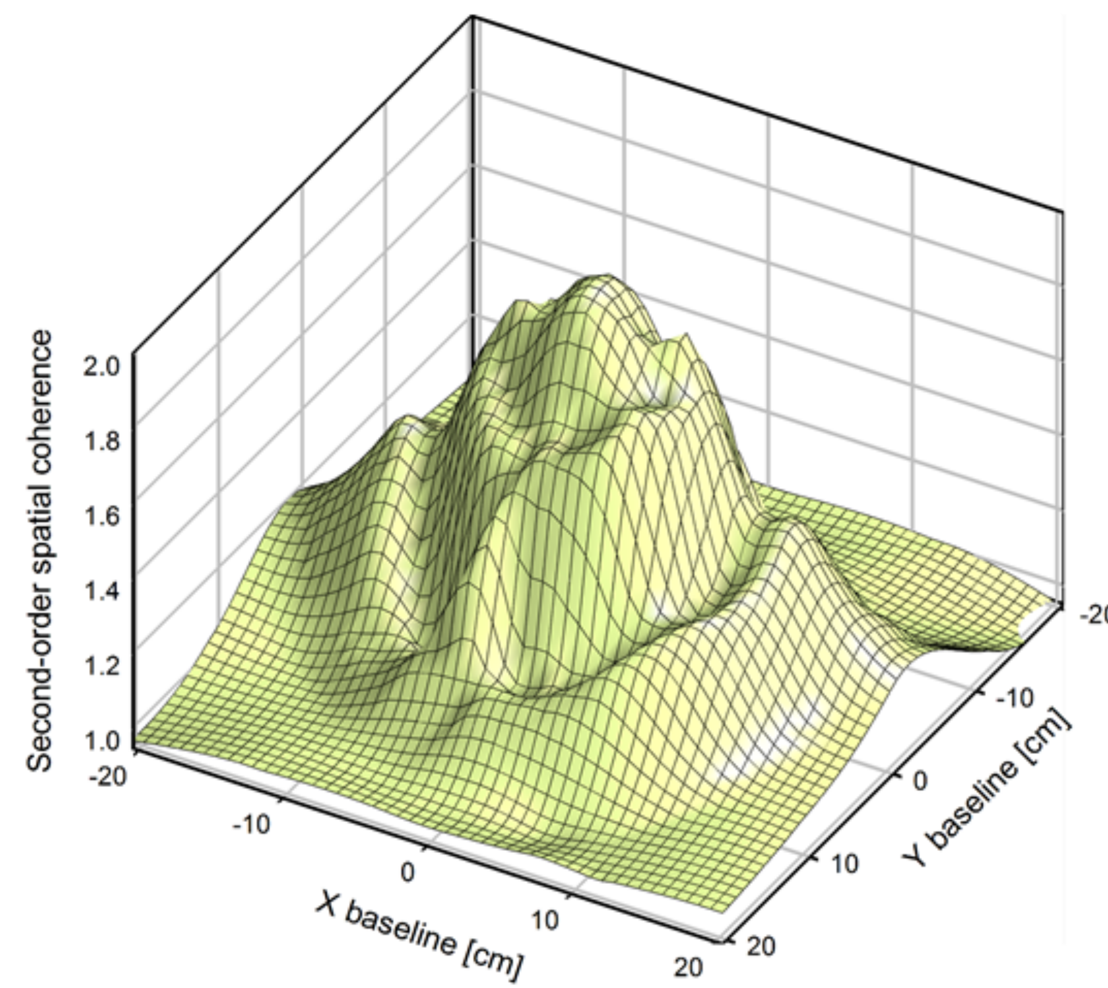


The results
2D angular diameter



Elliptic aperture

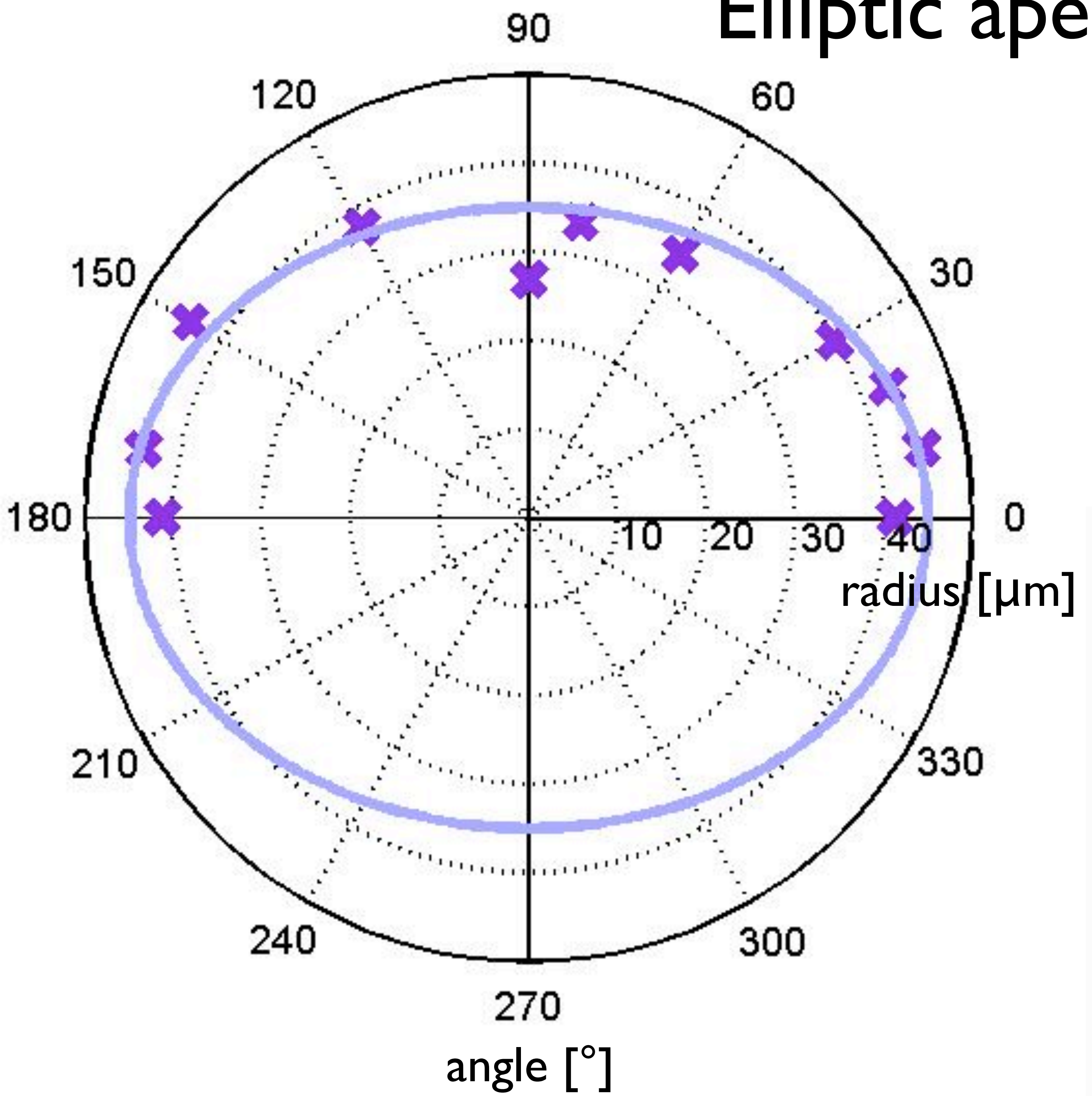


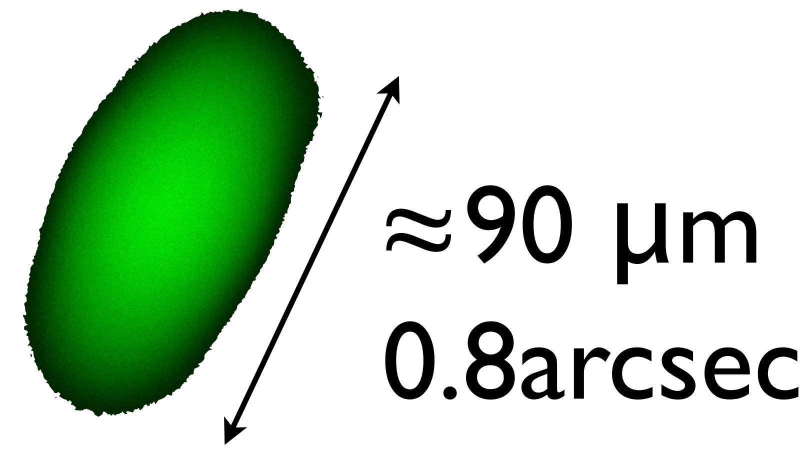


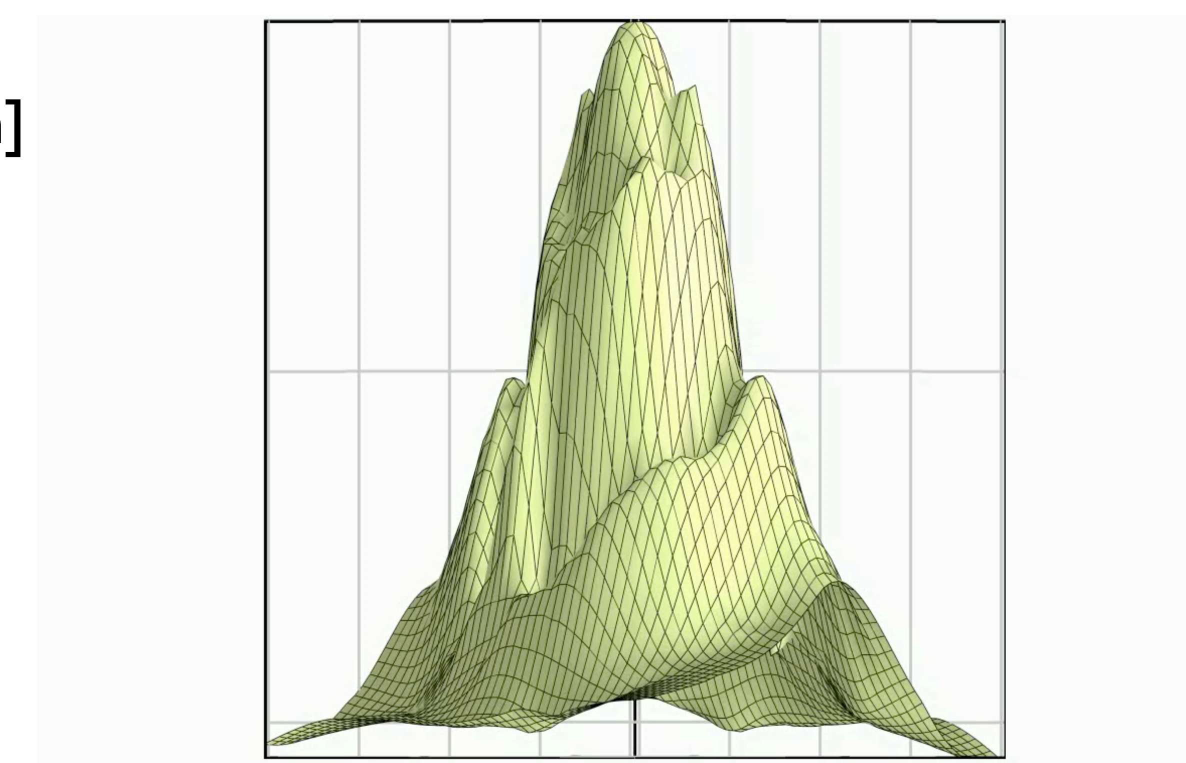
100 baselines

The results
2D angular diameter

Elliptic aperture



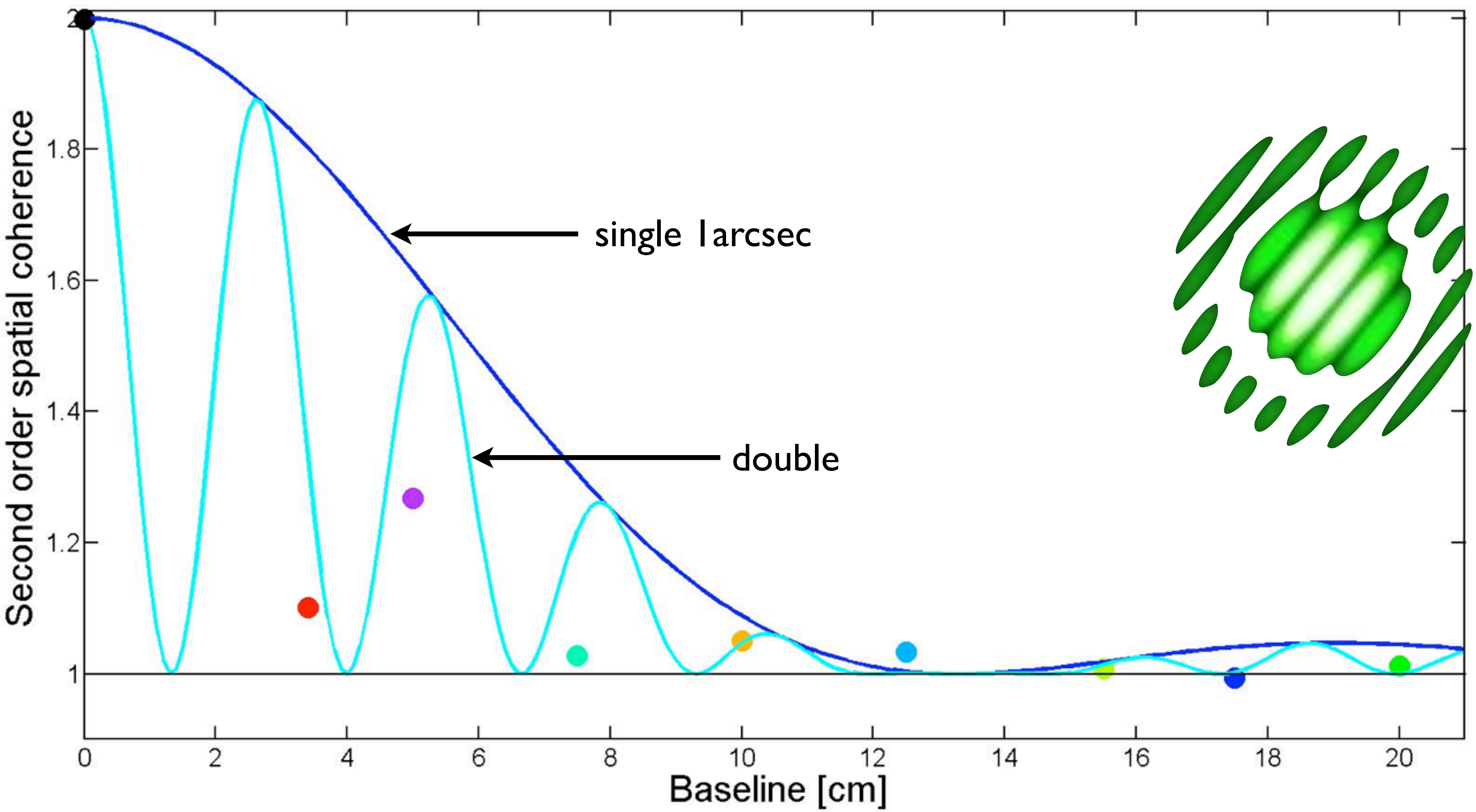




100 baselines

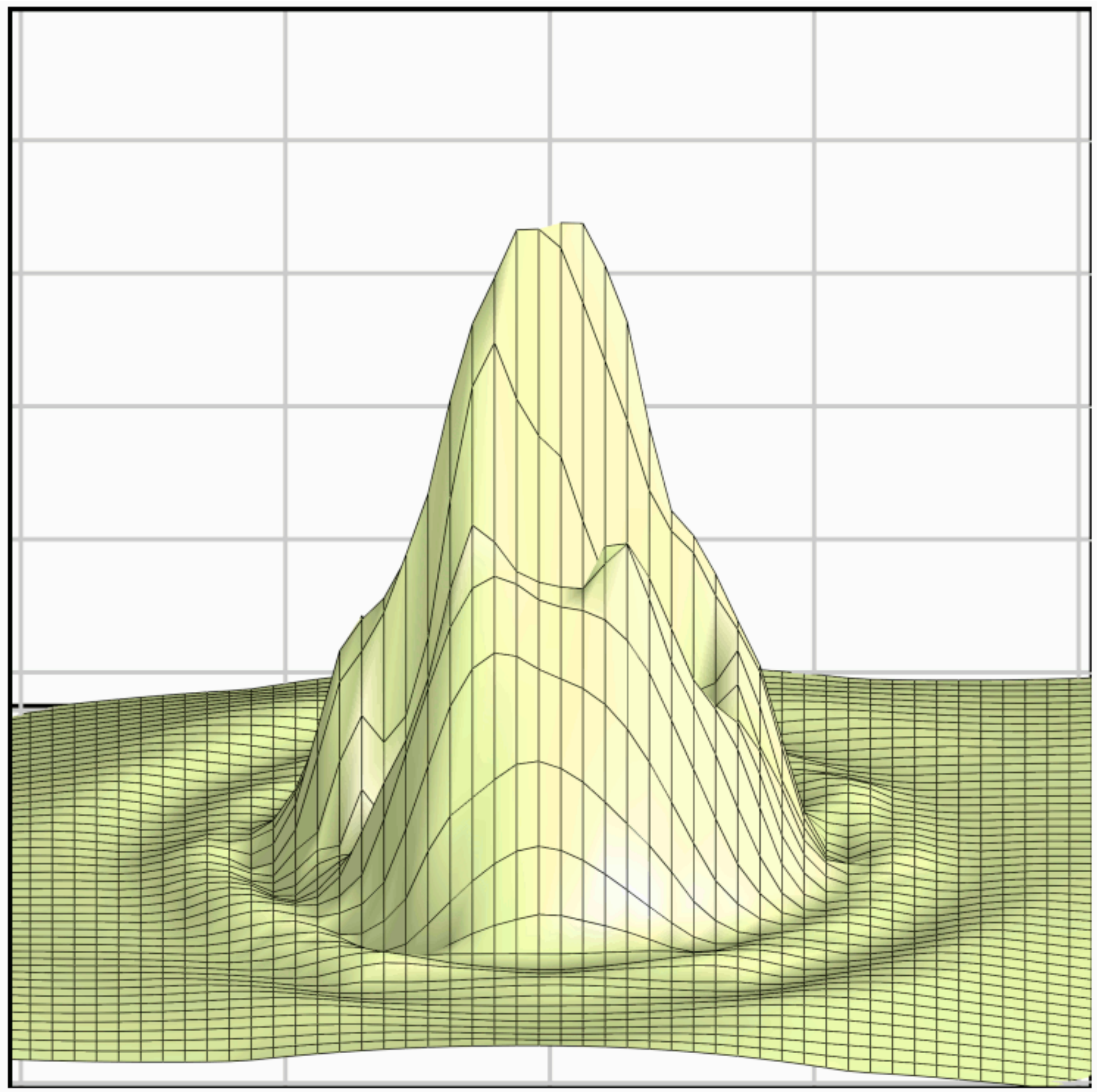
The results
2D binary star

Double aperture



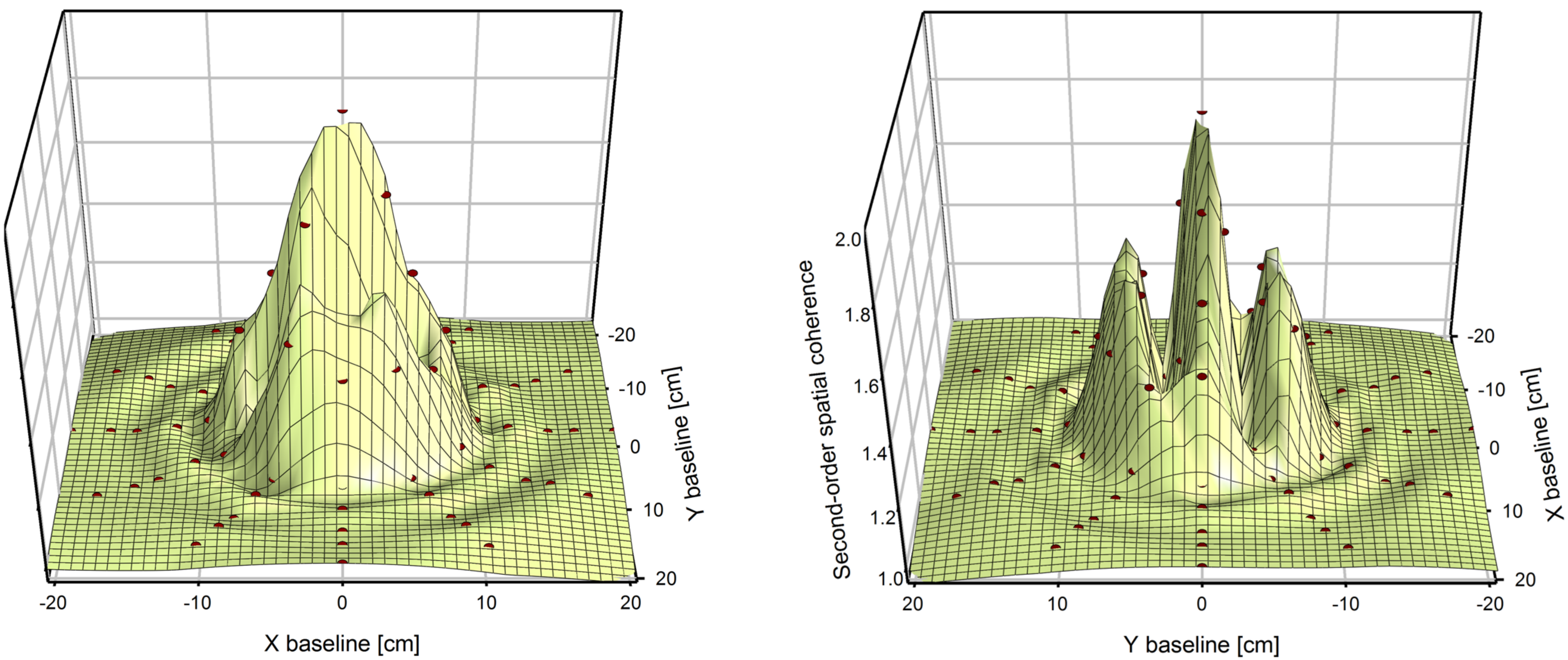
The results
2D binary star

60 baselines



The results
2D binary star

60 baselines



Pending issues

- *Image restoration*
- *Possible white light illumination ?*
- *Polarization effects ?*
- *Multiple spectral pass-bands ?*

For details see:

Dainis Dravins & Tiphaine Lagadec: "*Stellar intensity interferometry over kilometer baselines: Laboratory simulation of observations with the Cherenkov Telescope Array*", in J.K.Rajagopal, M.J.Creech-Eakman & F.Malbet (eds.): "Optical and Infrared Interferometry IV", SPIE Proc. 9146 (2014)

For details see:

Dainis Dravins & Tiphaine Lagadec: "*Stellar intensity interferometry over kilometer baselines: Laboratory simulation of observations with the Cherenkov Telescope Array*", in J.K.Rajagopal, M.J.Creech-Eakman & F.Malbet (eds.): "Optical and Infrared Interferometry IV", SPIE Proc. 9146 (2014)

Thank you for your attention!