The Large Binocular Telescope *Fizeau* Interferometer

Fundamental gain in high-contrast imaging

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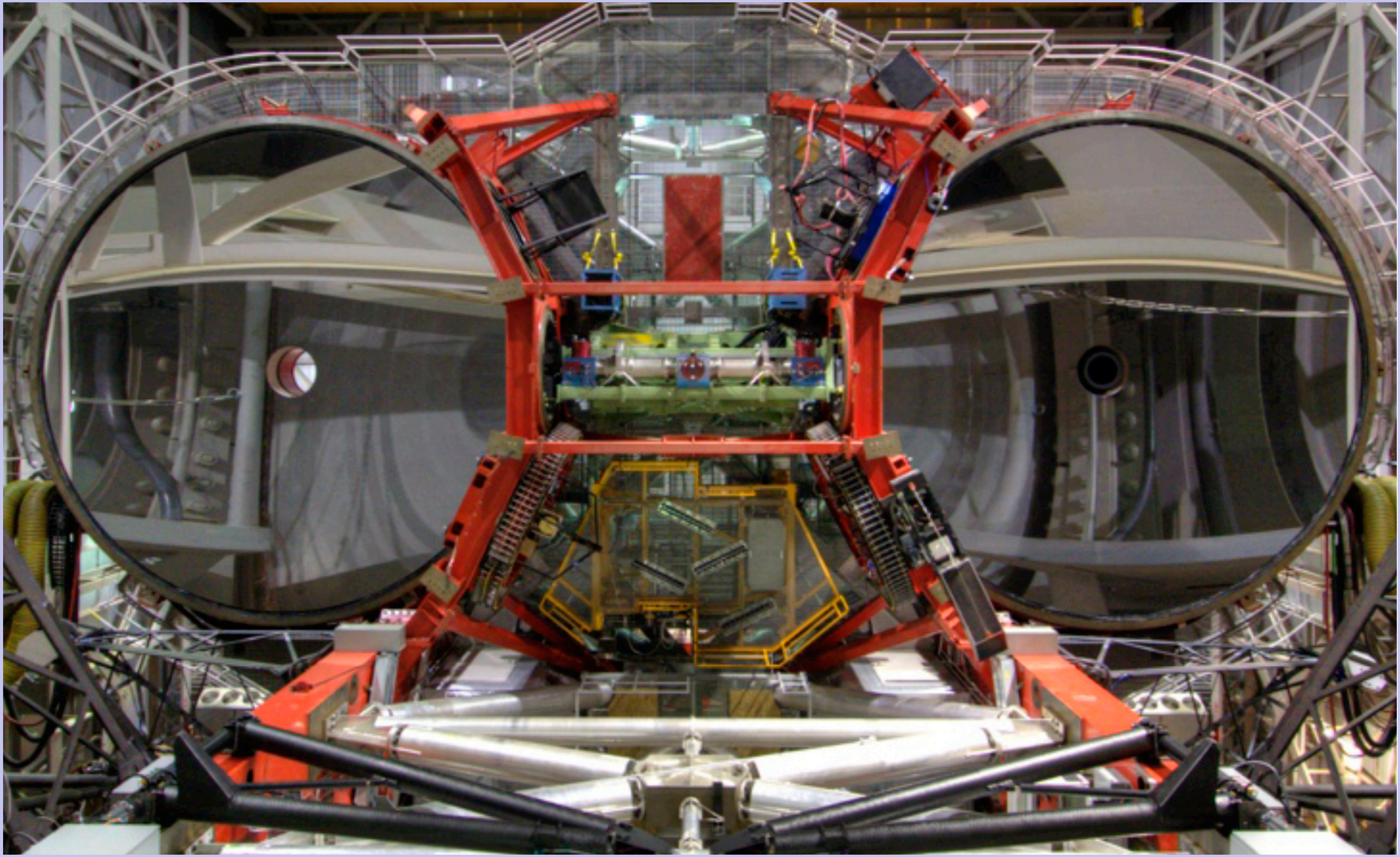
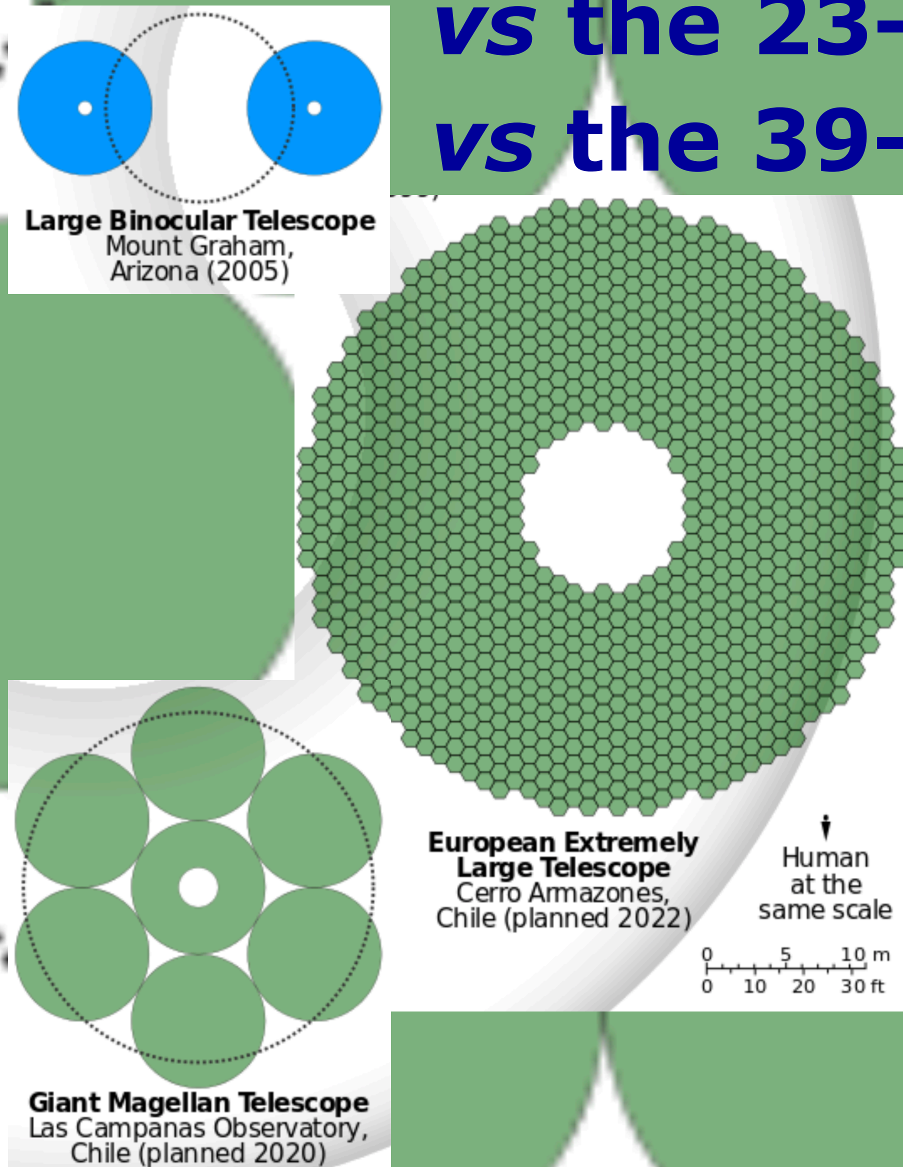
Observatoire de Paris Meudon, **LESIA**

OCA, Nice
06/02/2018

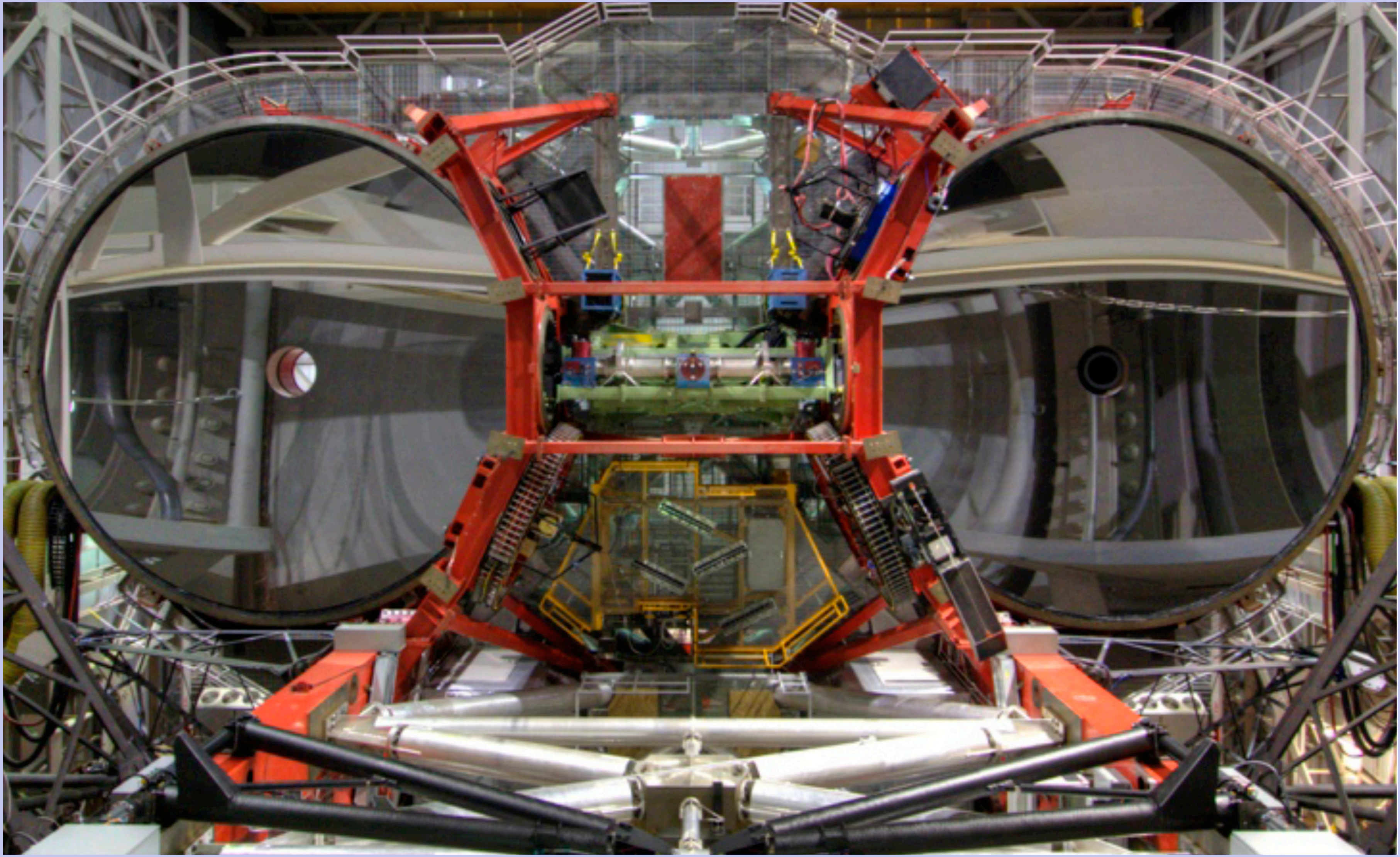
The 23-m binocular at LBT



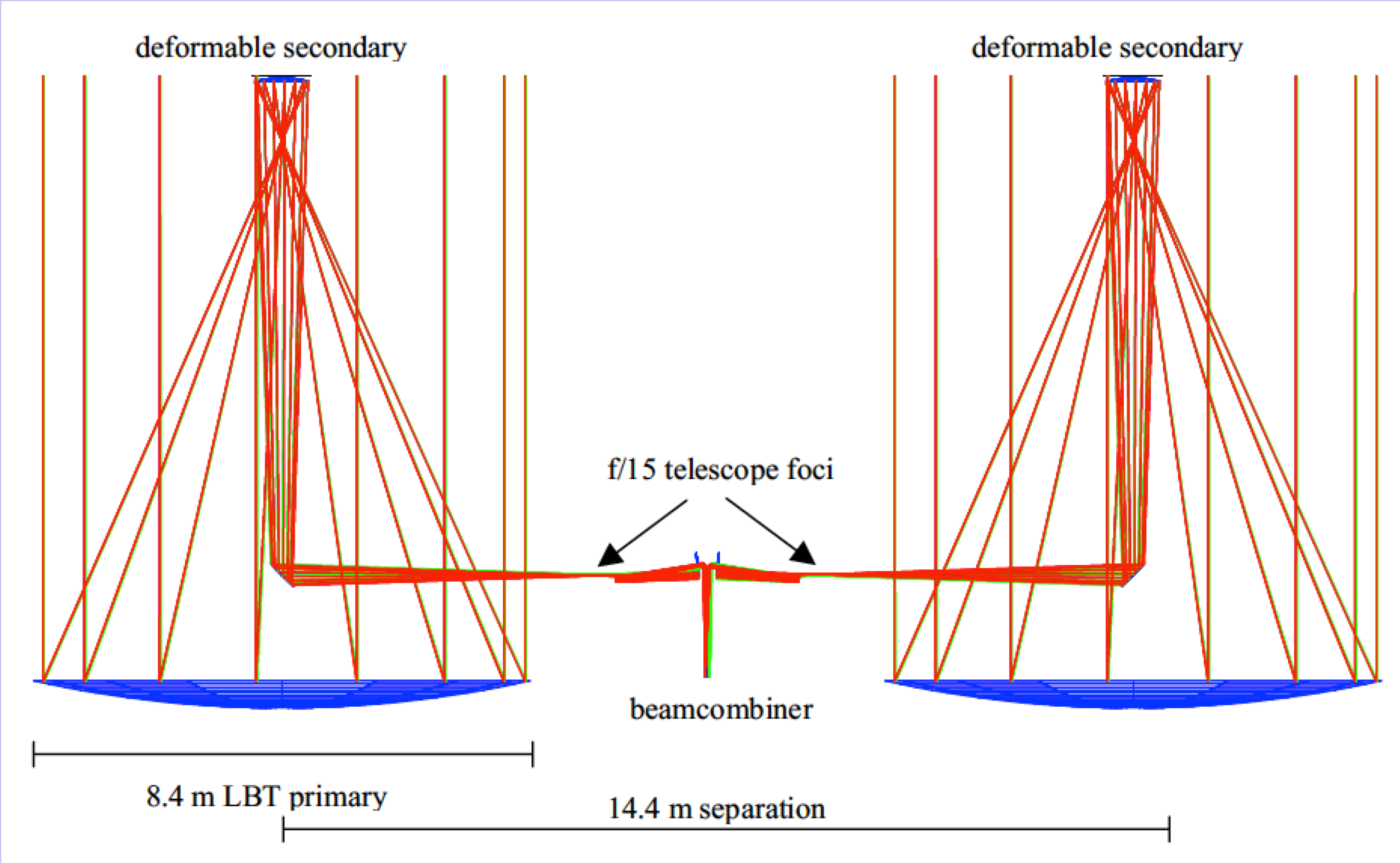
The 23-m binocular at LBT
vs the 23-m GMT
vs the 39-m E-ELT



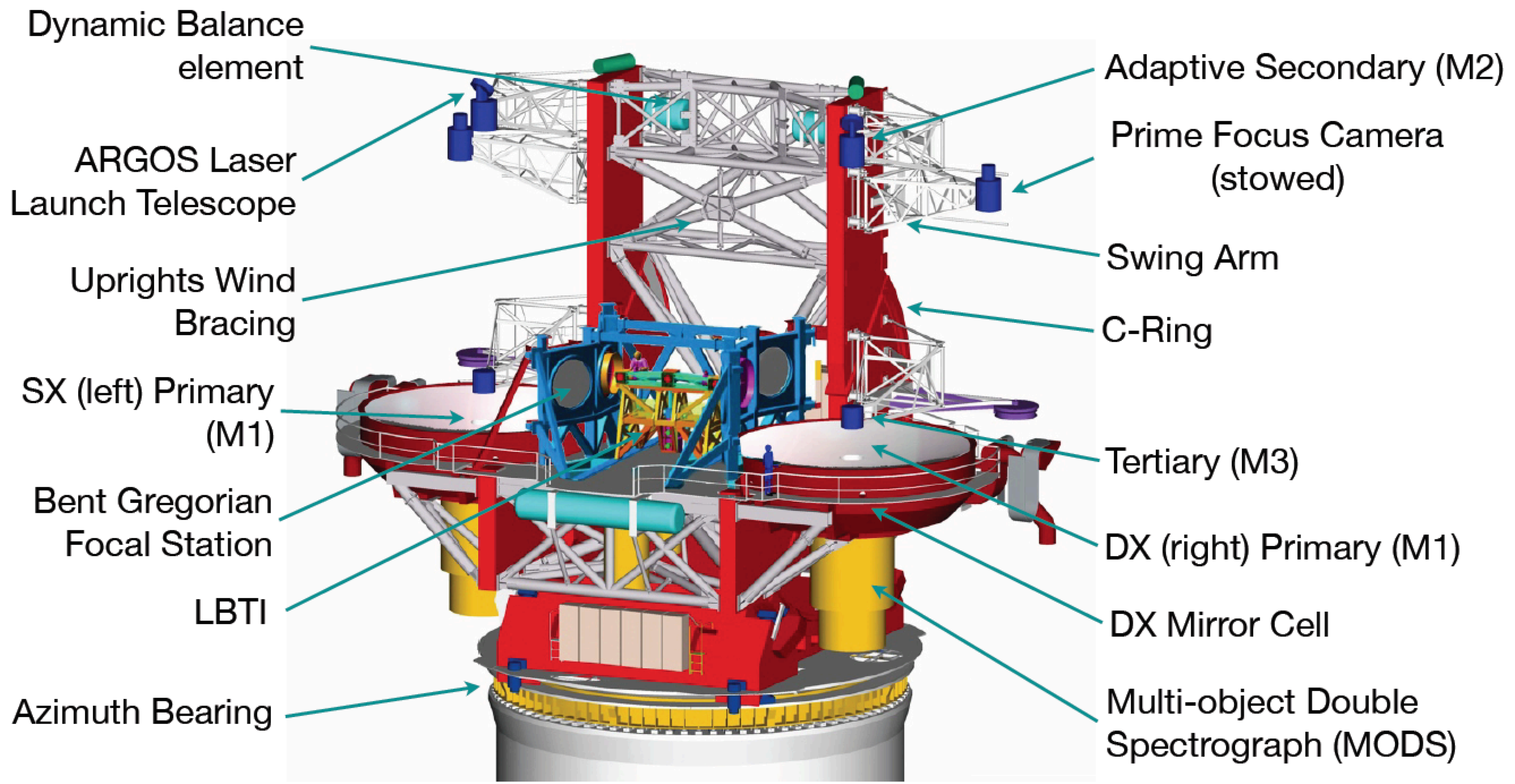
The 23-m binocular at LBT



Optical ray-tracing of the LBTI

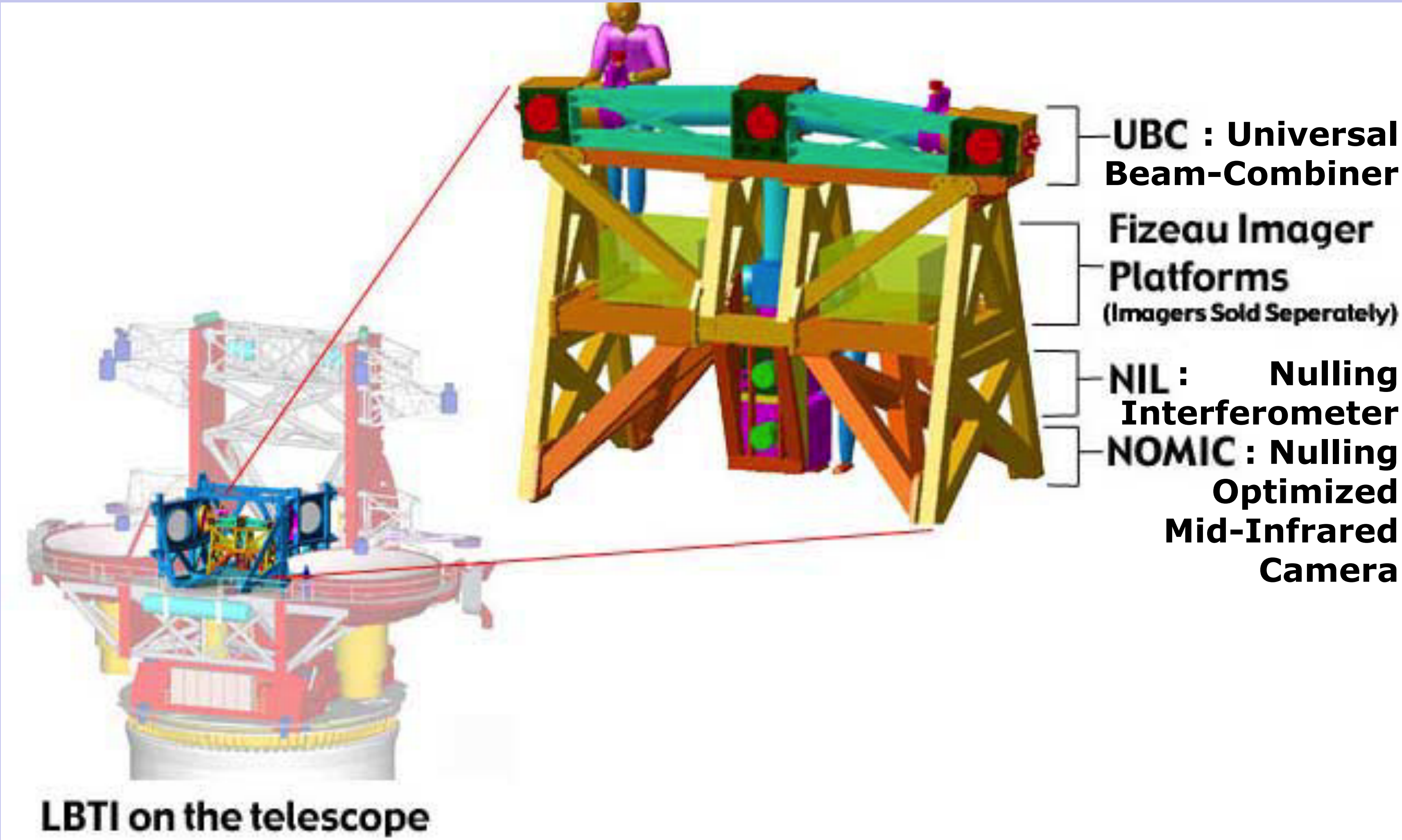


The LBTI telescope

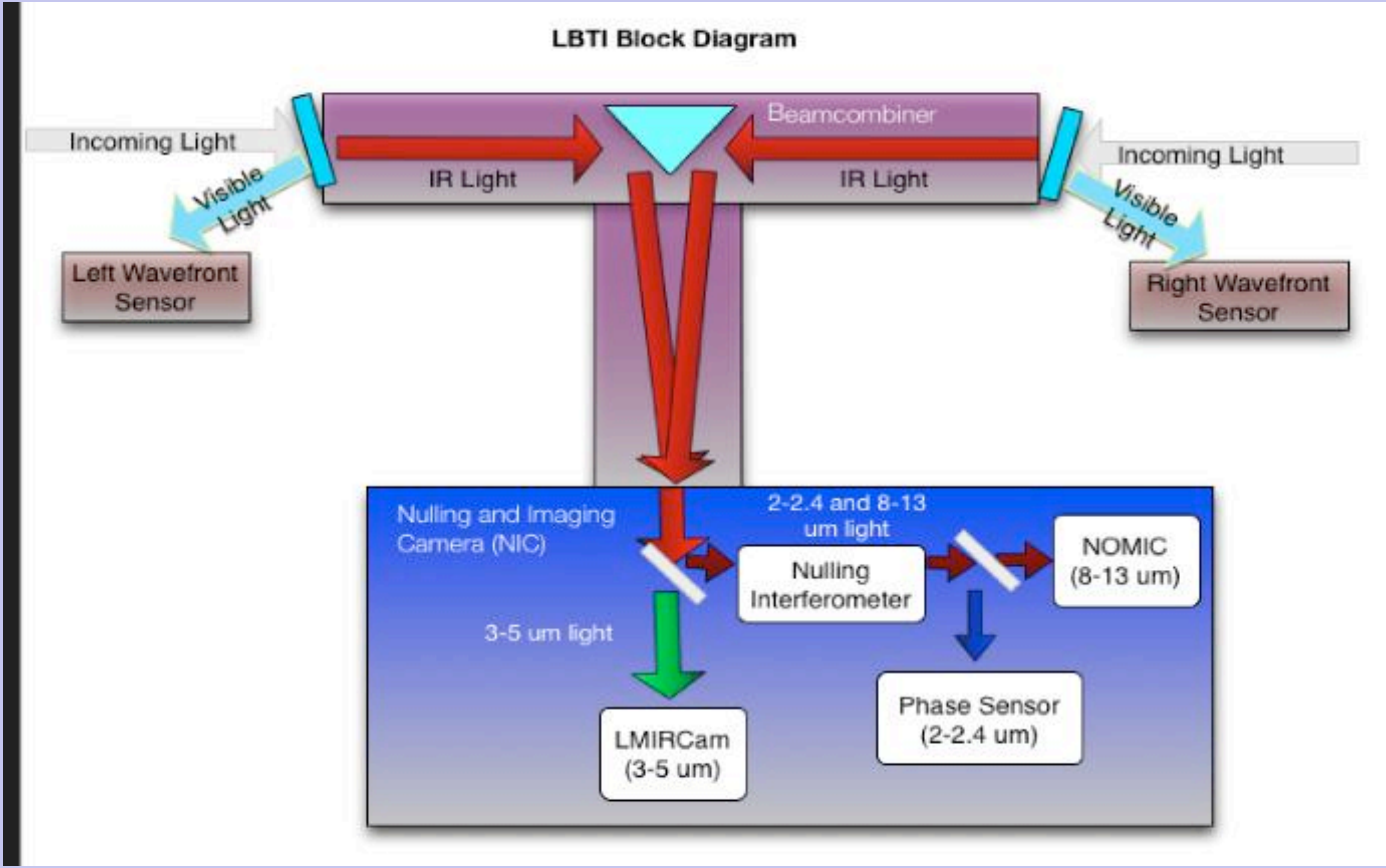


Rear View of LBT

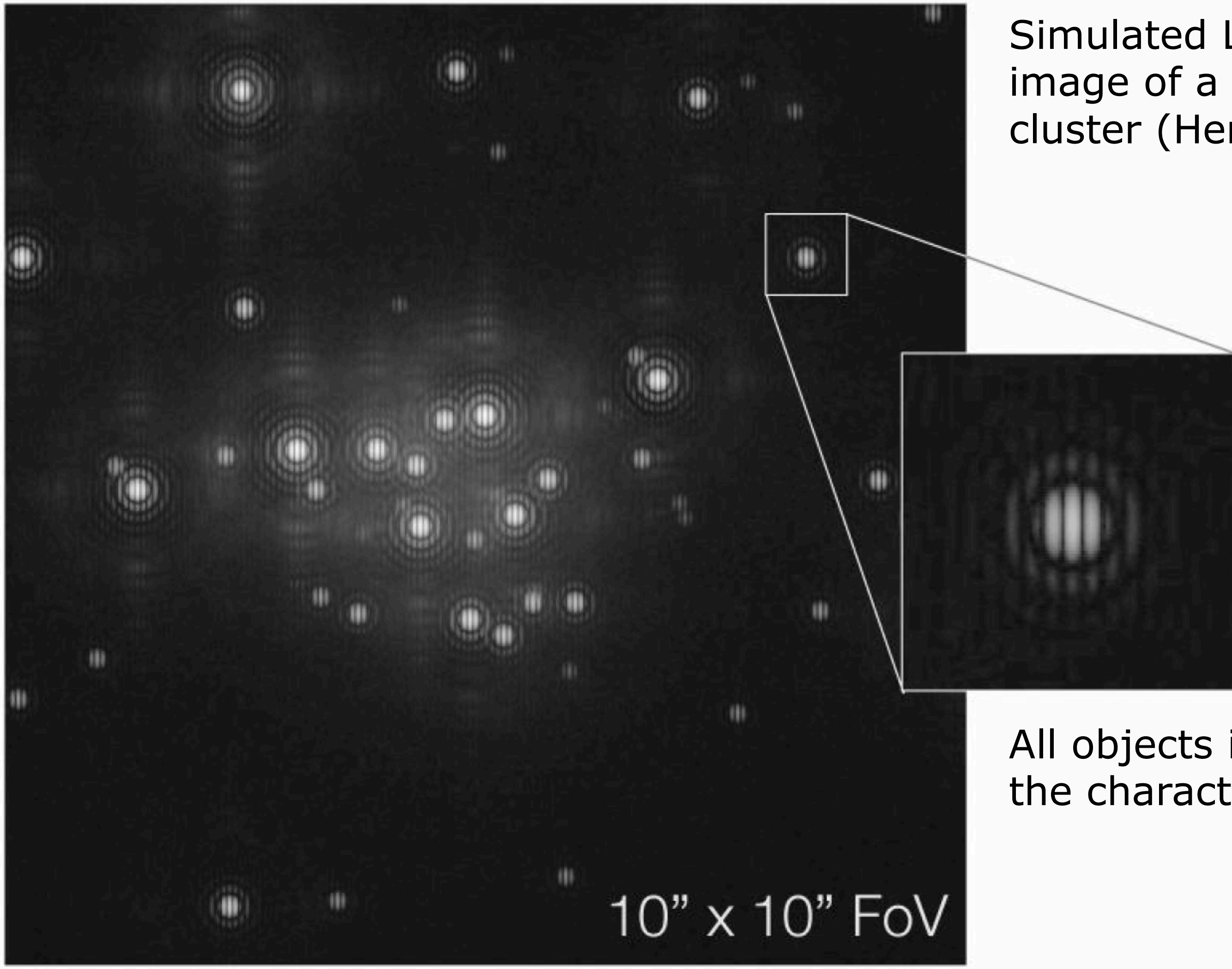
The LBTI beam combiner



The LBTI beam combiner



The LBTI focal image



Simulated LINC-NIRVANA image of a dense stellar cluster (Herbest & al. 2008).

All objects in the field show the characteristic PSF.

MNRAS paper I.

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The LBTI Fizeau imager – I. Fundamental gain in high-contrast imaging

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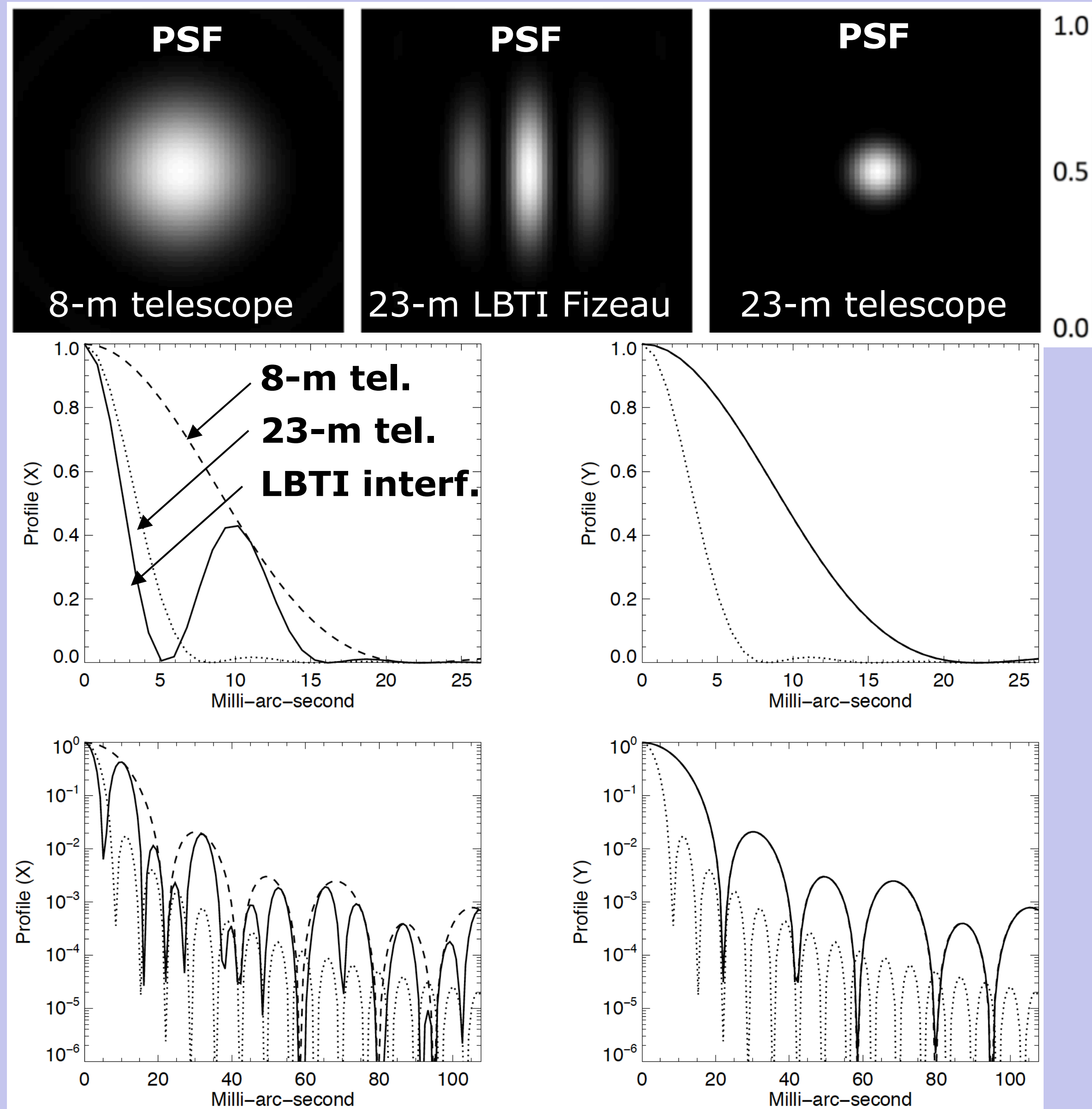
The theoretical PSF of the LBTI

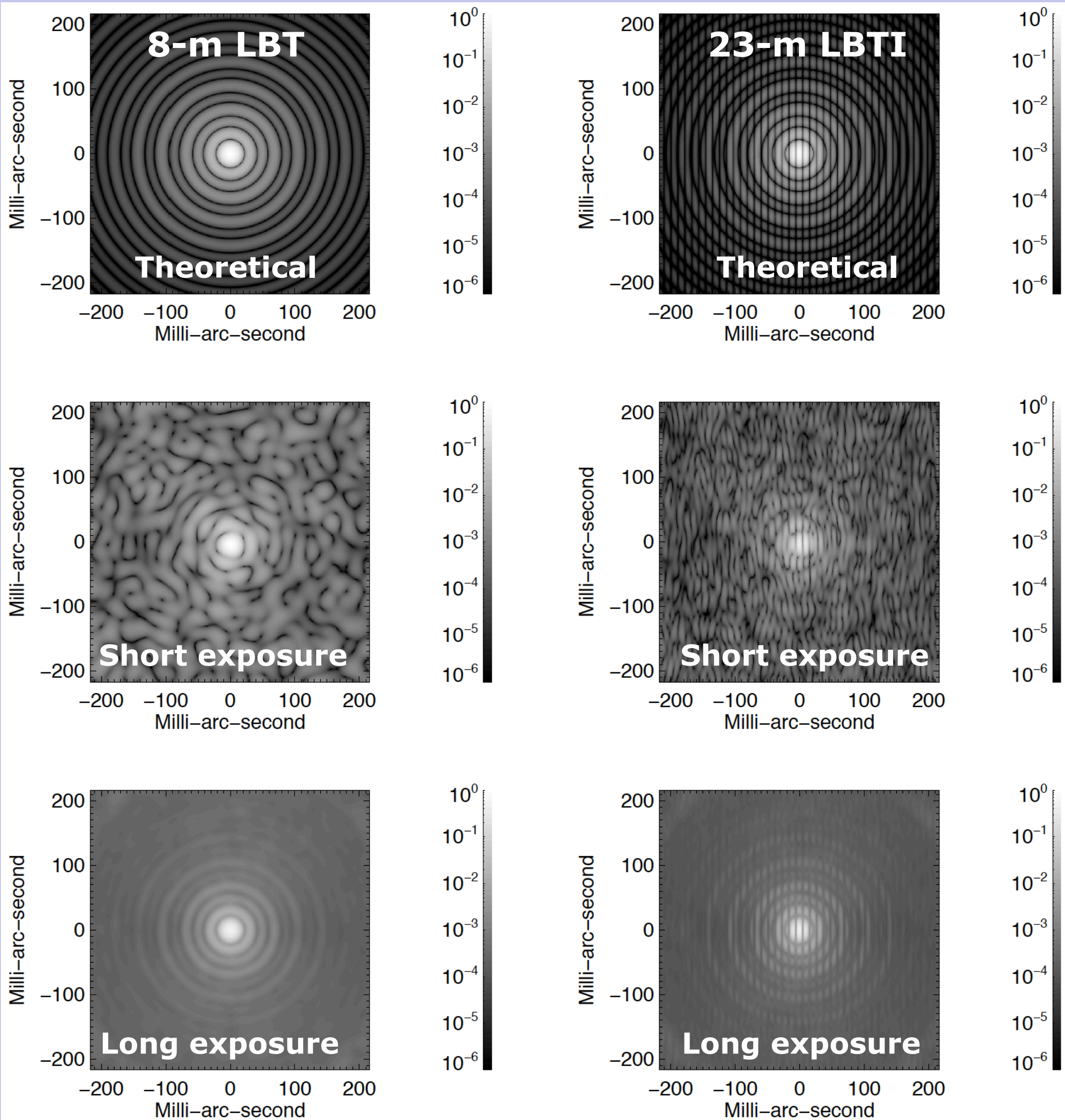
The PSF of the LBTI is made of :

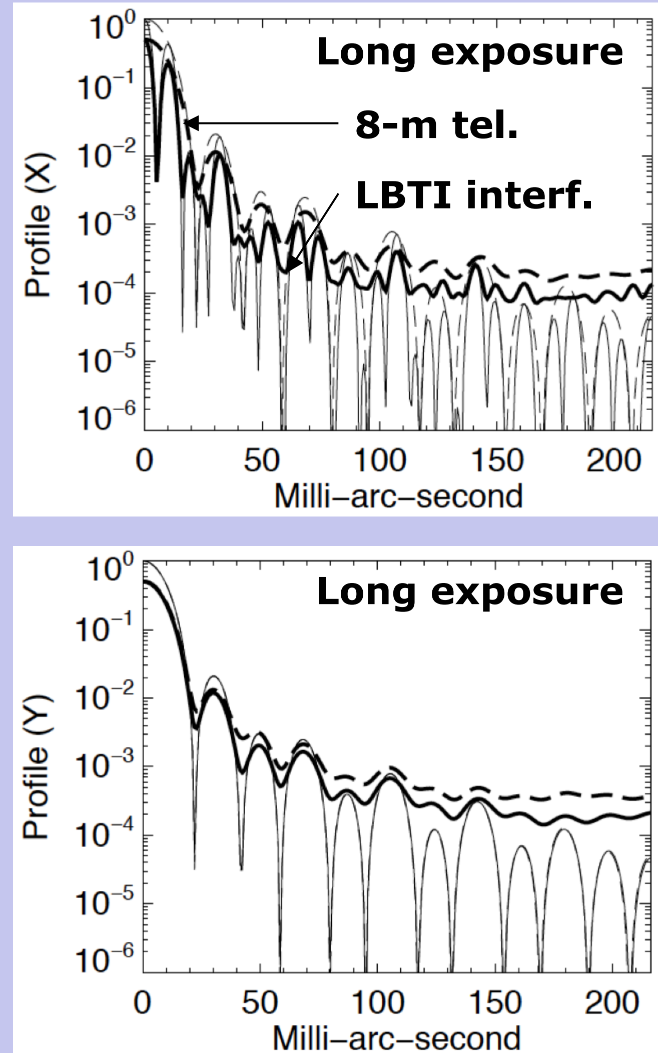
- **rings** (subaperture Airy pattern) &
- **fringes** (interference cosine pattern).

A huge contrast in narrow zones can be achieved when both a dark fringe and a dark ring overlap.

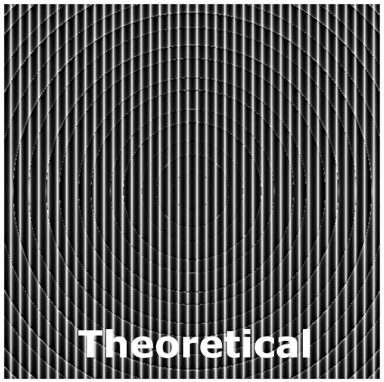


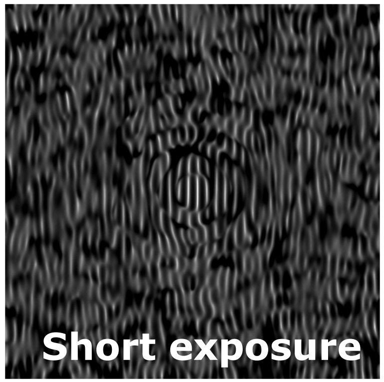
LBT *vs* LBTI point spread function

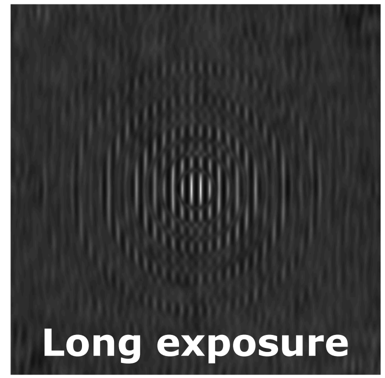


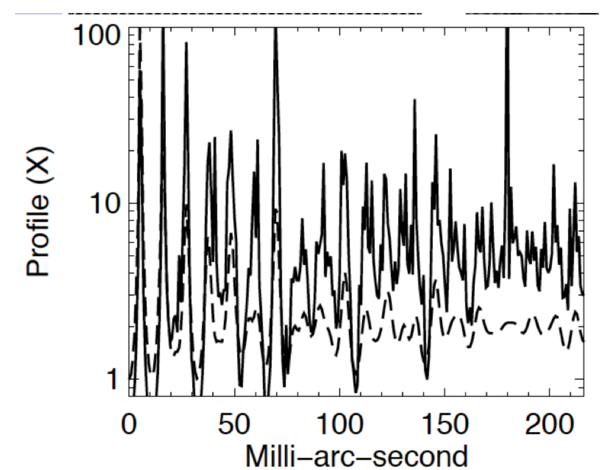


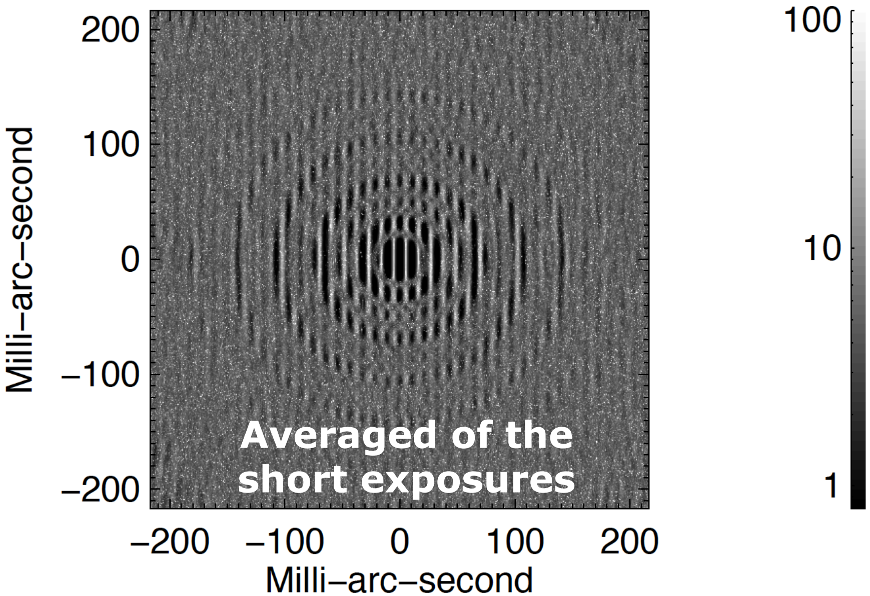
LBT/LBTI contrast gain map

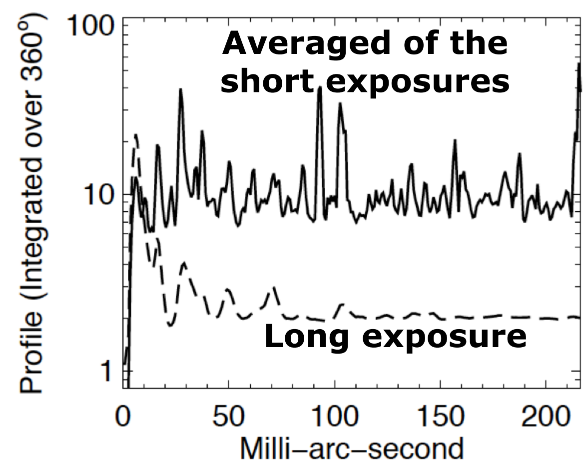






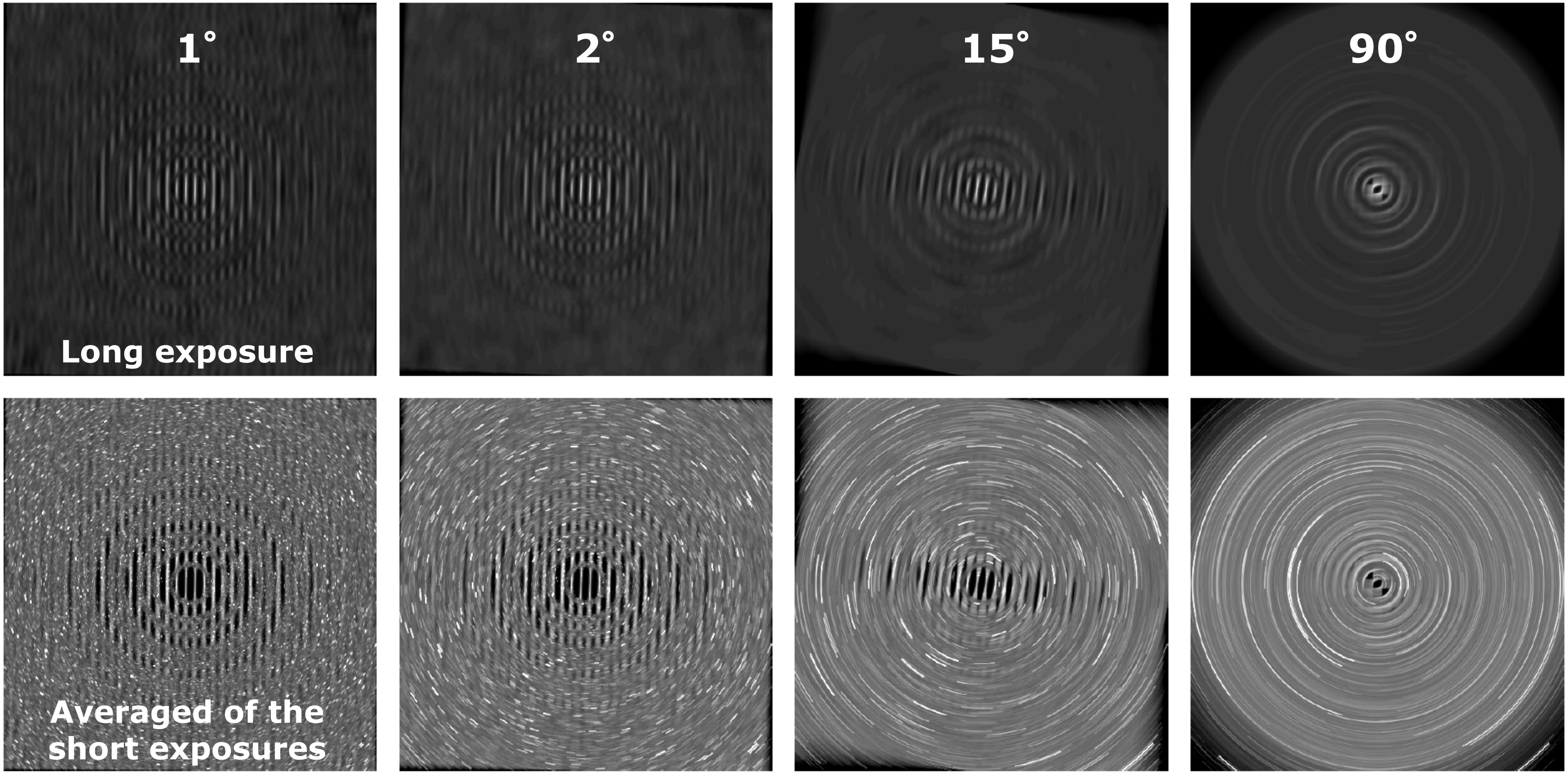






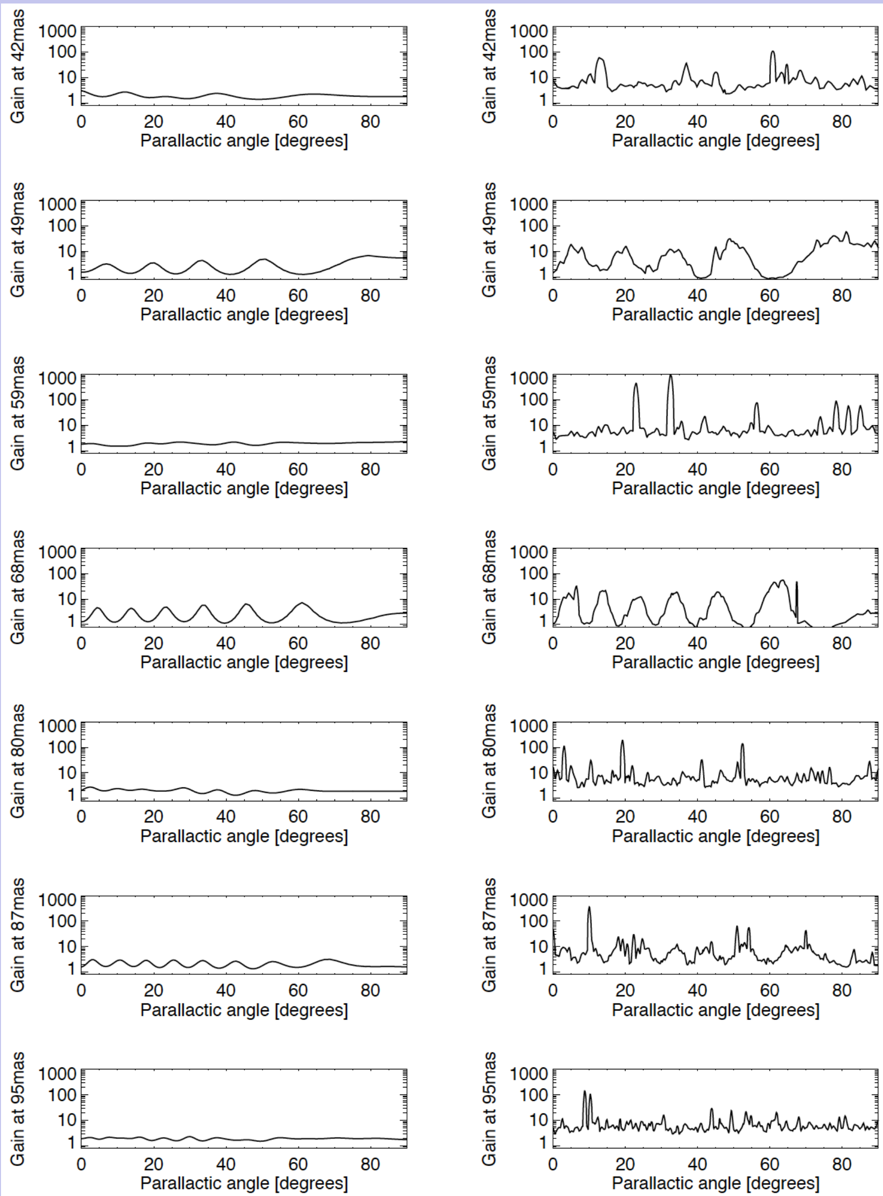
$$G(x, y) = \frac{\mathrm{PSF}_{\mathrm{LBT}} / \mathrm{PSF}^{\mathrm{Th.}}_{\mathrm{LBT}}(0, 0)}{\mathrm{PSF}_{\mathrm{LBTI}} / \mathrm{PSF}^{\mathrm{Th.}}_{\mathrm{LBTI}}(0, 0)} = 4 \cdot \frac{\mathrm{PSF}_{\mathrm{LBT}}}{\mathrm{PSF}_{\mathrm{LBTI}}}$$

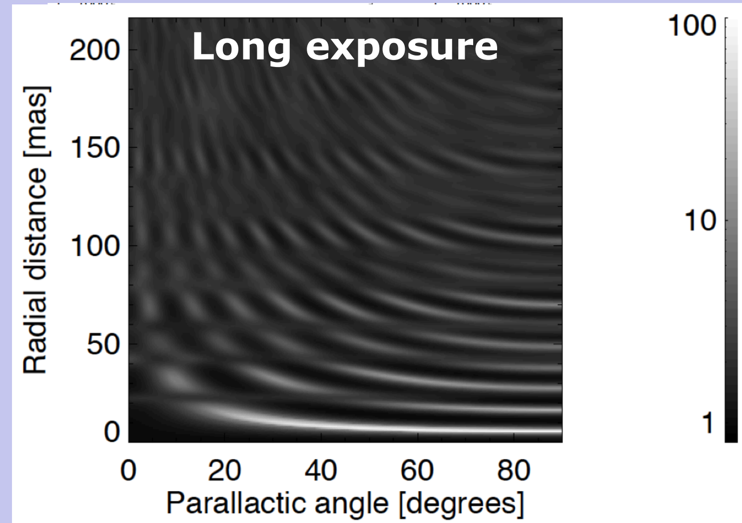
Contrast gain *vs* sky rotation

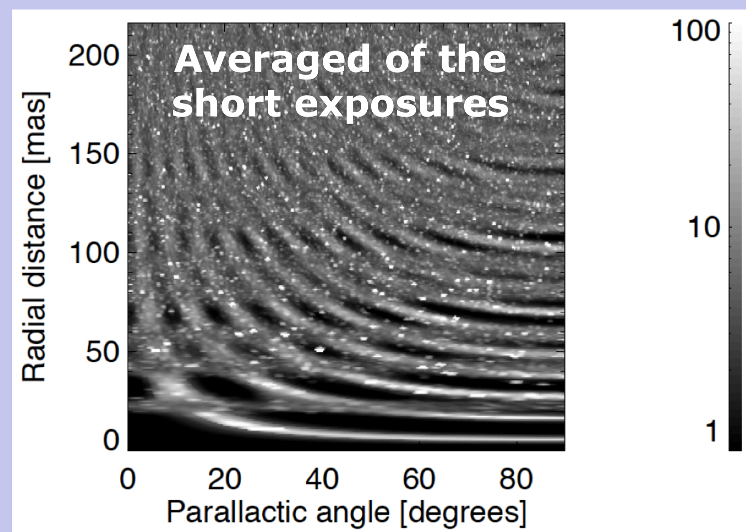


=> **ADI** Fizeau mode

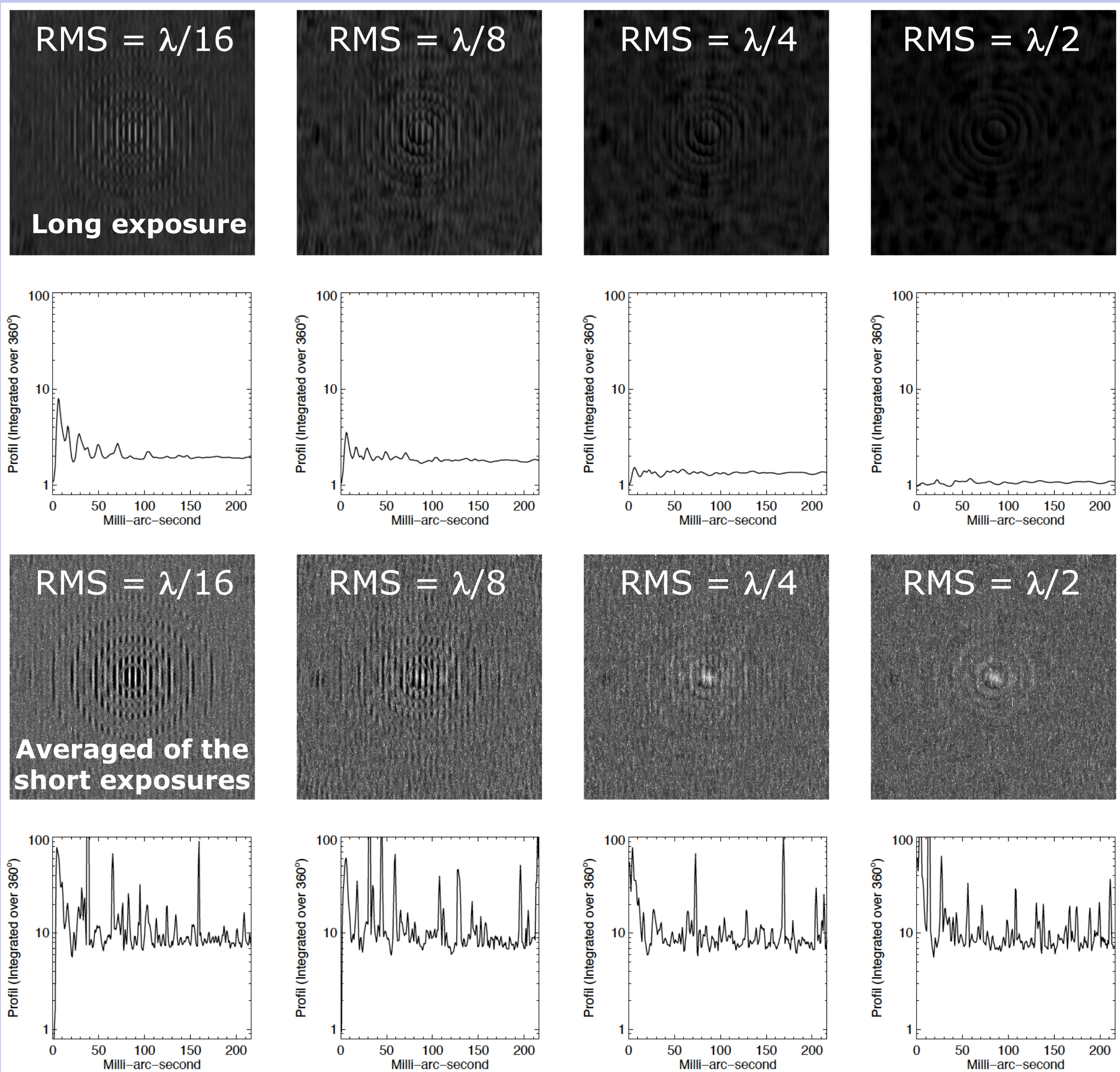
Contrast gain *vs* parallactic angle *vs* radial distance







Contrast gain *vs* piston errors



AO RMS = λ/8
(~100nm at 750nm)

Piston RMS
= λ/16, λ/8, λ/4, λ/2
(~50, 100, 200, 400 nm at 750nm)

The averaged contrast gain of ~10 over the AO FOV is **insensitive to piston errors in short exposures**

MNRAS paper II.

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The LBTI Fizeau imager – II. Sensitivity of the PSF and the MTF to adaptive optics errors and to piston errors

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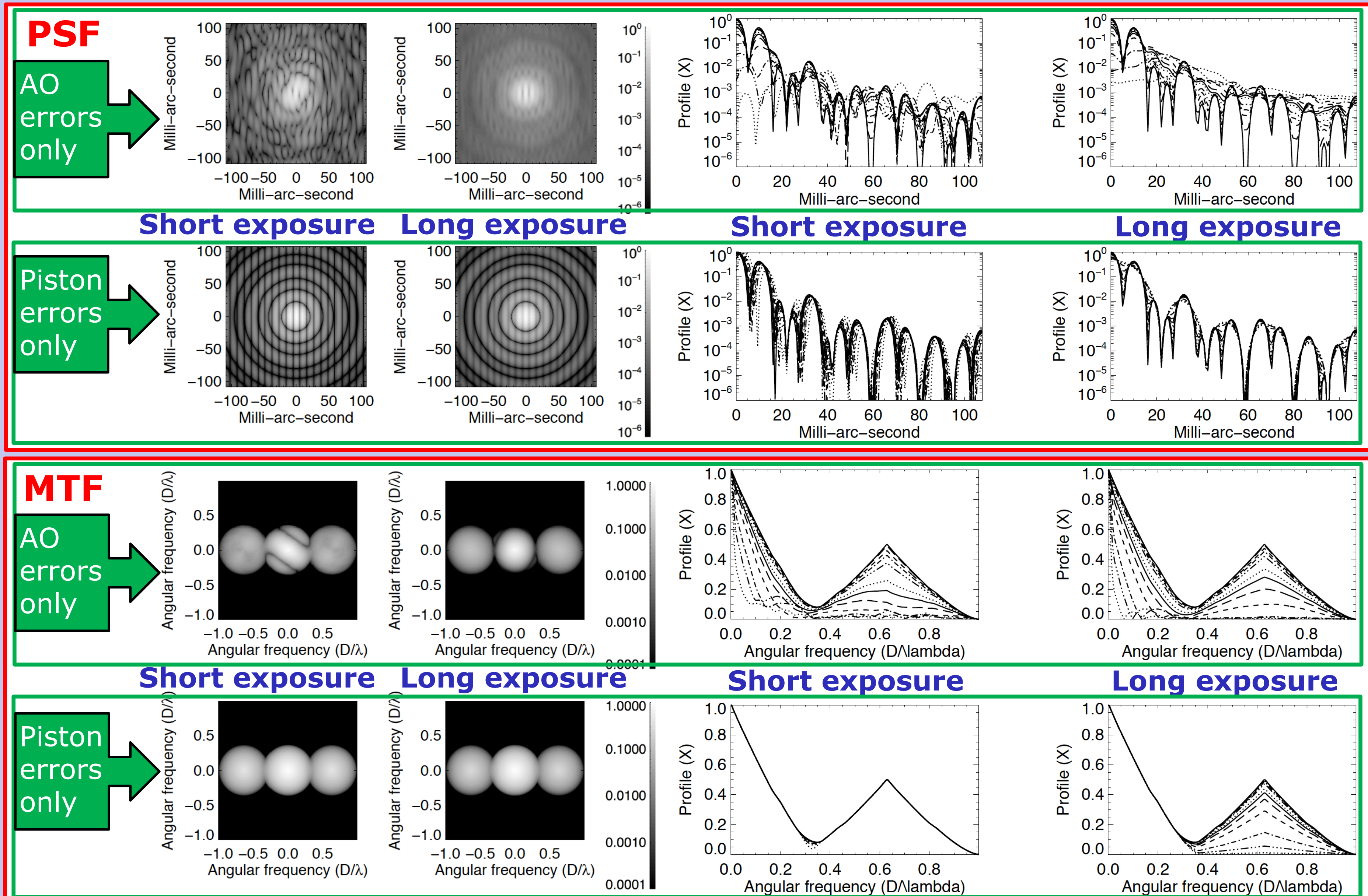
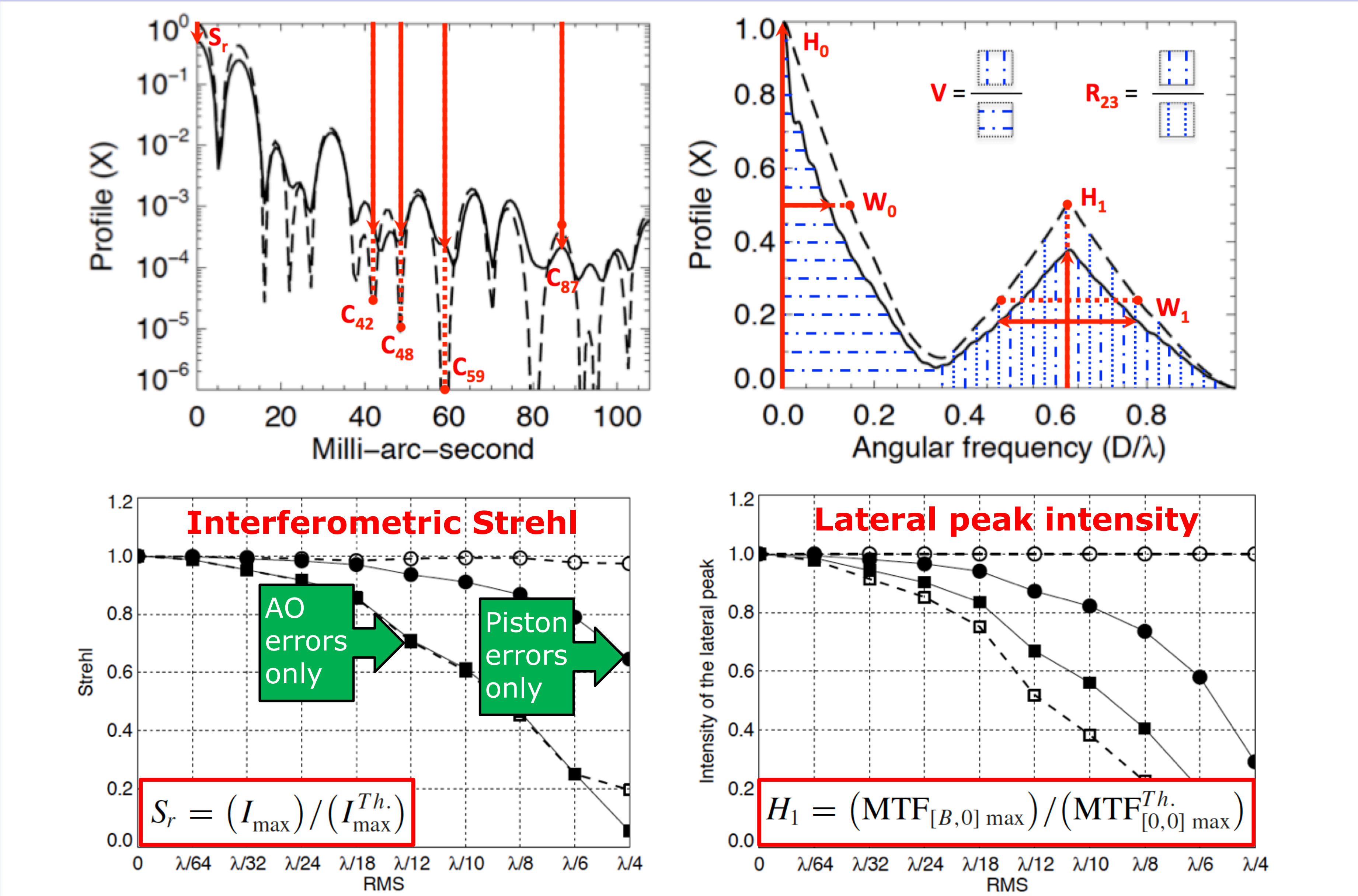
LBTI PSF & MTF *vs* AO & piston errors



LBTI PSF & MTF merit functions



The LBTI Fizeau imager : In brief

- **Fundamental gain in high-contrast imaging**
  - Global gain by a factor of **2 in long exposures** & of **10 in short exposures**
    - ***One-directional*** interferometric sampling,
    - ***Independent correction*** of AO & piston errors,
    - LBTI Fizeau imager *vs* ***speckle interferometry*** (Labeyrie 1970) using AO.
  - Compared to a single 8-m aperture, the 23-m LBTI Fizeau imager provides:
    - a gain in **sensitivity** (by a factor of 4),
    - a gain in **angular resolution** (by a factor of 3),
    - a gain in raw **contrast** (by a factor of 2–1000 varying over the AO FOV).

- **Low sensitivity of the PSF & MTF against AO & piston errors**
  - A Fizeau image of high-quality (Strehl > 70%) requires both at a time:
    - an **AO correction** better than **≈λ/18 RMS** for short & long exposures,
    - a **piston correction** better than **≈λ/8 RMS** for long exposures or simply below the coherence length for short exposures.
  - Limitations for high-contrast imaging: broadband, ***vibrations***, …
  - Right now feasible in the **near-infrared** (technical proposal on ***LMIRCam*** ?)

Thank you for your attention