

# NICI – The new Gemini South AO facility coronagraph

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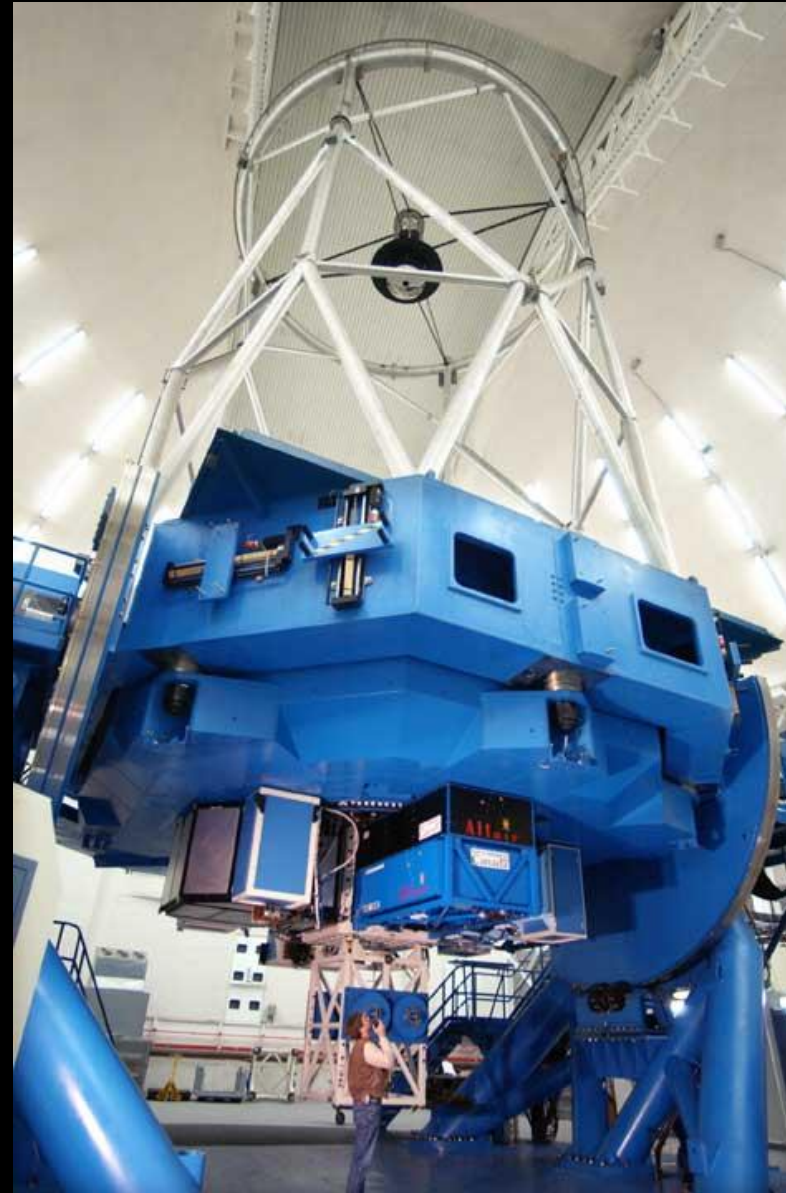
Background image courtesy: K. Davidson



# Gemini: A specialized telescope



- Gemini international community
- Optimized for:
  - Thermal IR
  - High angular resolution
- Optimization choices:
  - silver coating
    - low emissivity (2.5% M1+M2)
  - F/16 narrow field
  - Thin spiders
    - low diffraction
  - LLT space planed behind M2
- Cass: 3 instr.+Cal unit + AO system
- 90% Queue



Slide courtesy F. Rigaut

Kyoto, May 2009

NICI – the GS AO facility coronagraph

# NICI Overview

[www.gemini.edu](http://www.gemini.edu), see NICI

## NICI:

### AO System + Lyot Coronagraph + Dual-channel Near-IR Camera

- Optimized for high-contrast imaging  
(no lenses, minimal static aberrations, differential imaging)

#### AO System: 85-element curvature system

- natural guide stars
- H-band Strehl ratio between 0.2 ( $V \sim 13$ ) to  $\sim 0.4$  (bright stars)

#### Science Camera: Dual-channel InSb (1-5 $\mu\text{m}$ , only 1 – 2.5 offered)

Focal-plane and pupil masks

Beamsplitting elements, filters in each channel.

# NICI Overview

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## Observing Modes

### Angular Differential Imaging (ADI): Ideal PSF subtraction

- Cass Rotator fixed, static pupil □ stable speckle pattern

### Spectral Differential Imaging (SDI)

- Simultaneous dual-wavelength imaging
- contrast gain for targets with CH<sub>4</sub> absorption ( $T_{\text{eff}} < 1300 \text{ K}$ )

NICI combines both techniques (ASDI)

## Meanwhile 1 semester experience

- Planet-finding campaign (M. Liu et al.)
- Special DD programs on bright targets

## NICI for 2009B

- 17 proposals for a total of 257 hours for 2009B.  
Given oversubscription rates, up to 130 hours of awarded PI NICI time for 2009B
- 120 hour commitment for NICI Campaign
- Mostly used as summer instrument (good weather and seeing conditions)

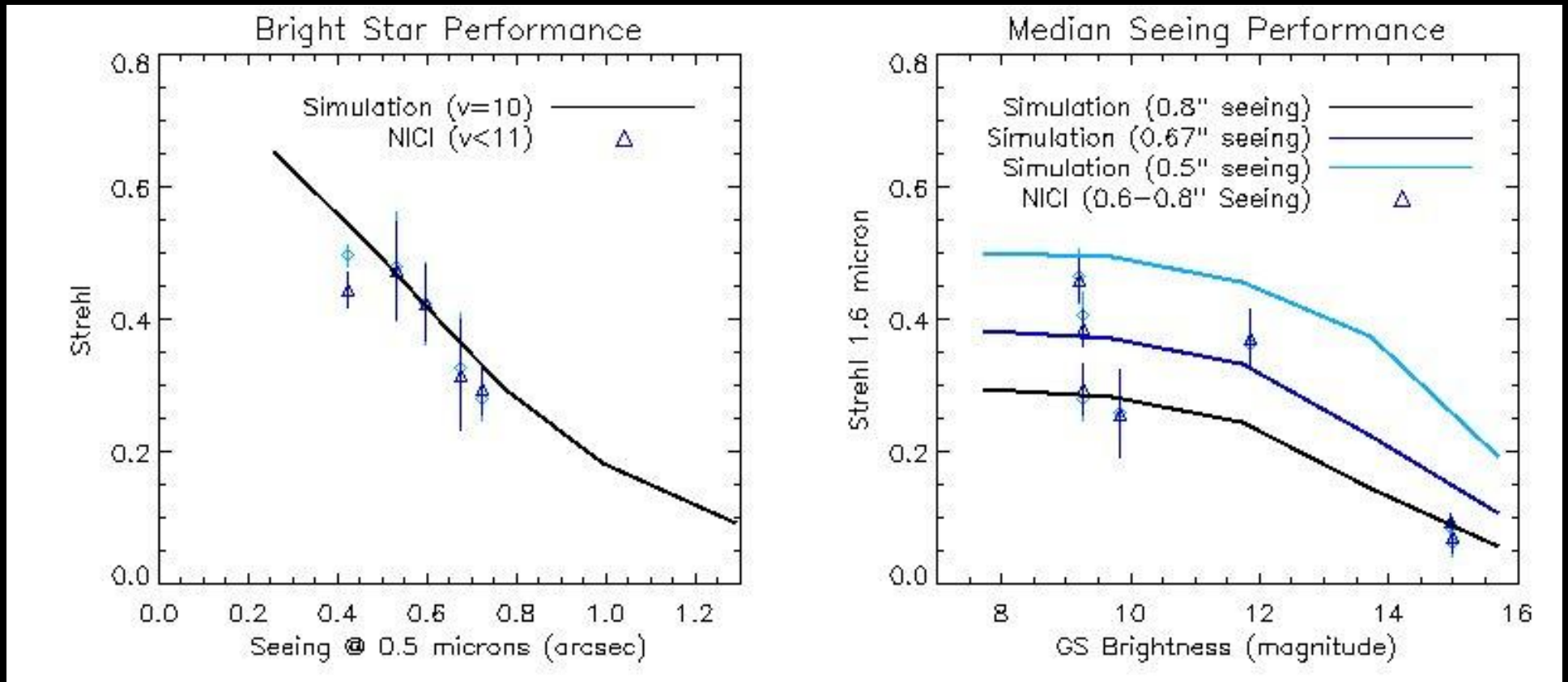
NICI Campaign: ~190 observed already, close to 40% of full awarded Campaign time (500 h)

Something to touch (from Chris Ftaclas' laboratory, Univ. Hawaii)

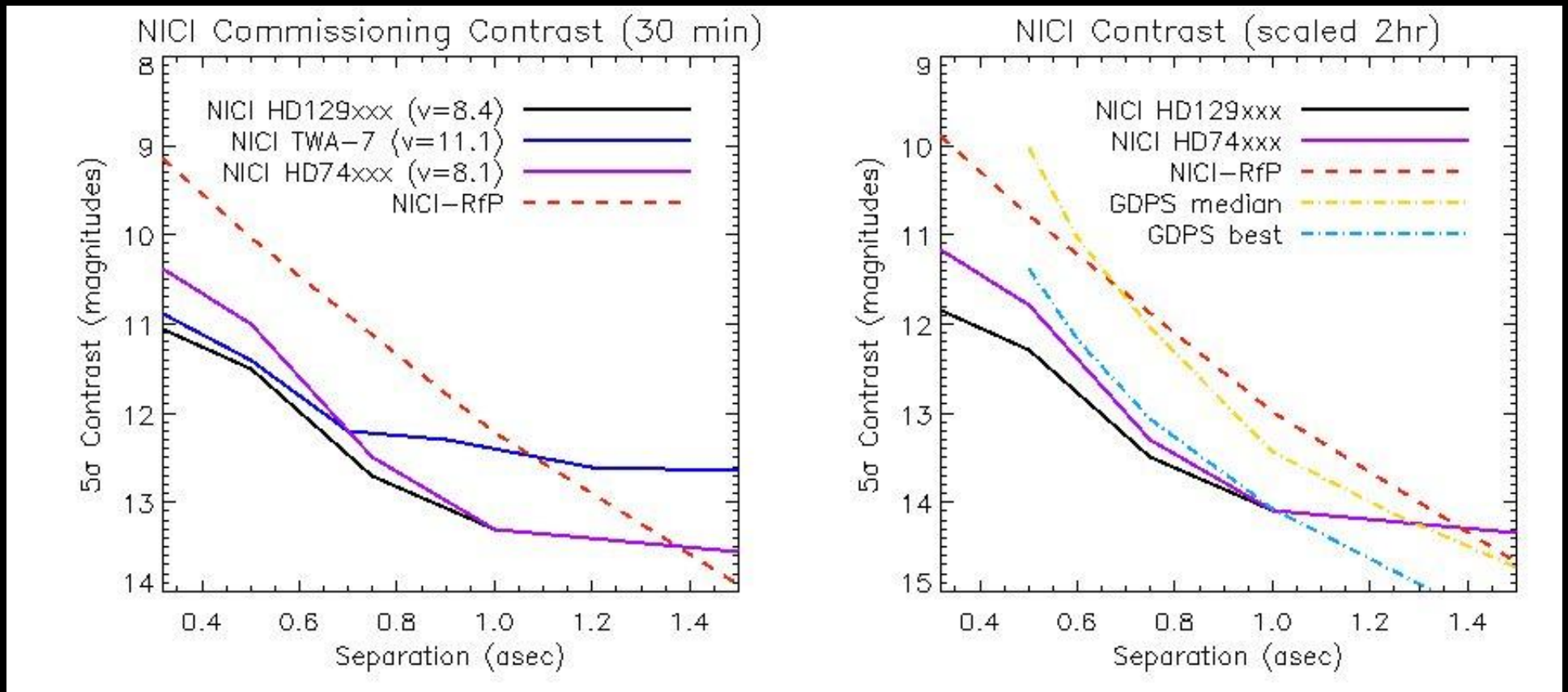
- DM (bimorph), Hokupa'a 85 electrode pattern, as in NICI now
- ground between the plates
- curvature AO system: circular arrangement
- front electrode (to apply a strong focus)
- ~ 15 m radius (or ~30 fringes or stroke of 20 to 30 microns)



corresponding lenslet array

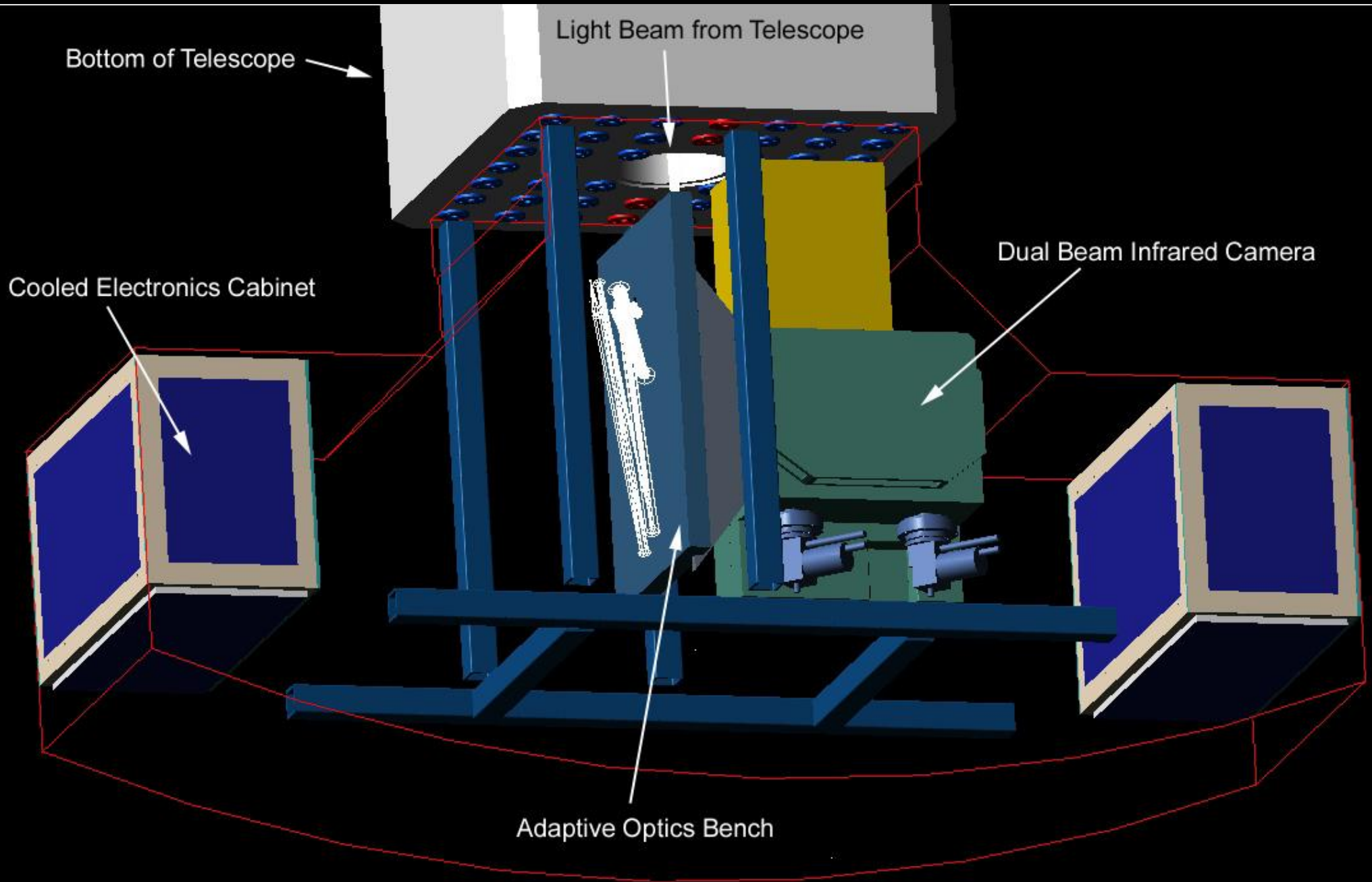


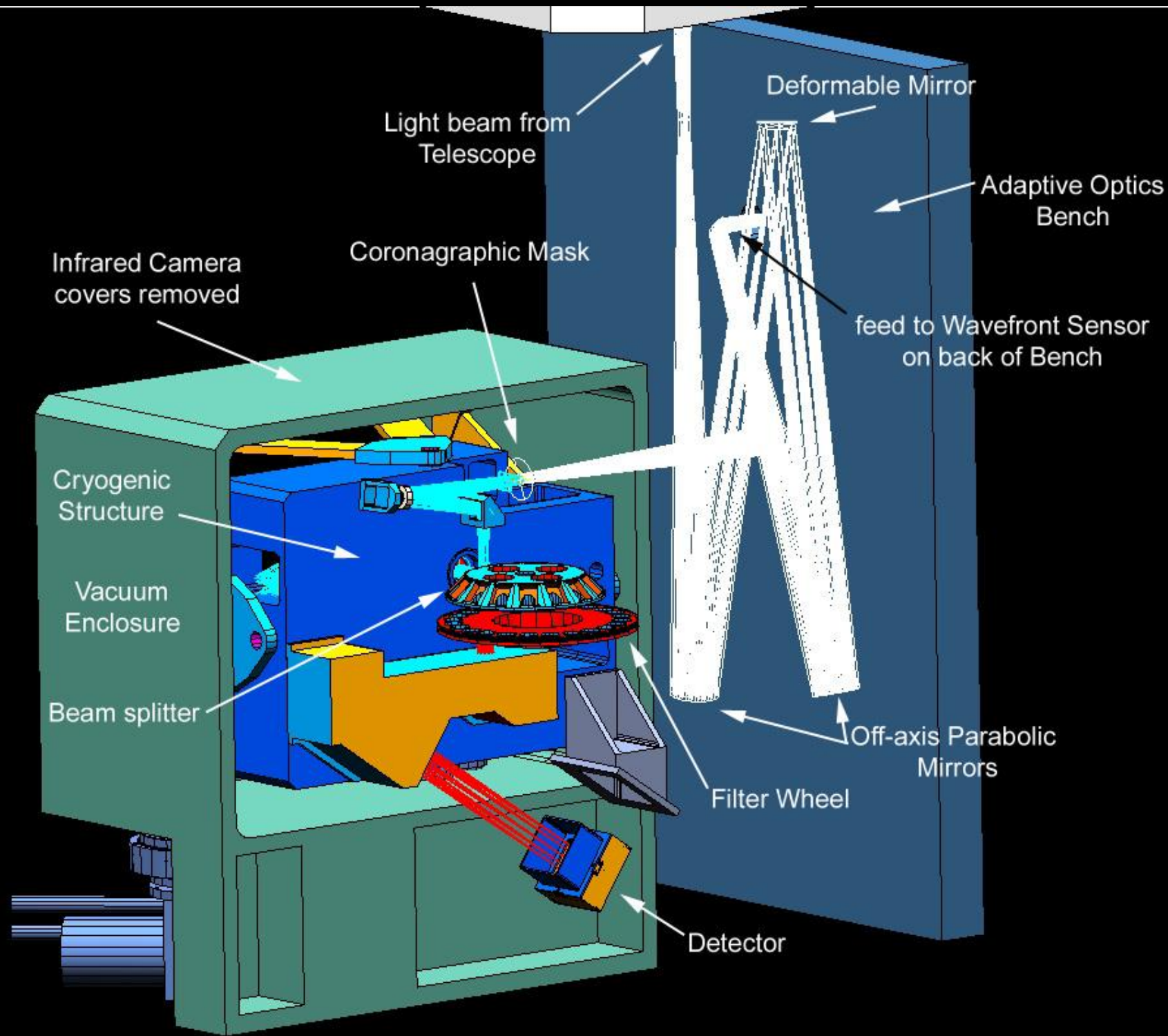
<http://www.gemini.edu/sciops/instruments/nici/itc-sensitivity-and-overheads>

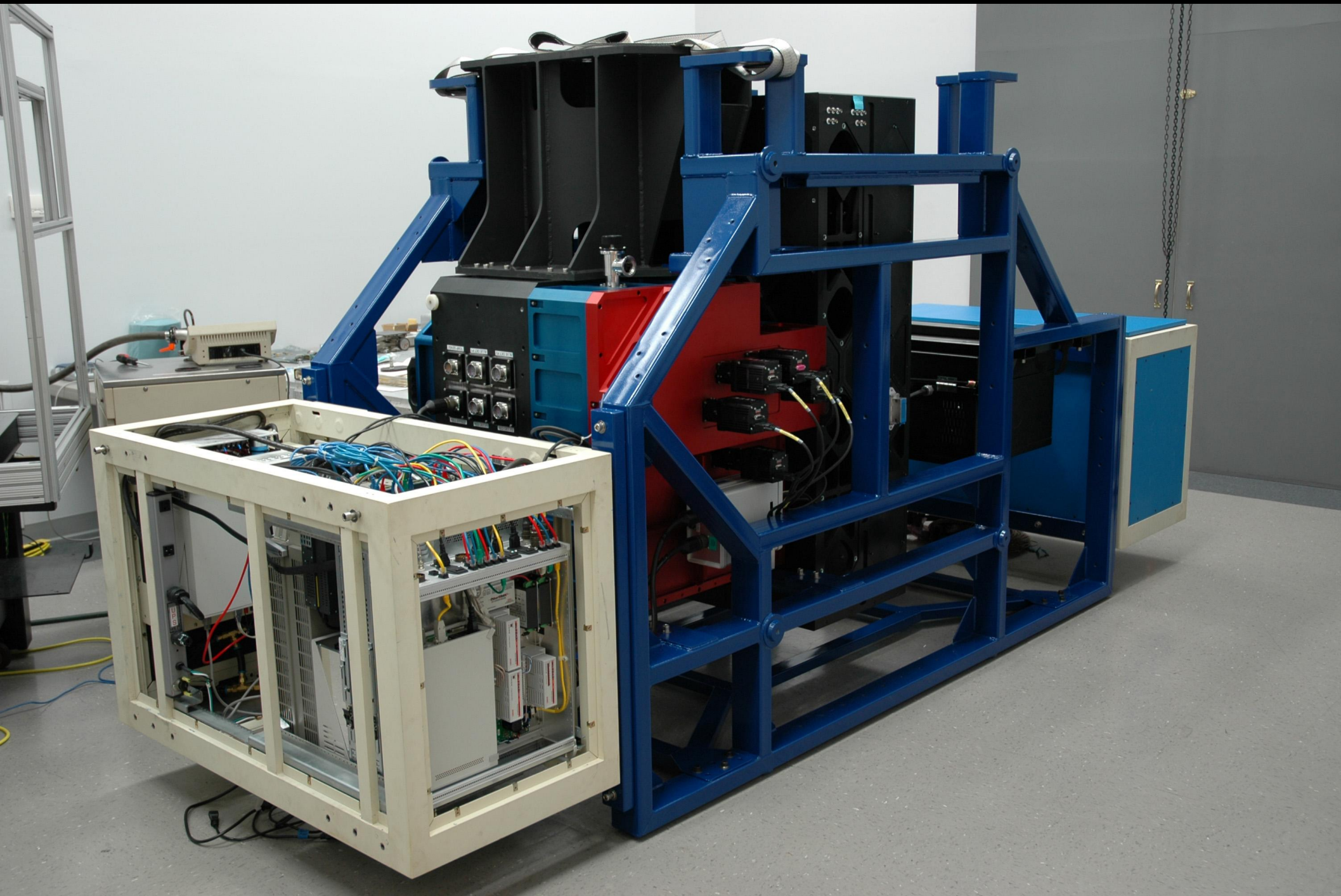


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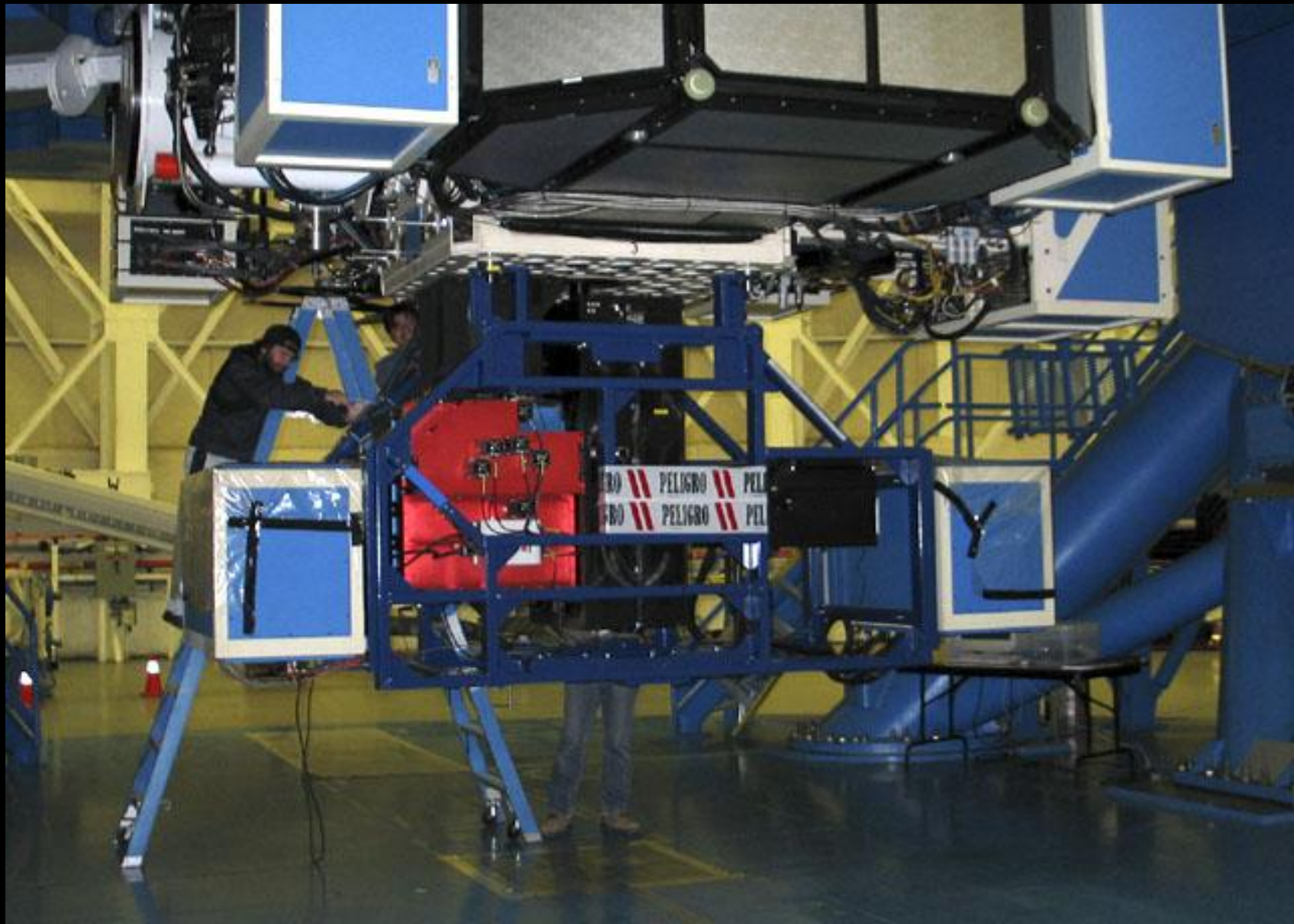








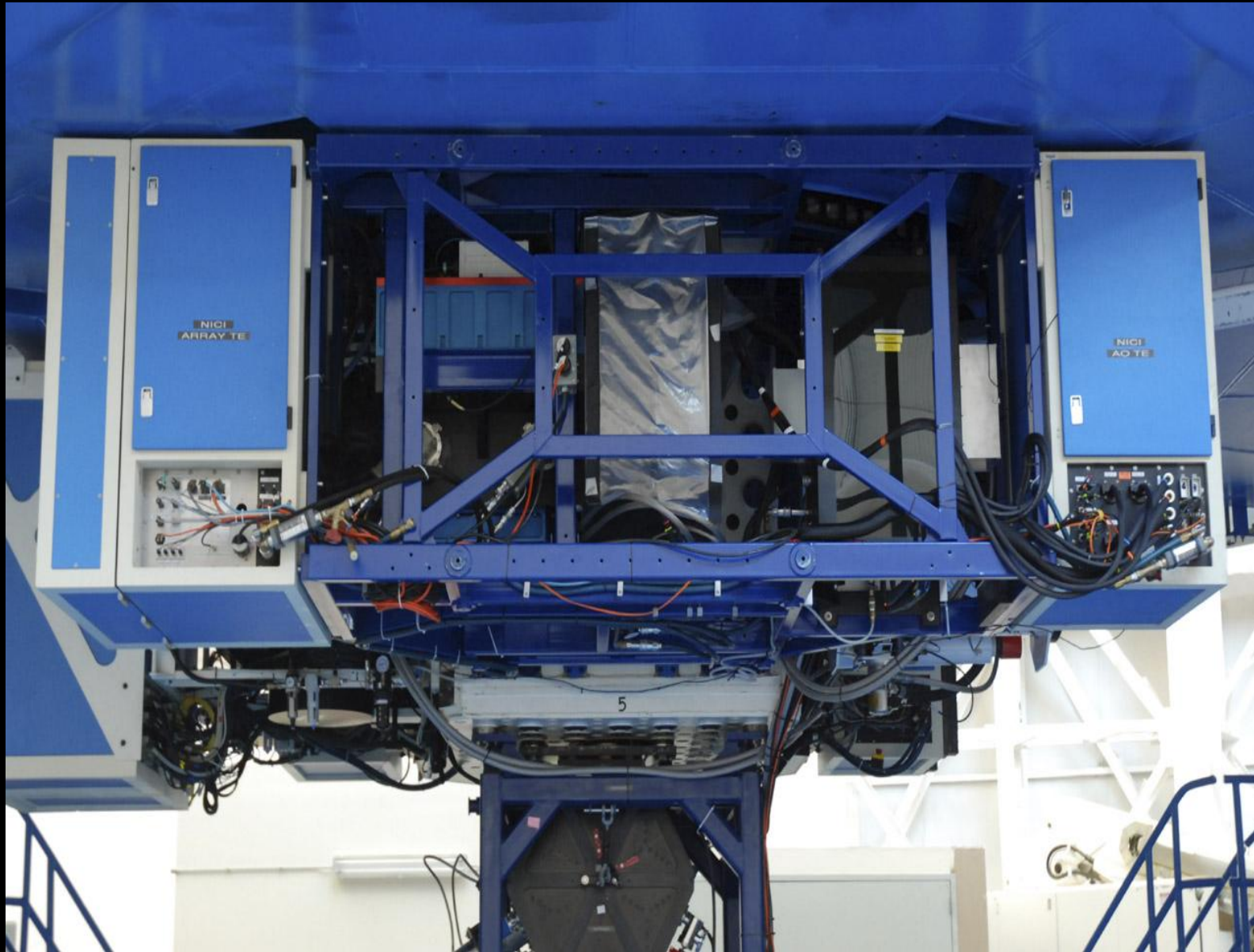
# Bottom port



Kyoto, May 2009

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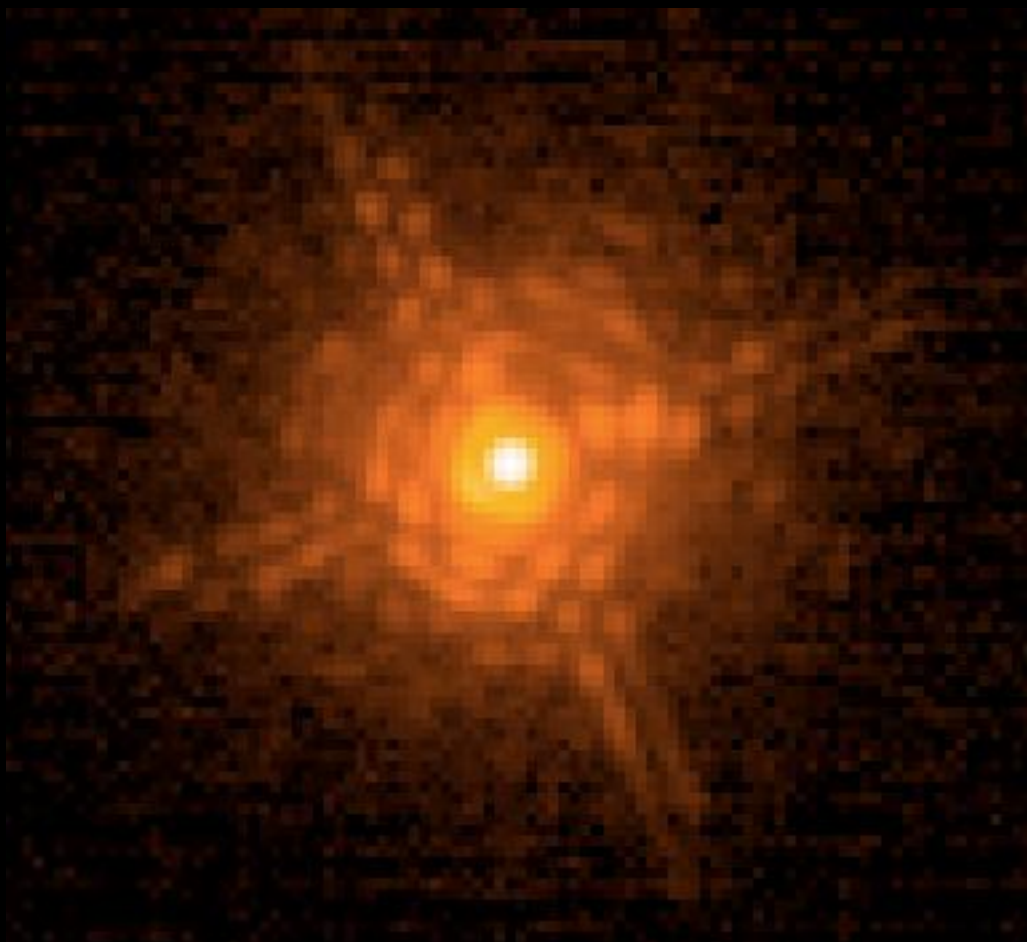
# Side port



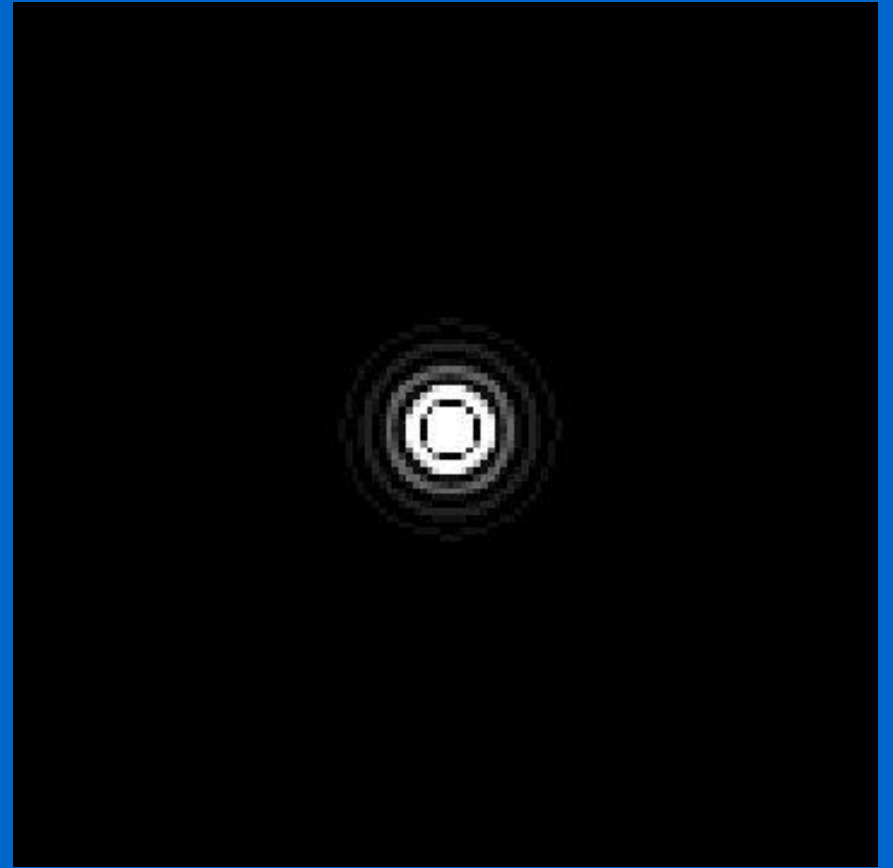
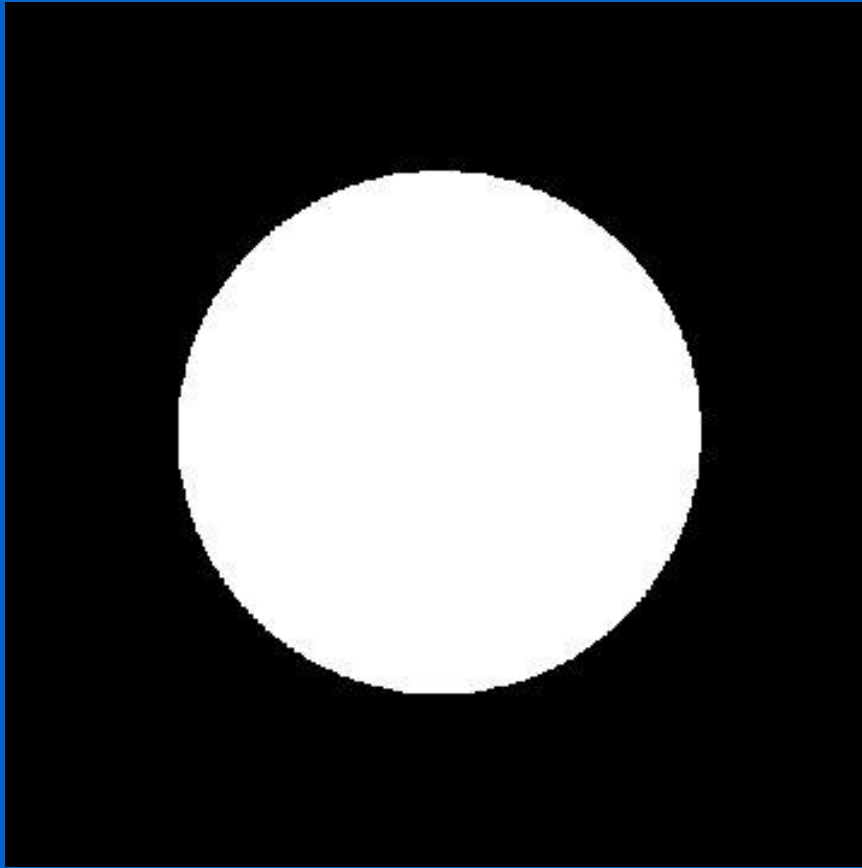
Kyoto, May 2009

NICI – the GS AO facility coronagraph

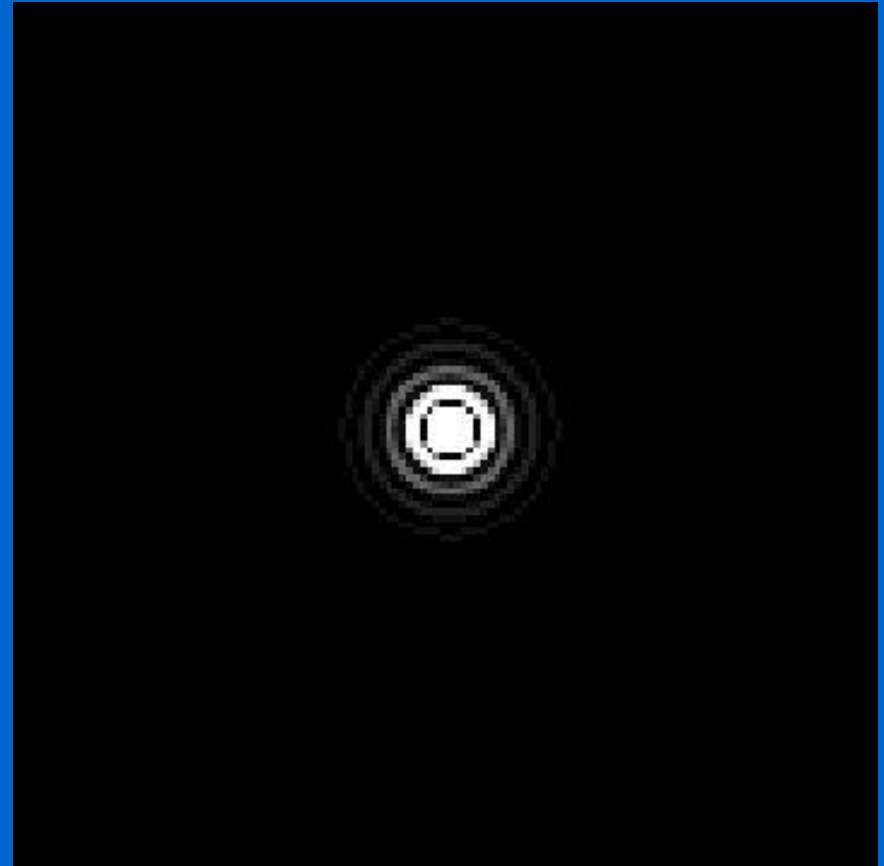
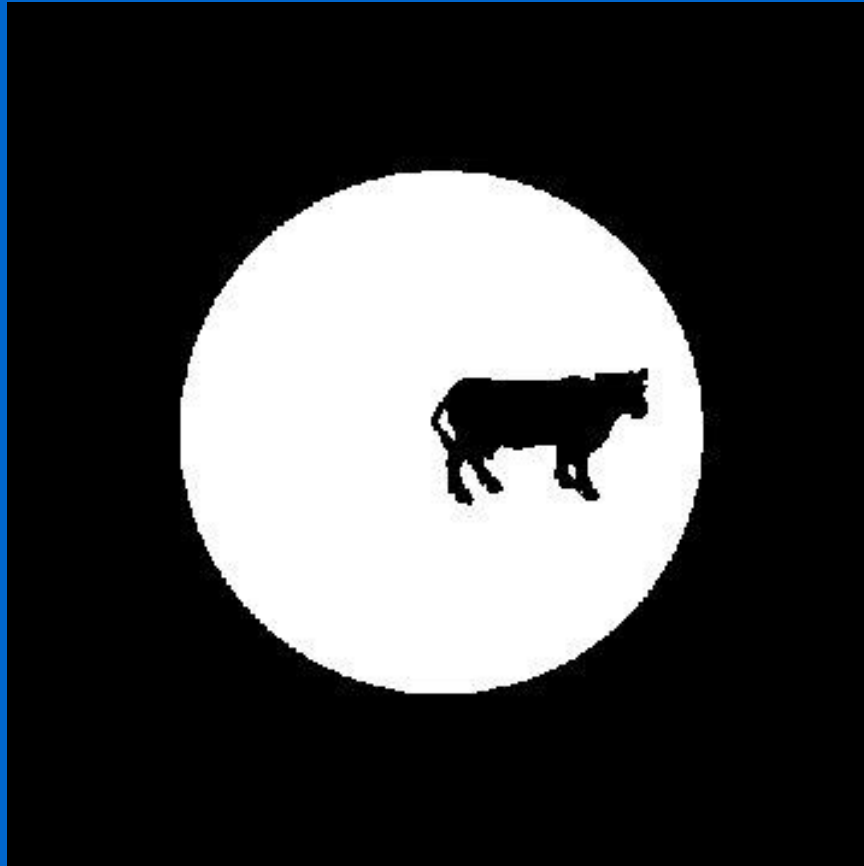
## NICI PSF in H-Band



without coronagraphic mask

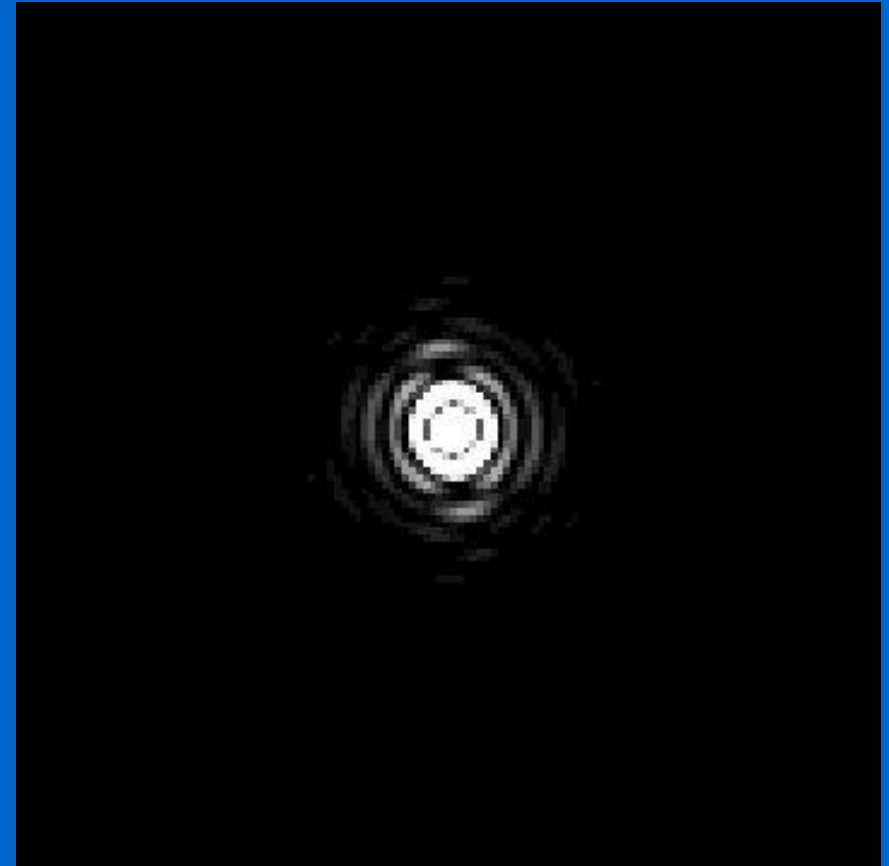
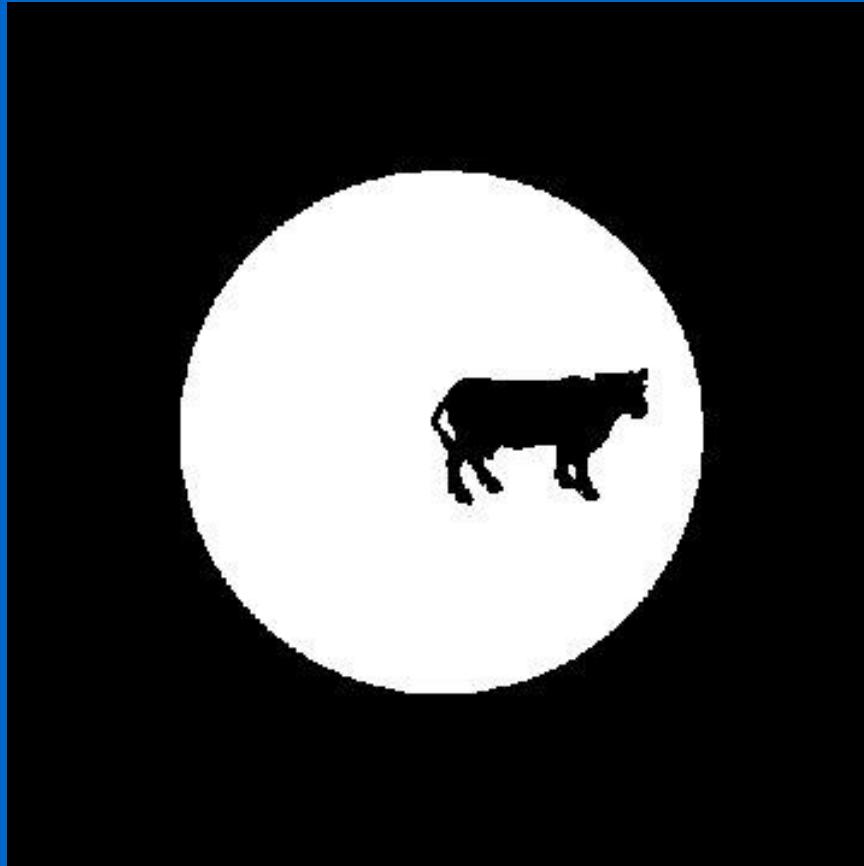


2.3" x 2.3" FOV



2.3" x 2.3" FOV

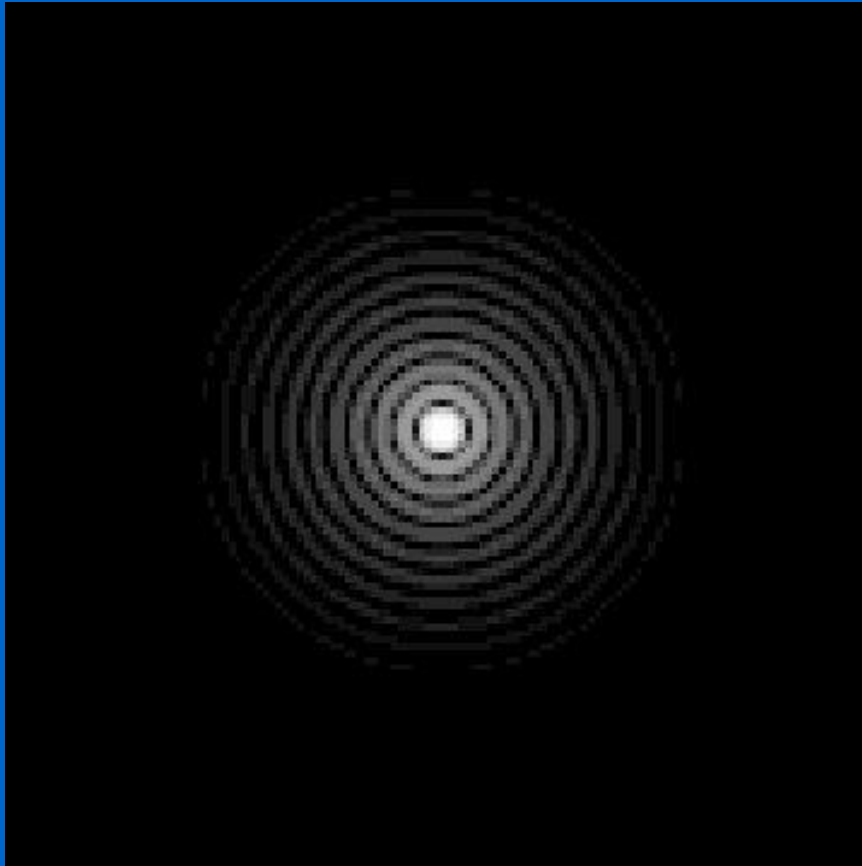




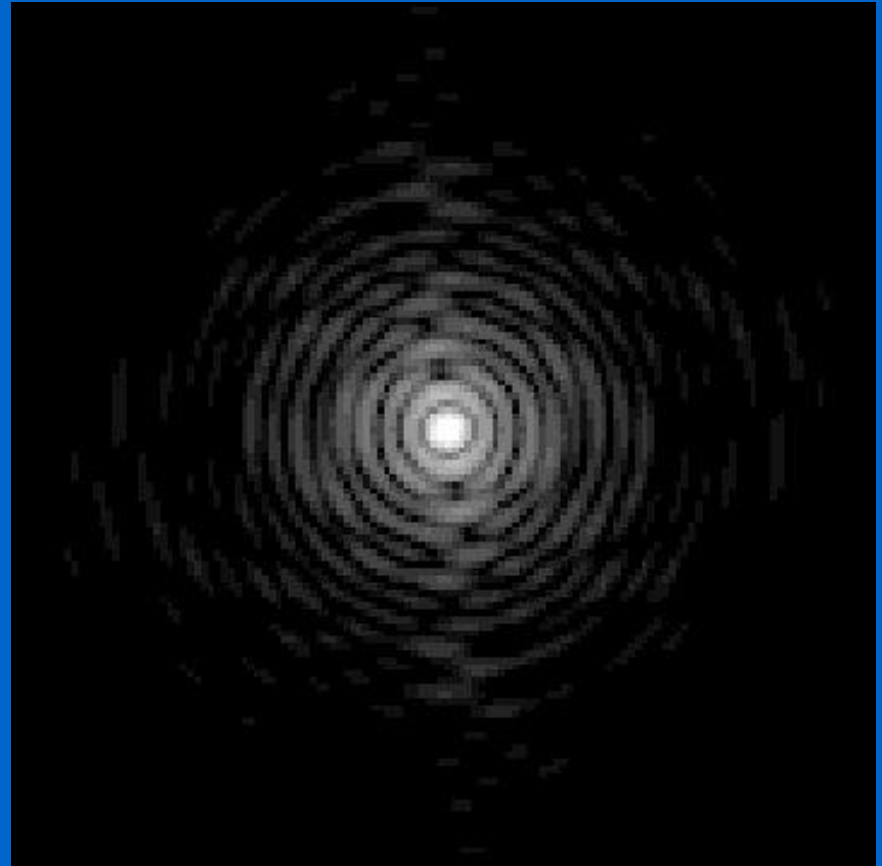
Linear stretch

2.3" x 2.3" FOV

PSF without cow

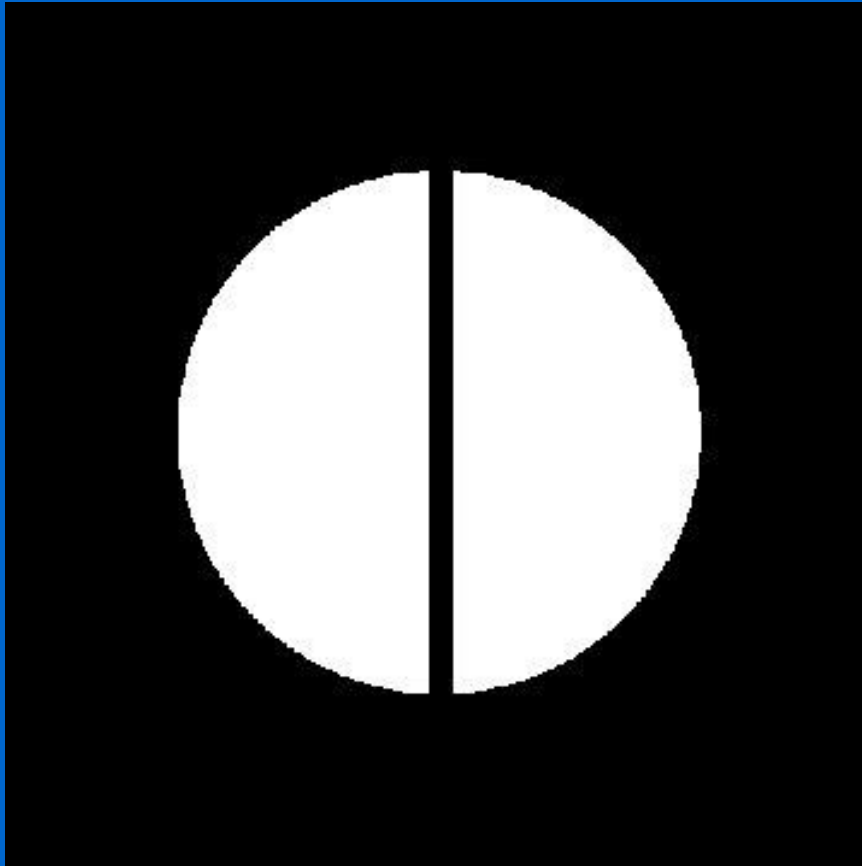


PSF with cow

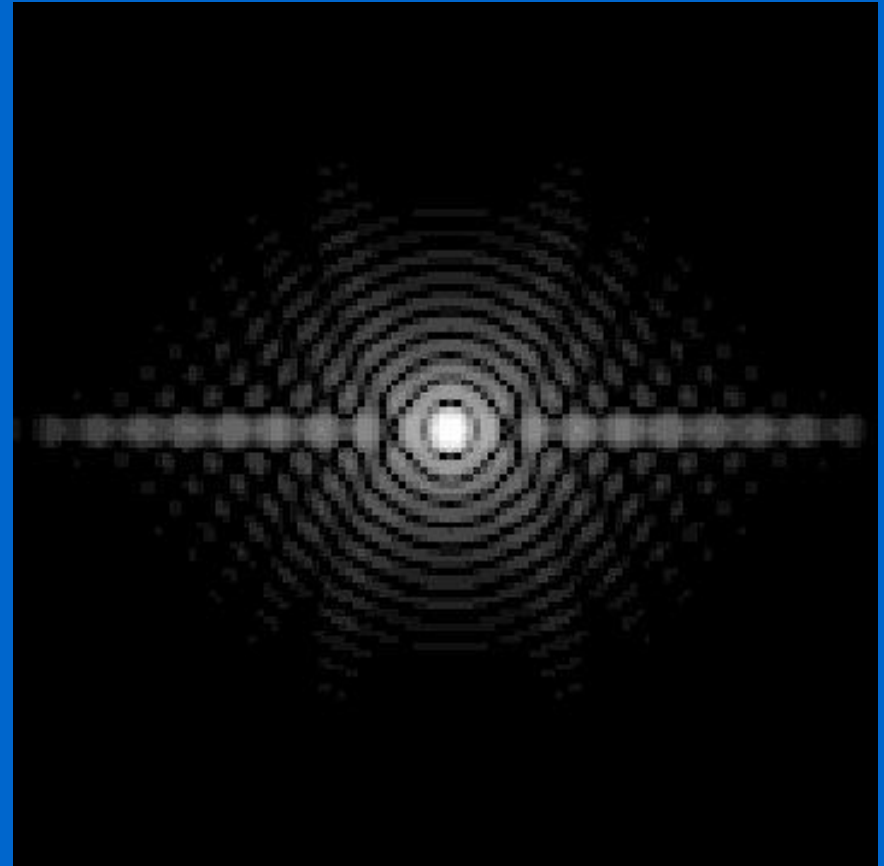
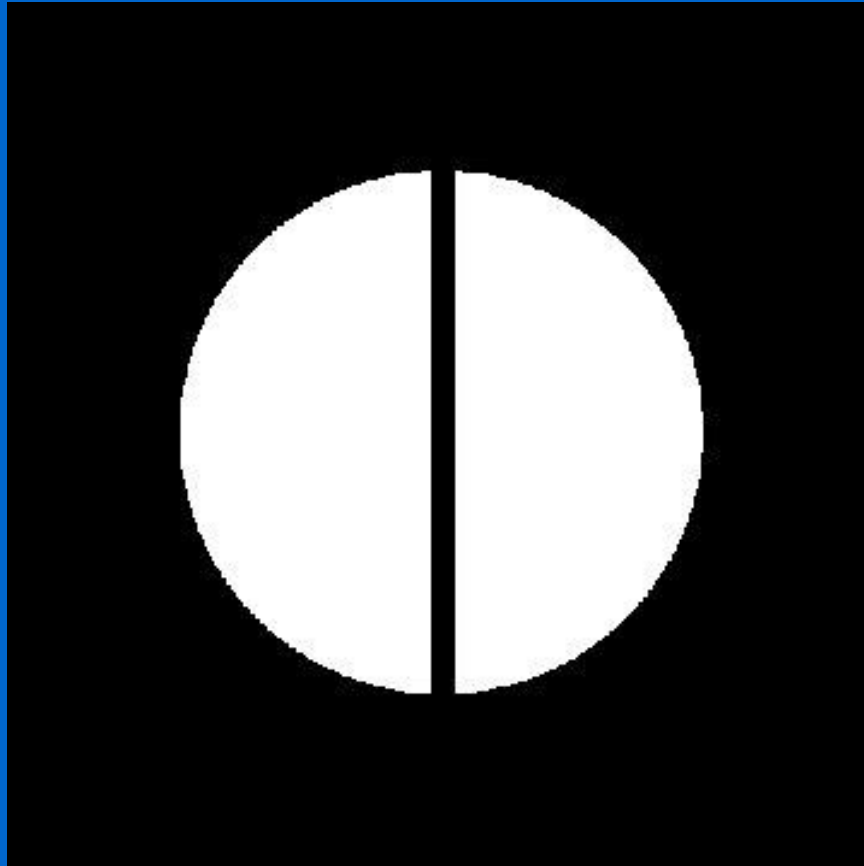


Log stretch ...

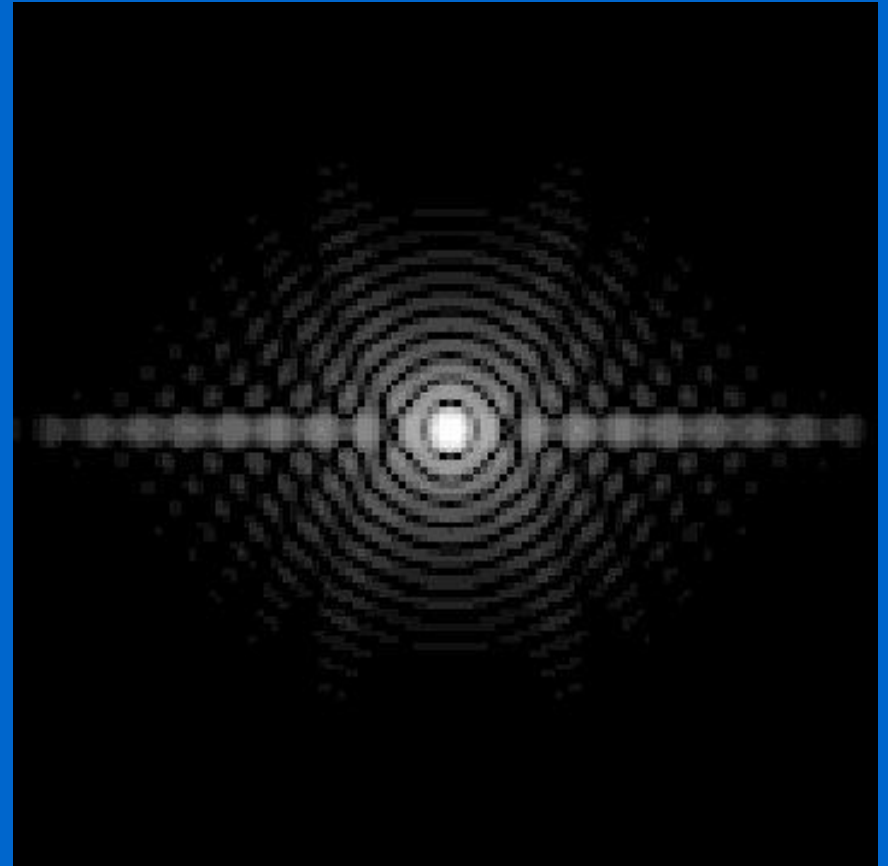
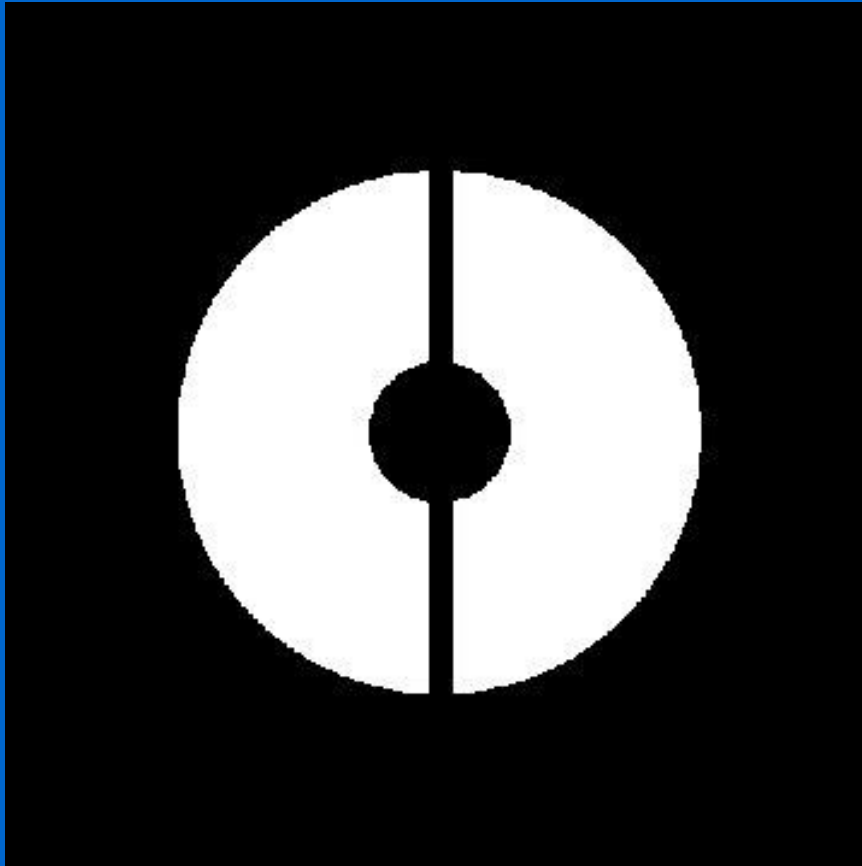
2.3" x 2.3" FOV



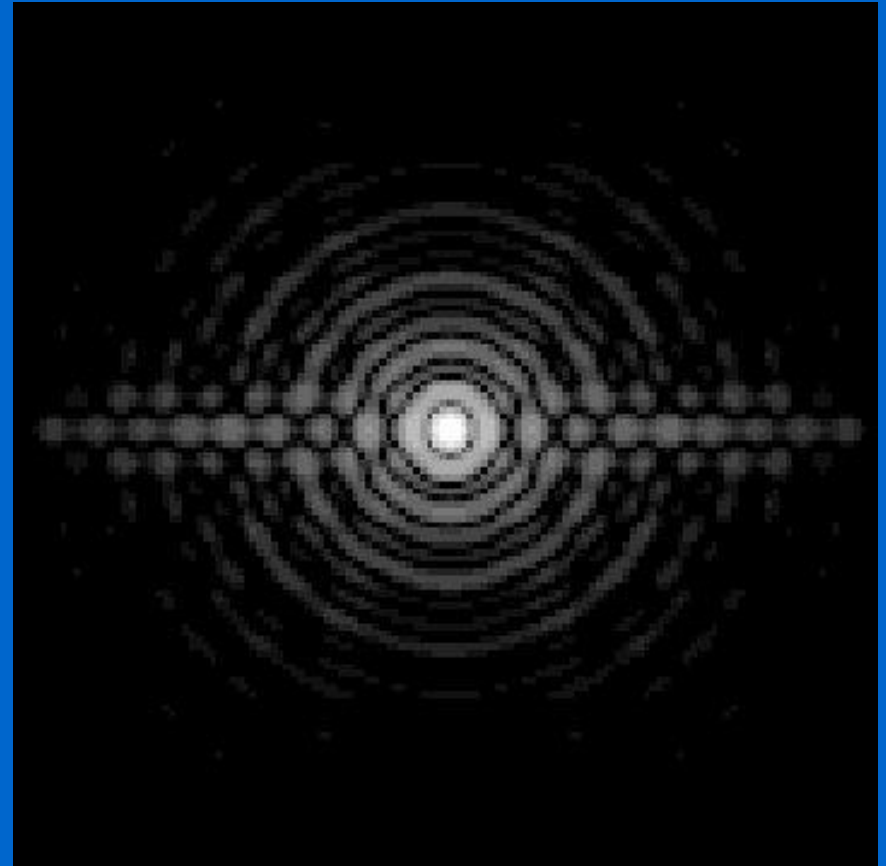
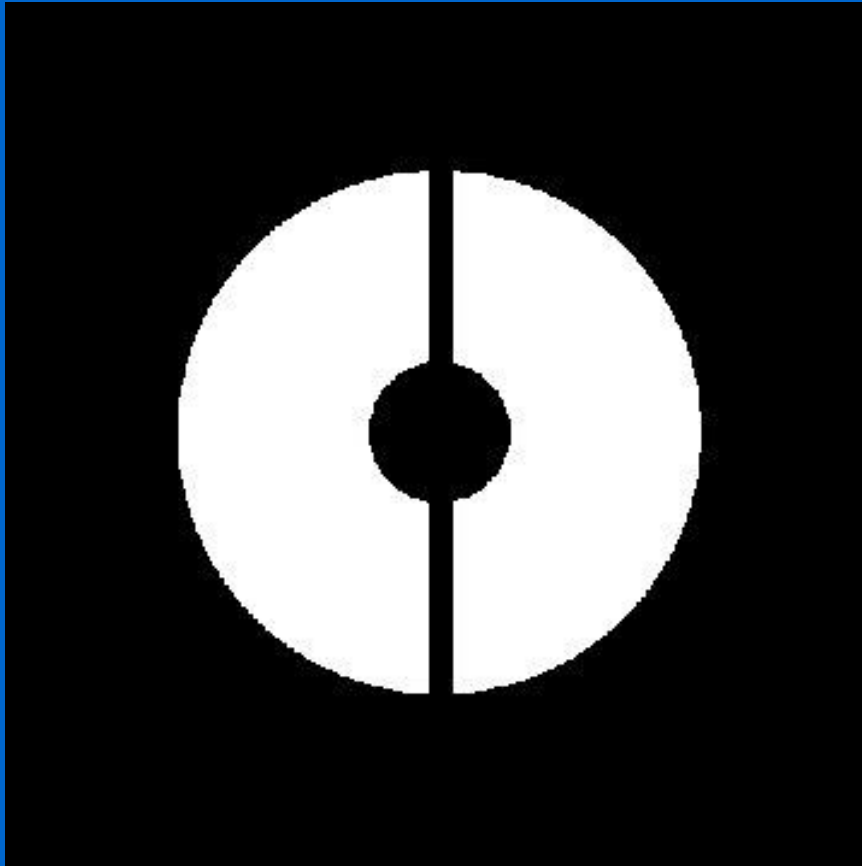
Thick spider arm (30 x the imaged M2 support arm)



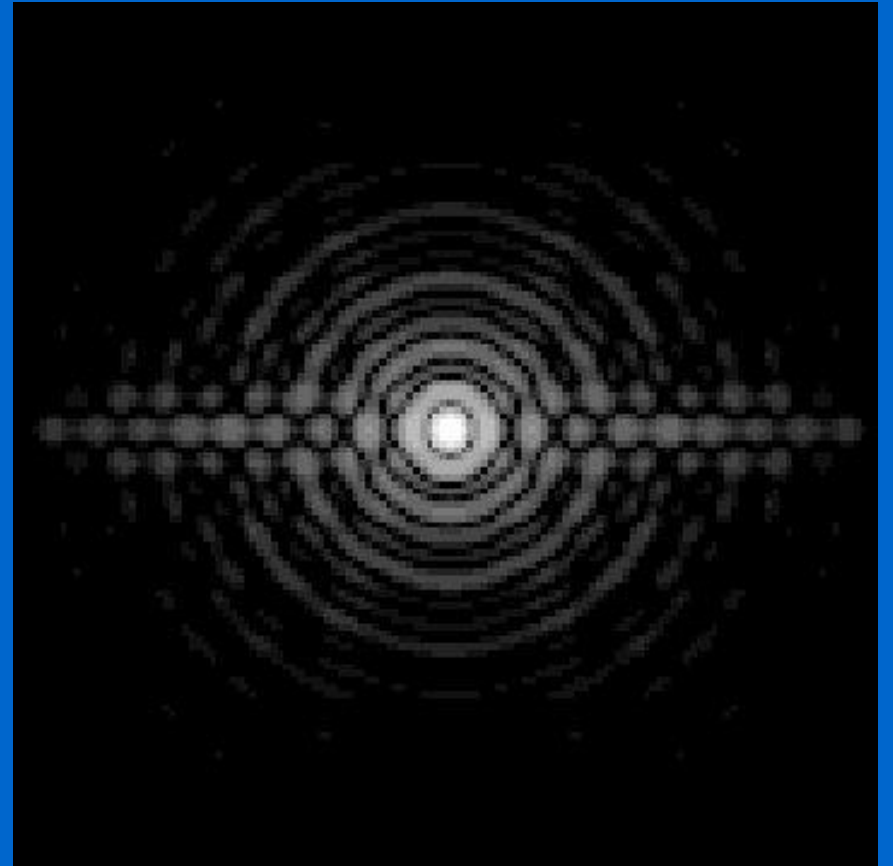
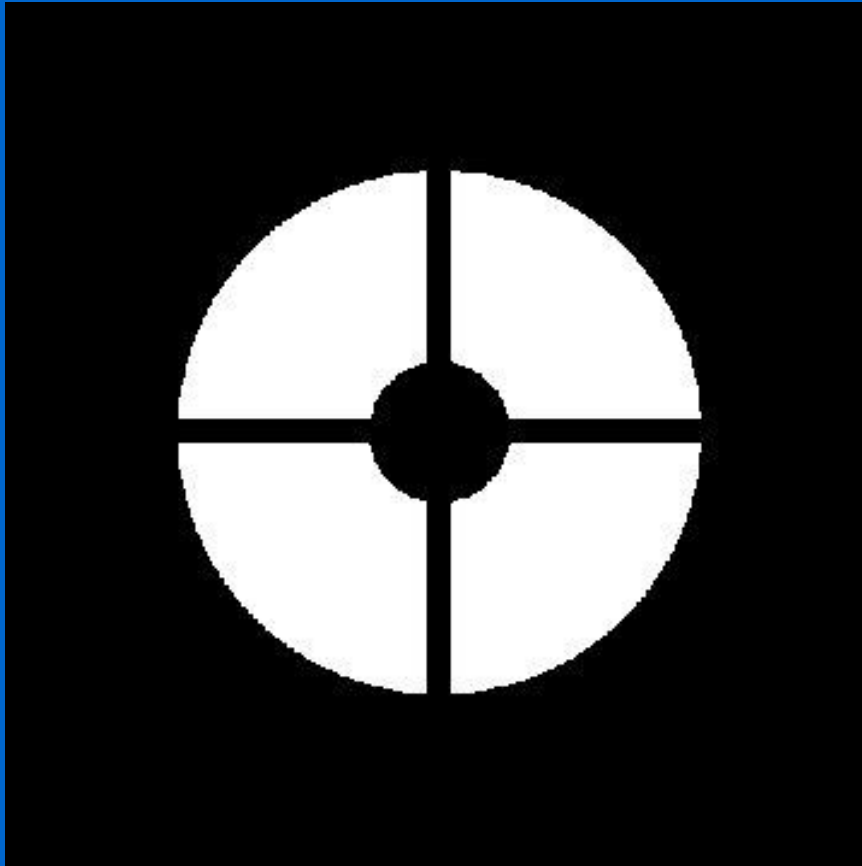
2.3" x 2.3" FOV



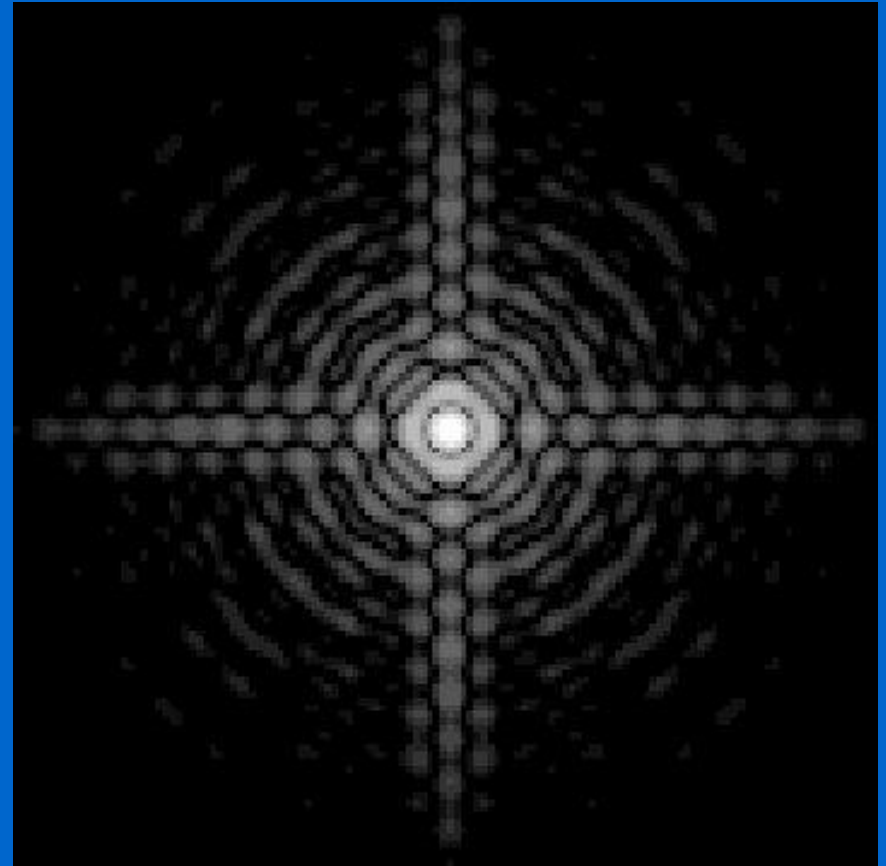
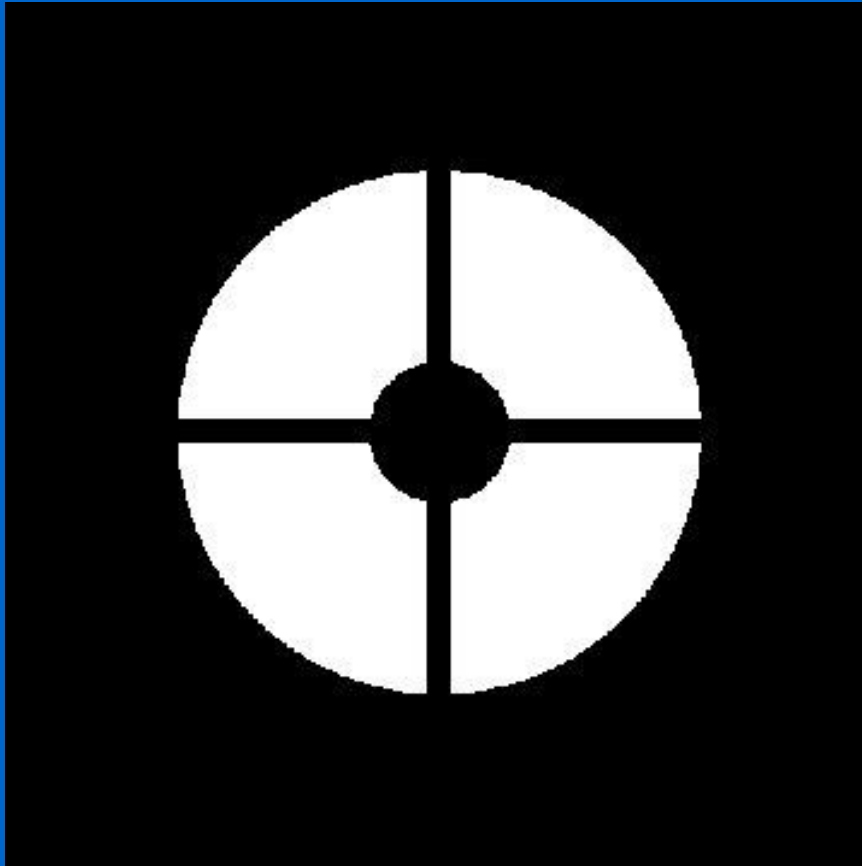
2.3" x 2.3" FOV



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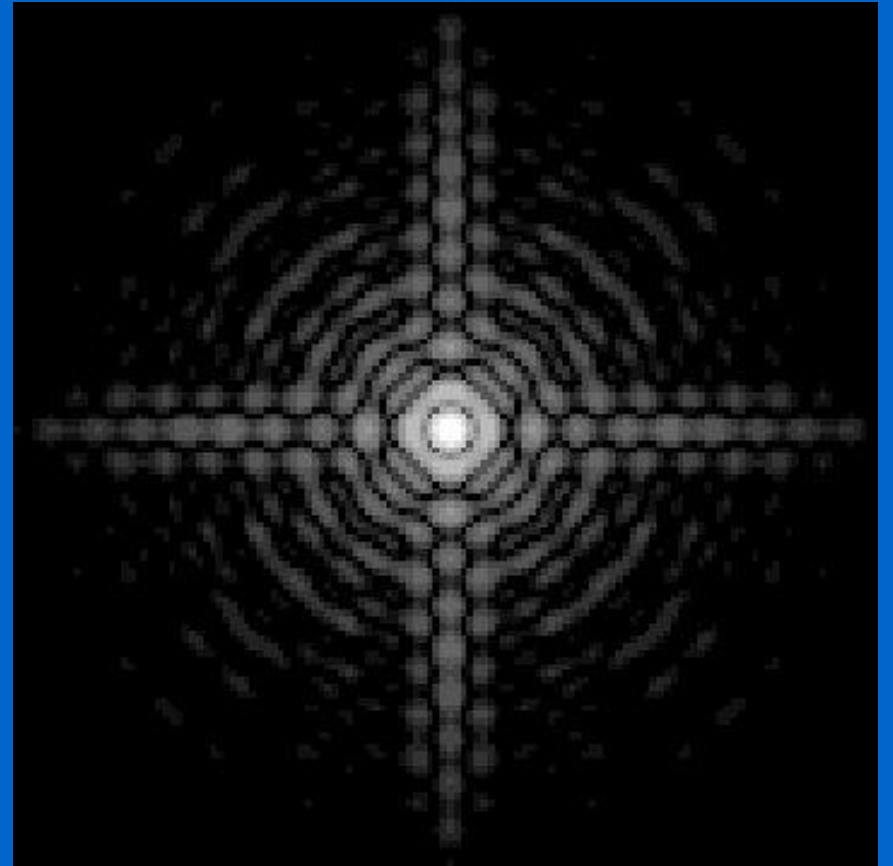
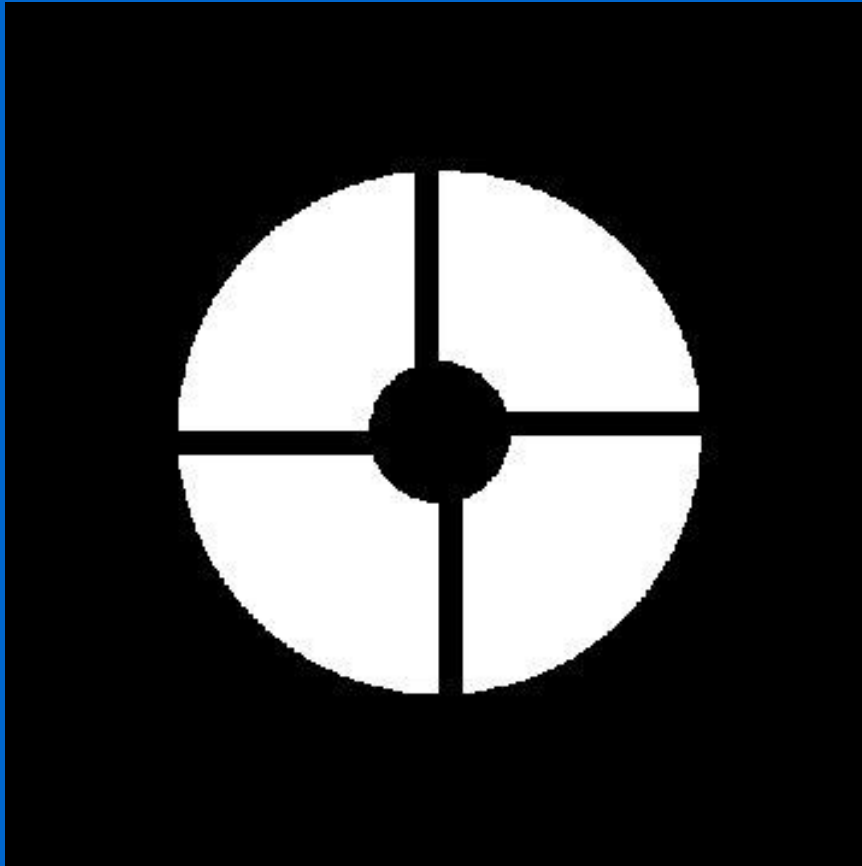


2.3" x 2.3" FOV

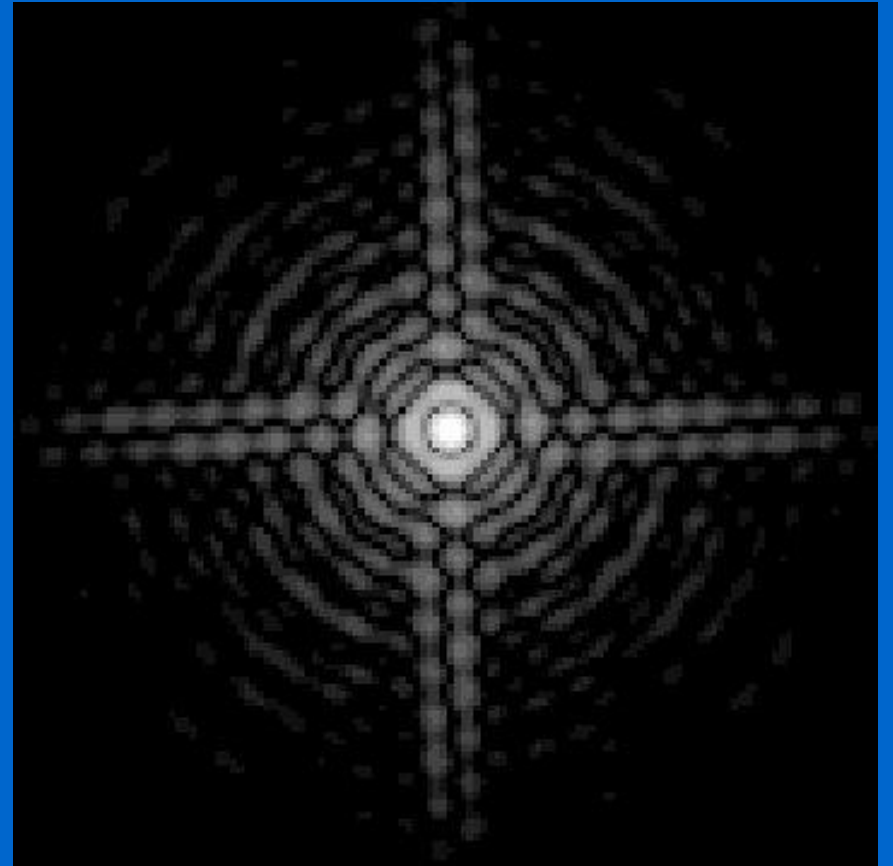
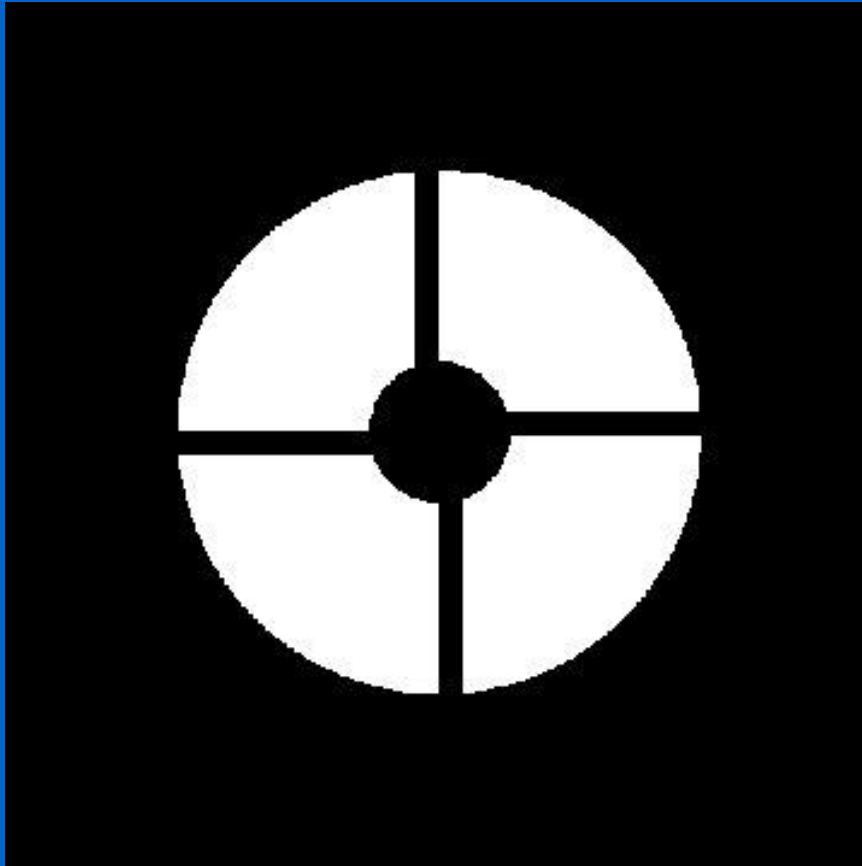


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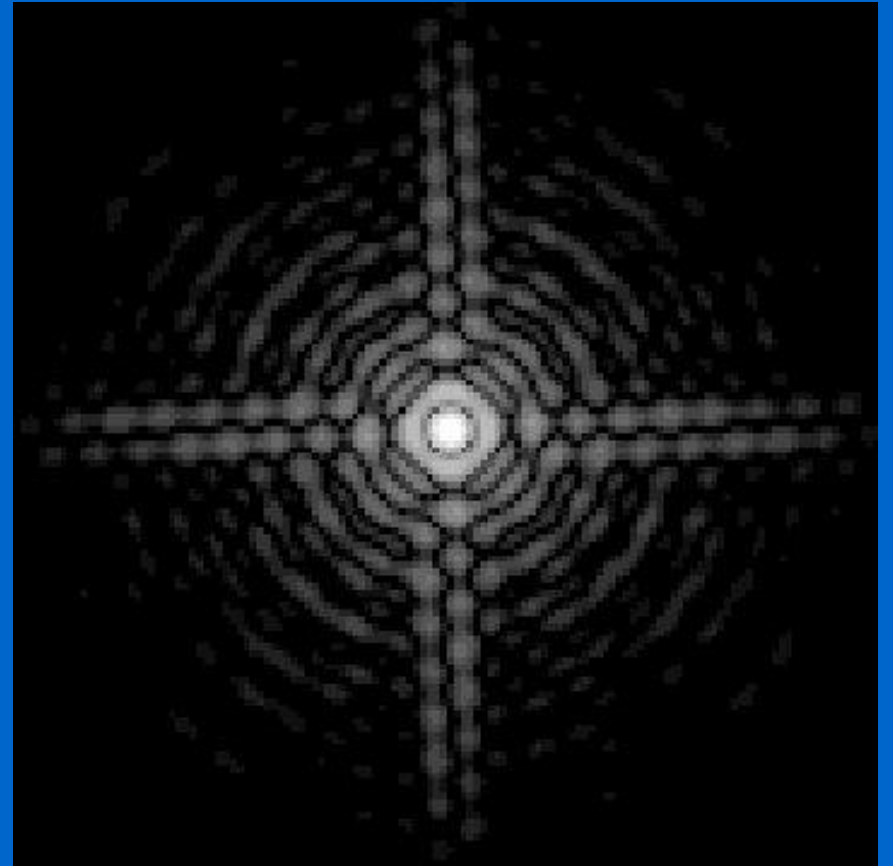
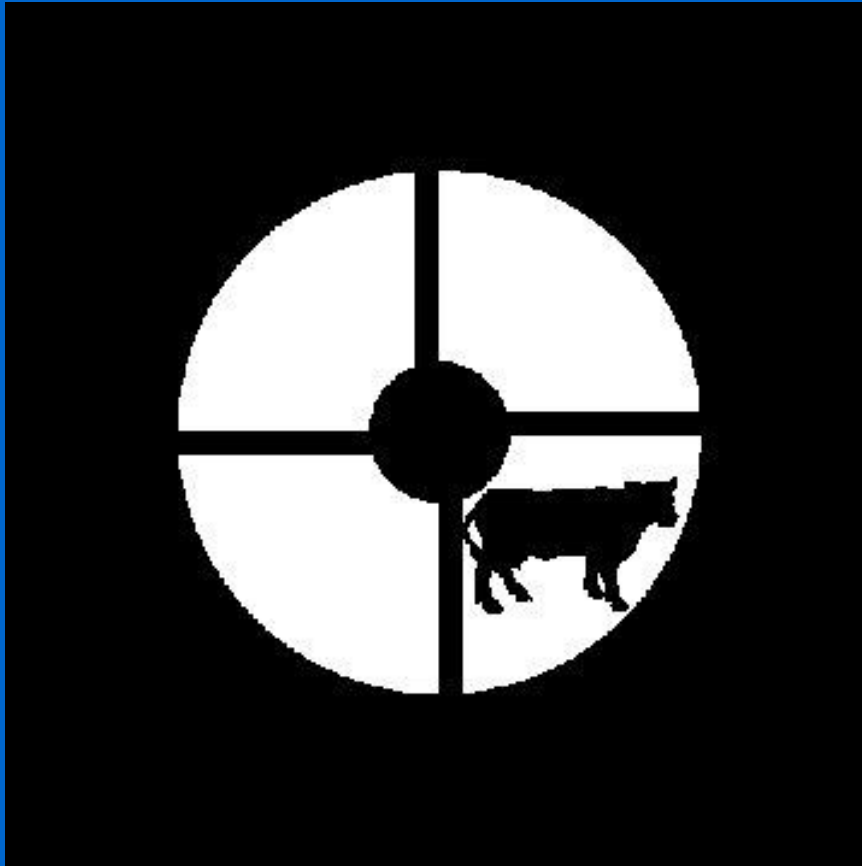




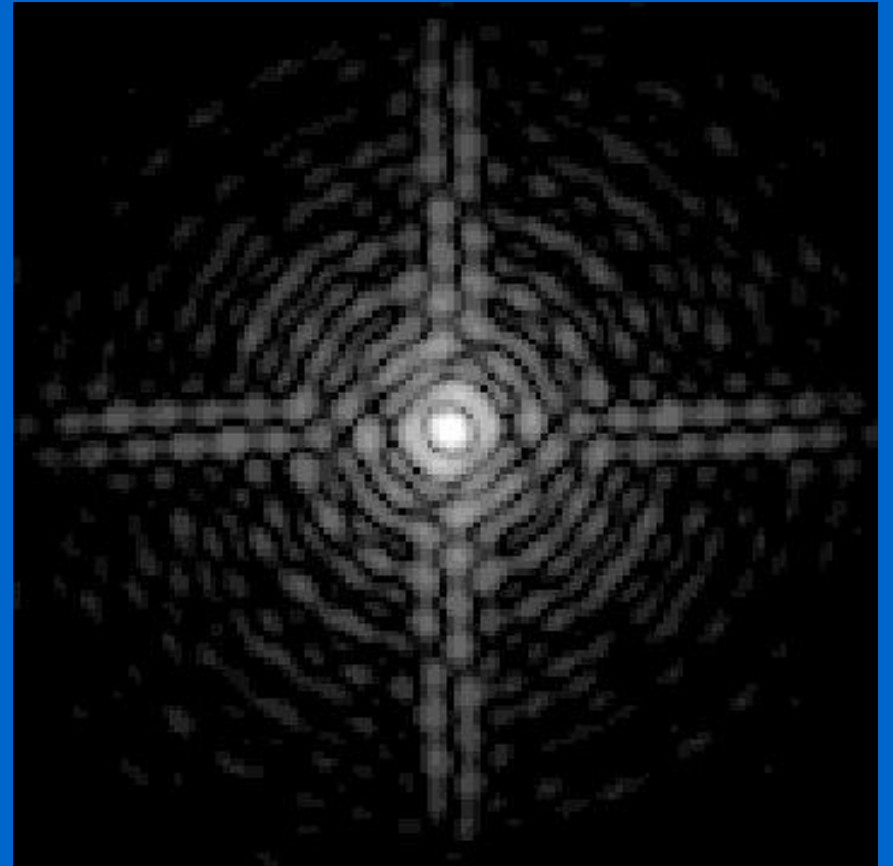
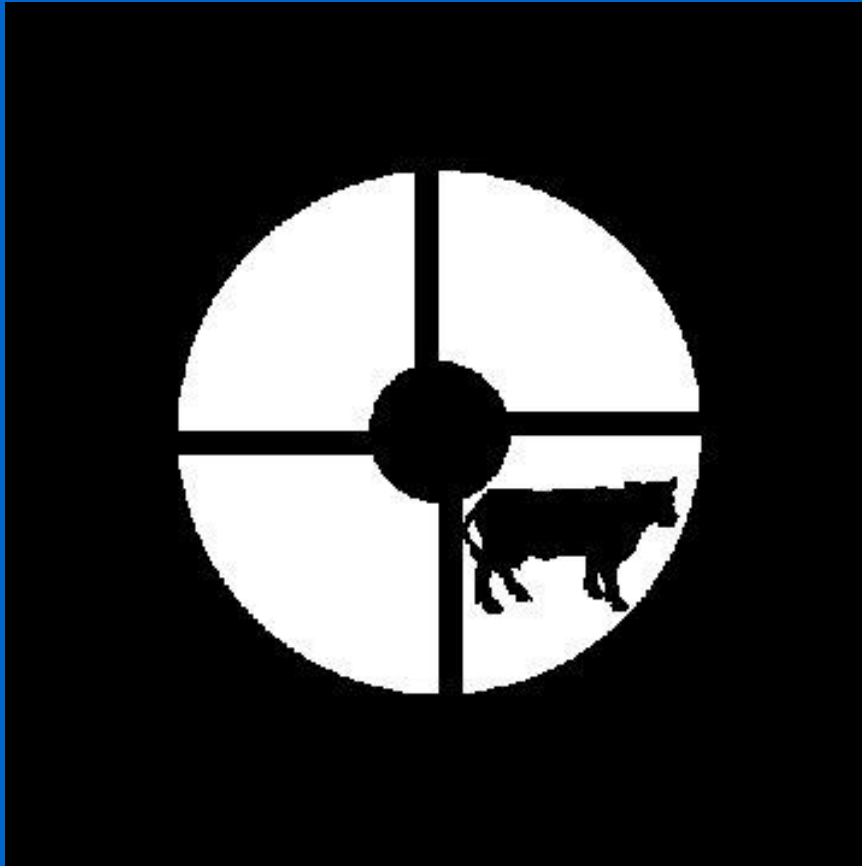
2.3" x 2.3" FOV



2.3" x 2.3" FOV



2.3" x 2.3" FOV



2.3" x 2.3" FOV

## ADI reduction

(Angular Differential Imaging – Cassegrain rotator fixed, pupil fixed => optimal PSF subtraction)

For the red arm, for the blue arm separately:

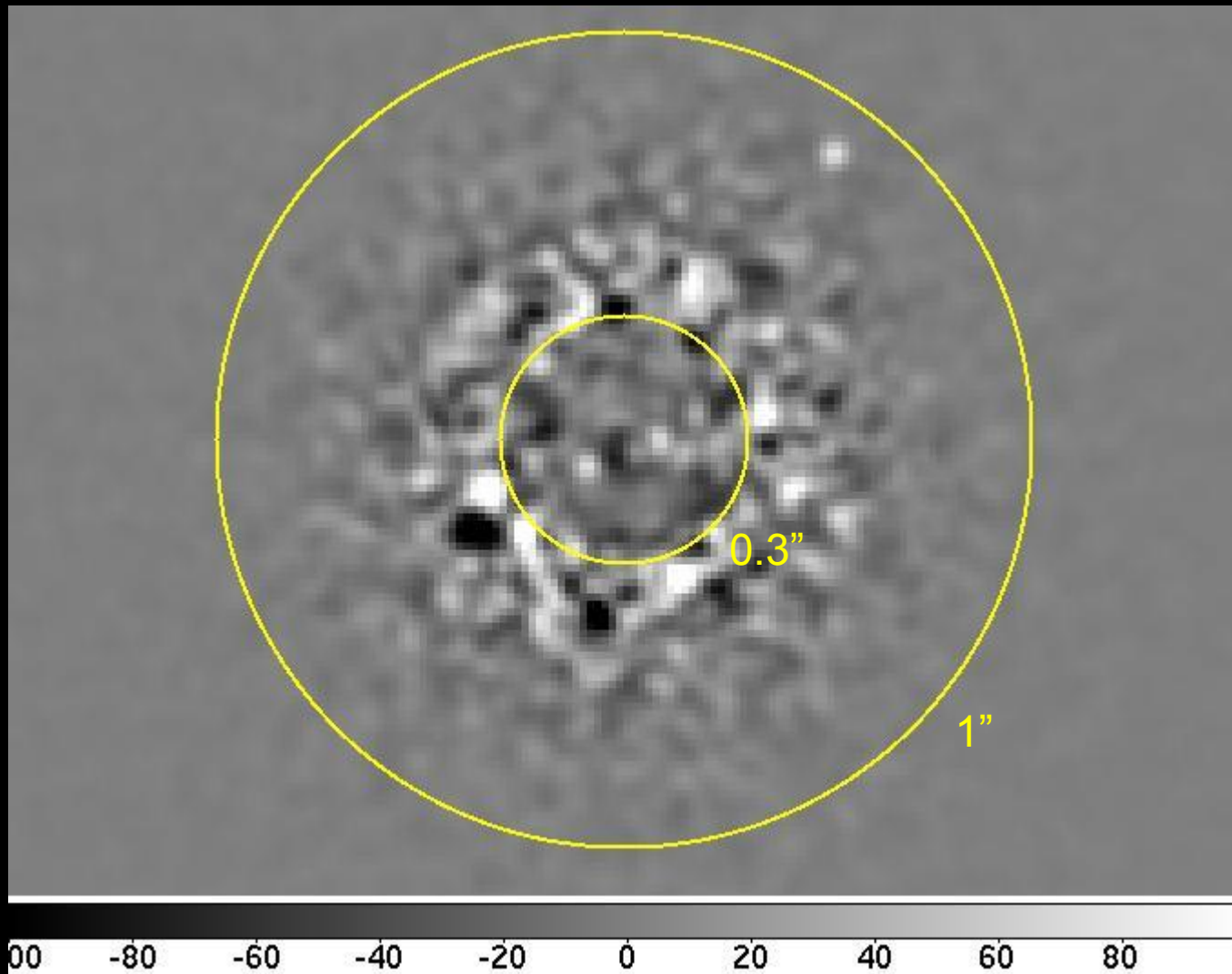
- dark, flat, bad pixel corr
- Register (subpixel shift) to central star (below the occulting mask, if not saturated, spot can be used for centering, Strehl, and flux esitation!)
- Highpass (looking for point sources!)
- match speckles (e.g. simplex minimization), scale intensity
- median ADI cube to get PSF frame (potential companions cancel out if enough field rotation)
- subtract PSF frame from cube (matching speckles of individual frames)

## SDI reduction

(Simultaneous or Spectral Differential Imaging - cancel primary, keep cool methane containing object)

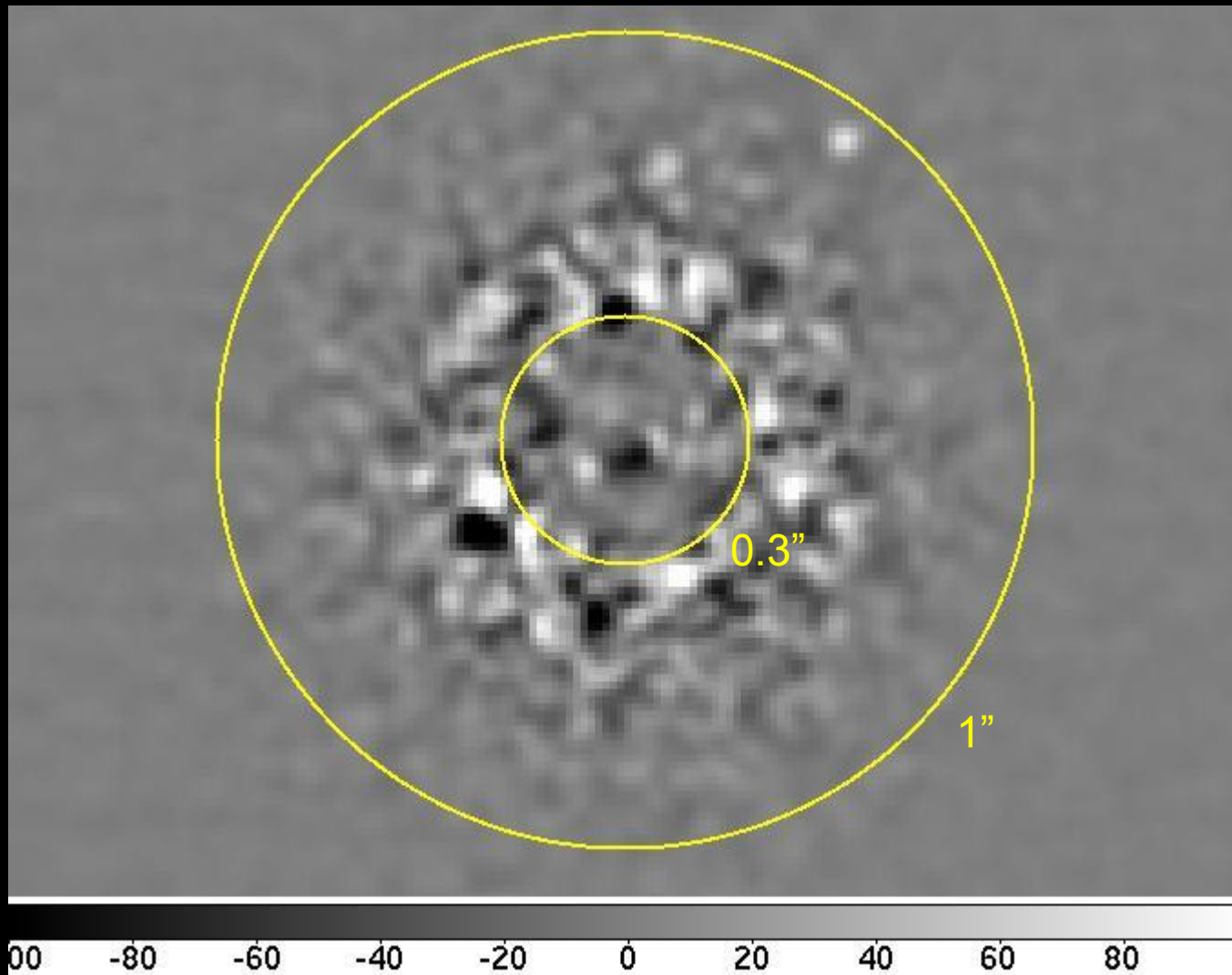
- shift, adjust image scale according to filter wavelength of red and blue channel
- subtract final results of both arms

*Lit. ADI/SDI e.g. from GDPS, authors e.g. Marois, Lafreniere, Artigau, Biller, etc.*



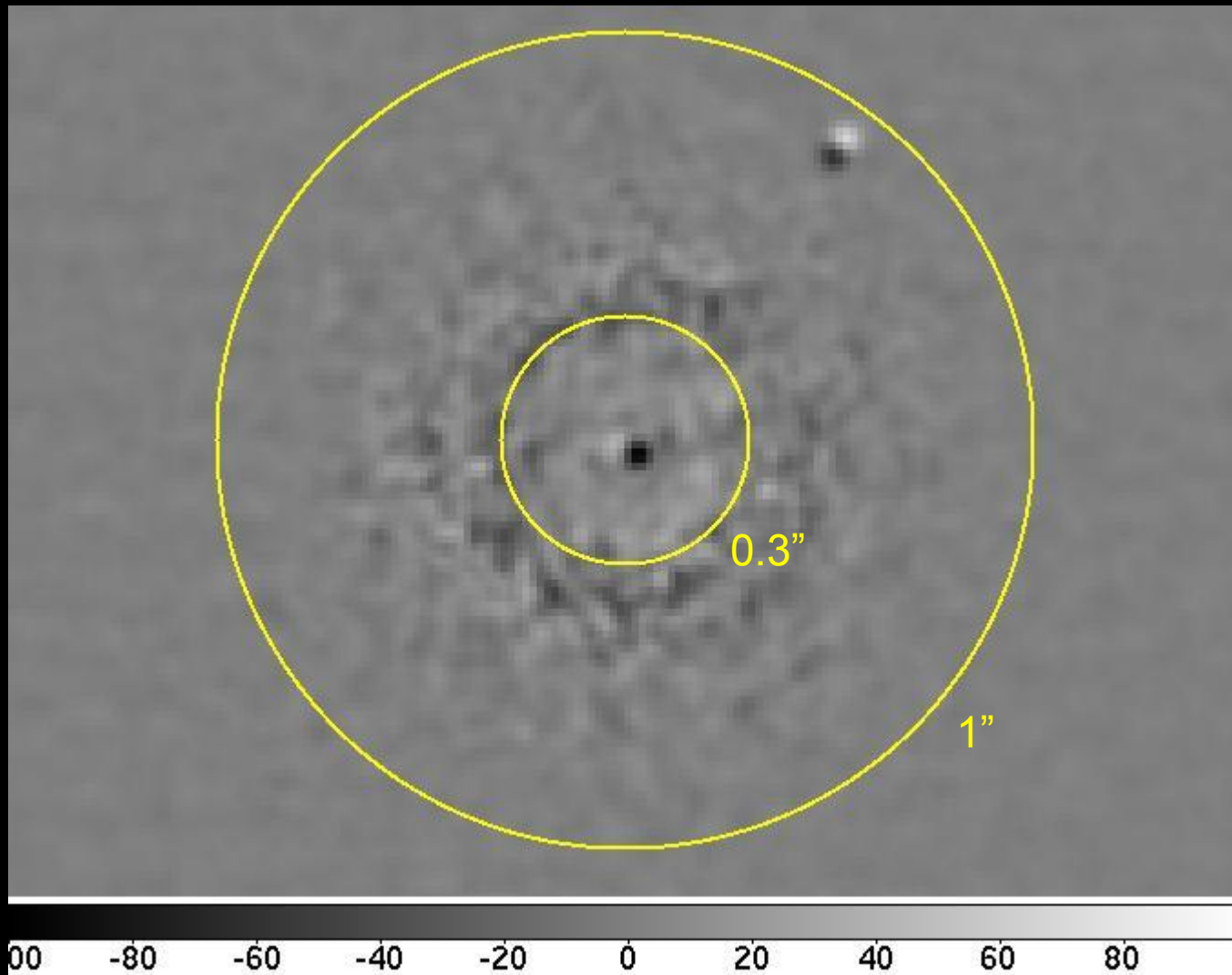
Kyoto, May 2009

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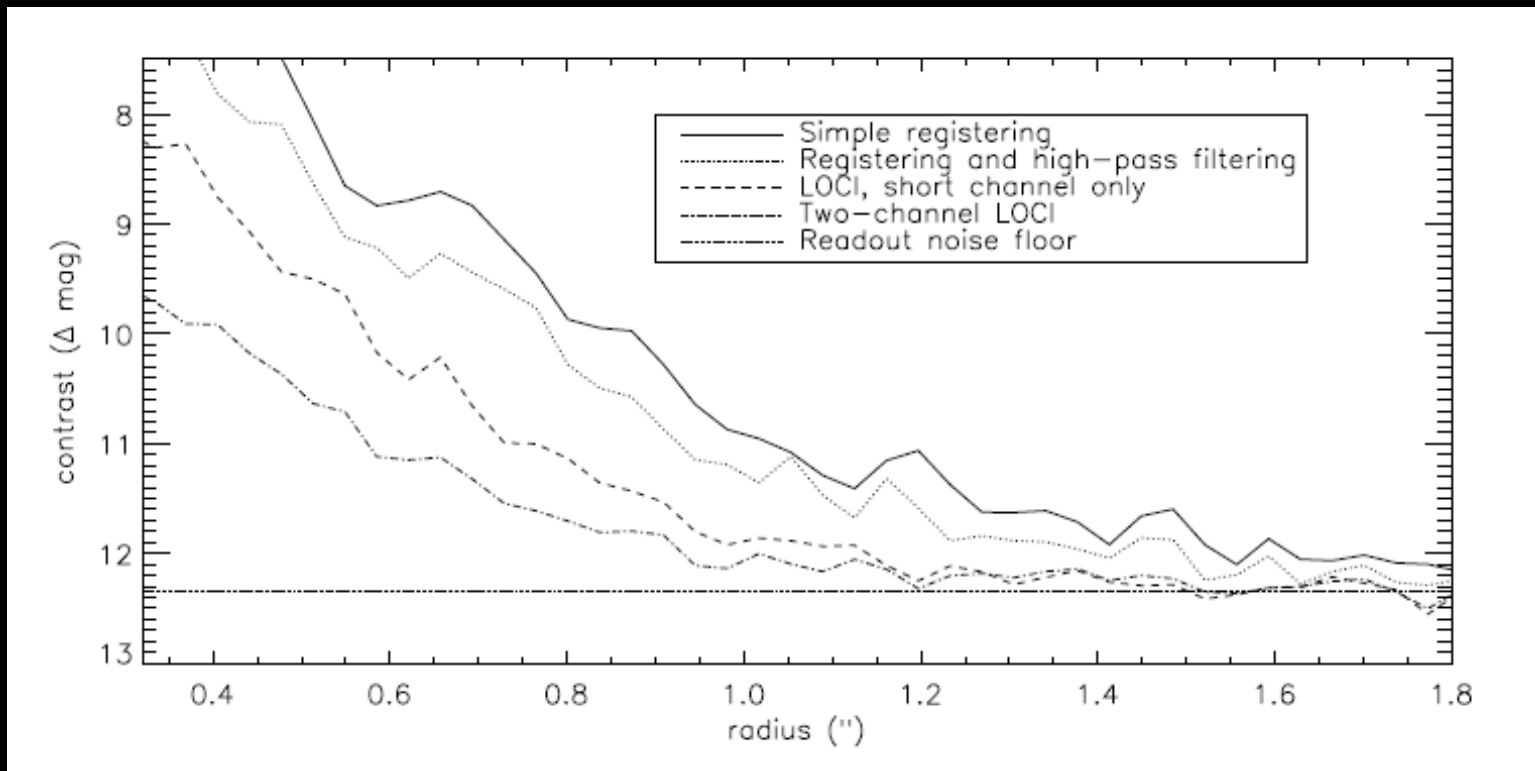
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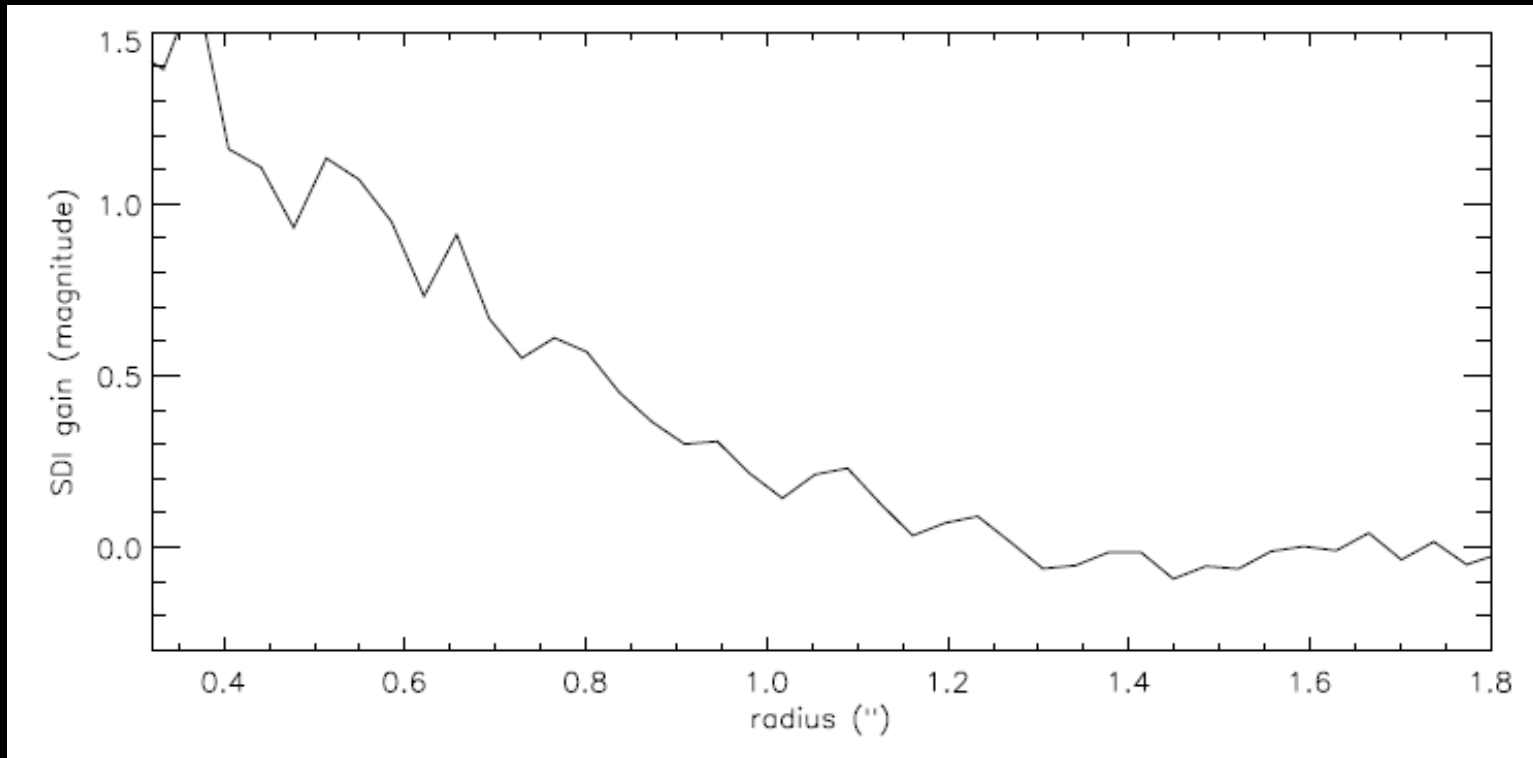




Artigeau et al., SPIE, 2008

## Contrast Gain applying SDI (on top of ADI)

SDI most effective inside 1". Efficiency for ADI increases for larger radii.



Artigeau et al., SPIE, 2008

# LOCI

Locally Optimized Combination of Images

$$\sigma^2 = \sum_i (O_i^T - \sum_k c^k O_i^k)^2$$

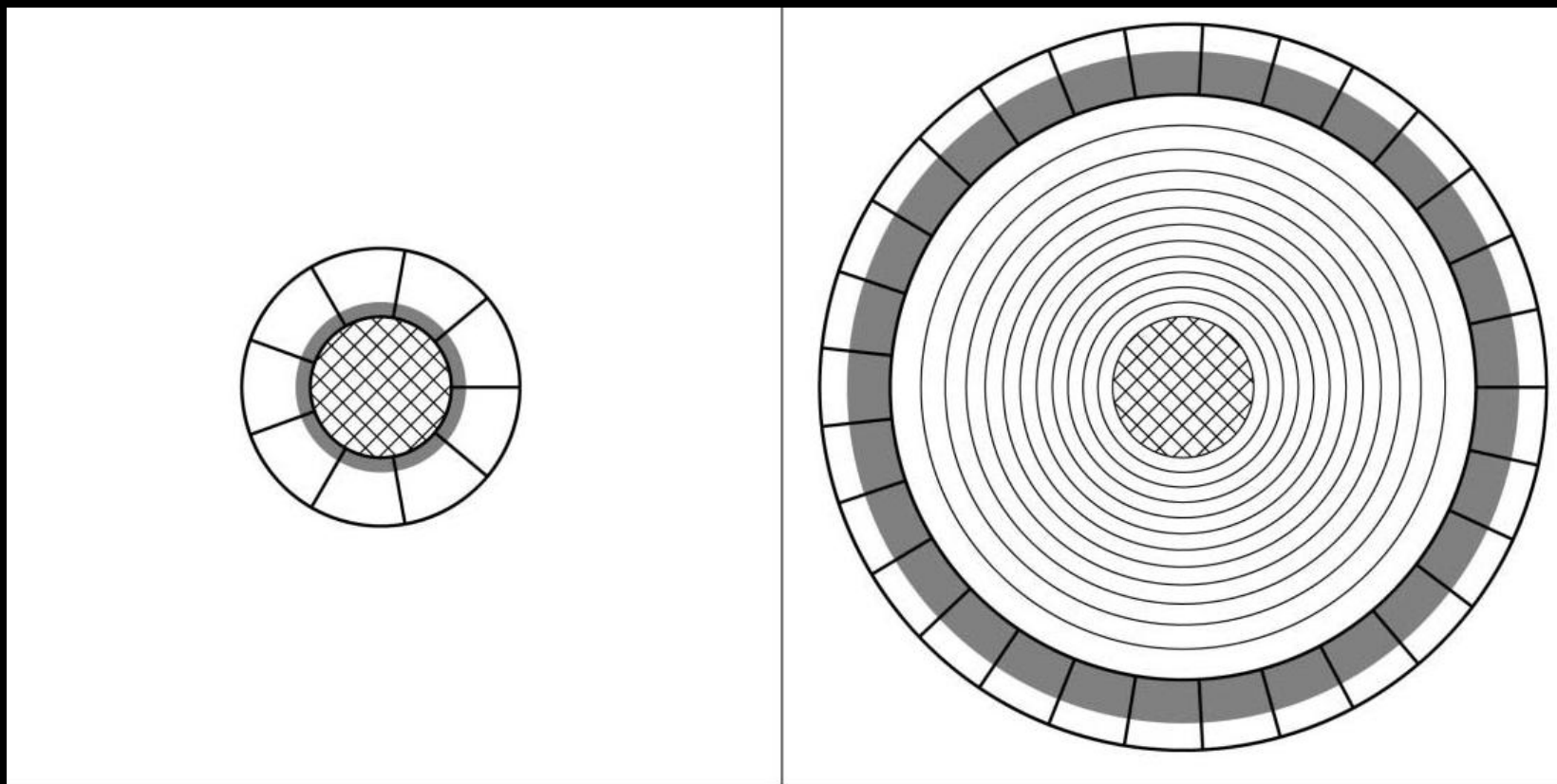
$O^T$  Region of image for which reference PSF is reconstructed

$O^k$  Same Region of  $k^{\text{th}}$  reference image

$i$  Pixel index of this region

Artigeau et al., SPIE, 2008

Lafreniere, Marois, Doyon, Nadeau, Artigau, A&A, 2007



Lafreniere, Marois, Doyon, Nadeau, Artigau, A&A, 2007

# NICI Pipeline release

- Pyraf (but using python only for NICI)
- Beta release July 2009, Nelson Zarate
- Update February 2010, Nelson Zarate

Pipeline will output many intermediate products  
(standard reduction, ADI, SDI, ASDI, LOCI, etc.)

[www.gemini.edu](http://www.gemini.edu) , see DATA, Gemini IRAF package

# Summary

- Contrast up to  $dH = 13.5 @ 0.5''$  (90 min) “bad house number”
- Verify pipelines (fake planets, simulations, photometry)
- Do it yourself, pipeline releases no grant for being science proof
- Solid understanding of PSF and its artifacts needed
- And ...

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- Do it yourself, pipeline releases no grant for being science proof
- Solid understanding of PSF and its artifacts needed
- And check your telescope for a cow