VORTEX

An Update on the VORTEX Project

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Université de Liège

UPPSALA UNIVERSITET

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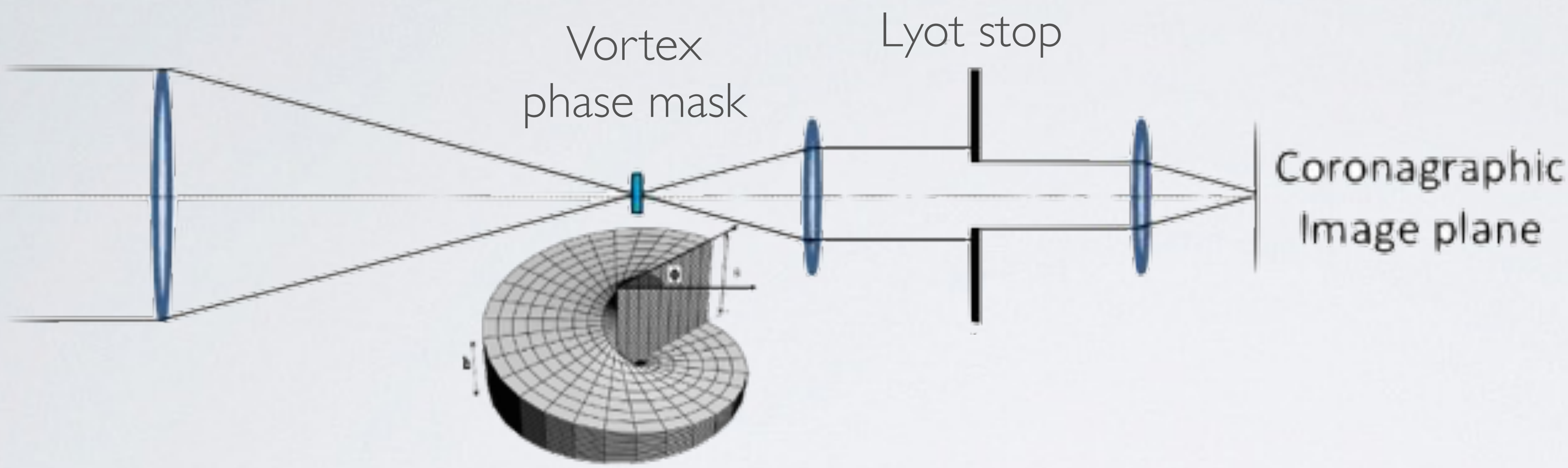
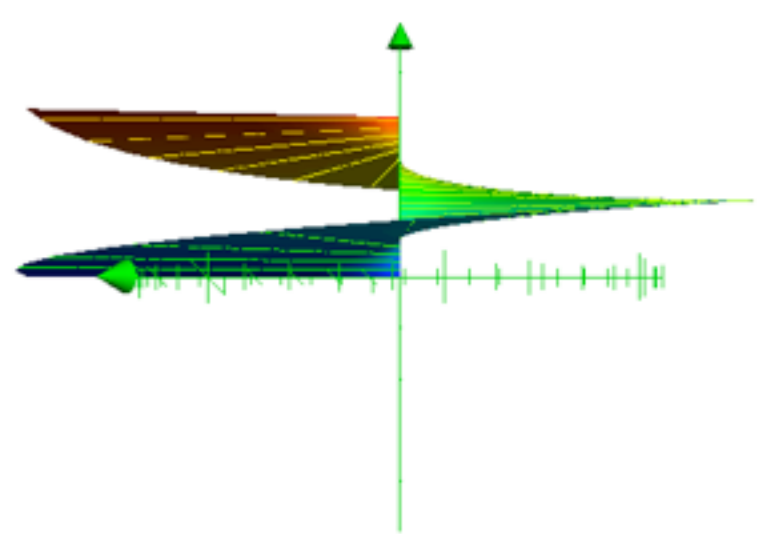
The Vortex Coronagraph in a Nutshell

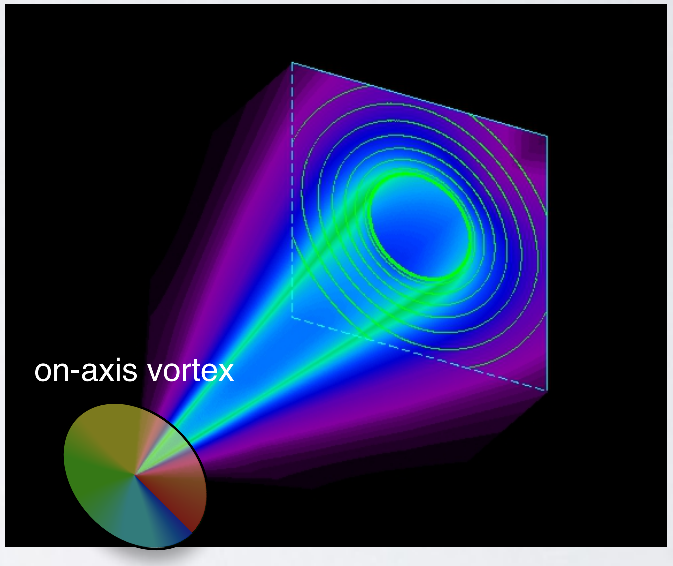


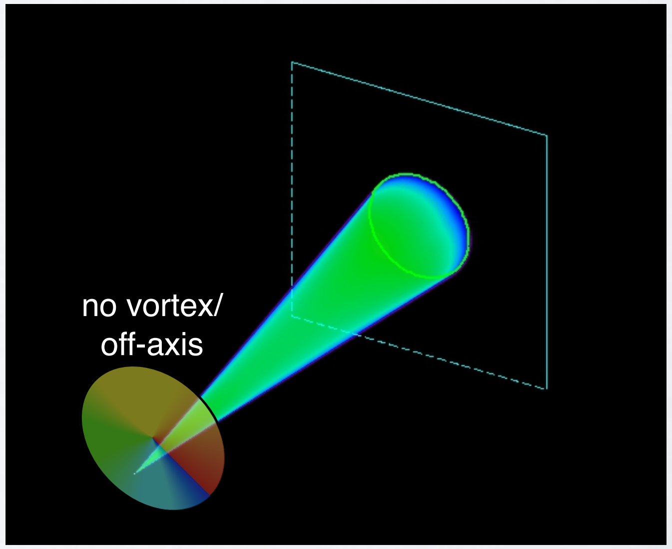
$e^{il\theta}$



l = topological charge (winding number)
= height of the screw dislocation

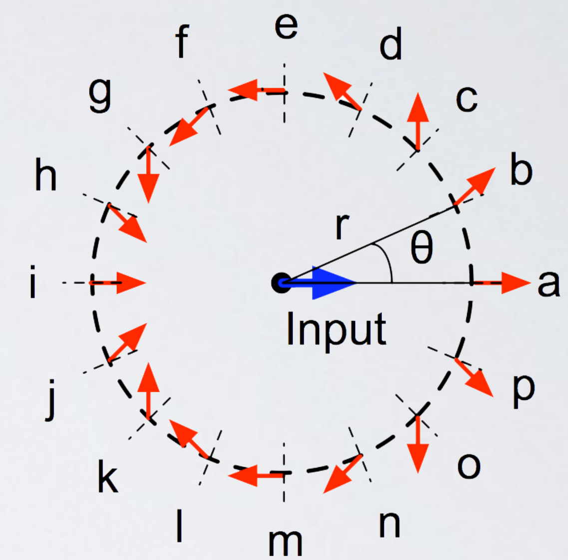
Perfect on-axis cancellation





Annular Groove Phase Mask (AGPM)

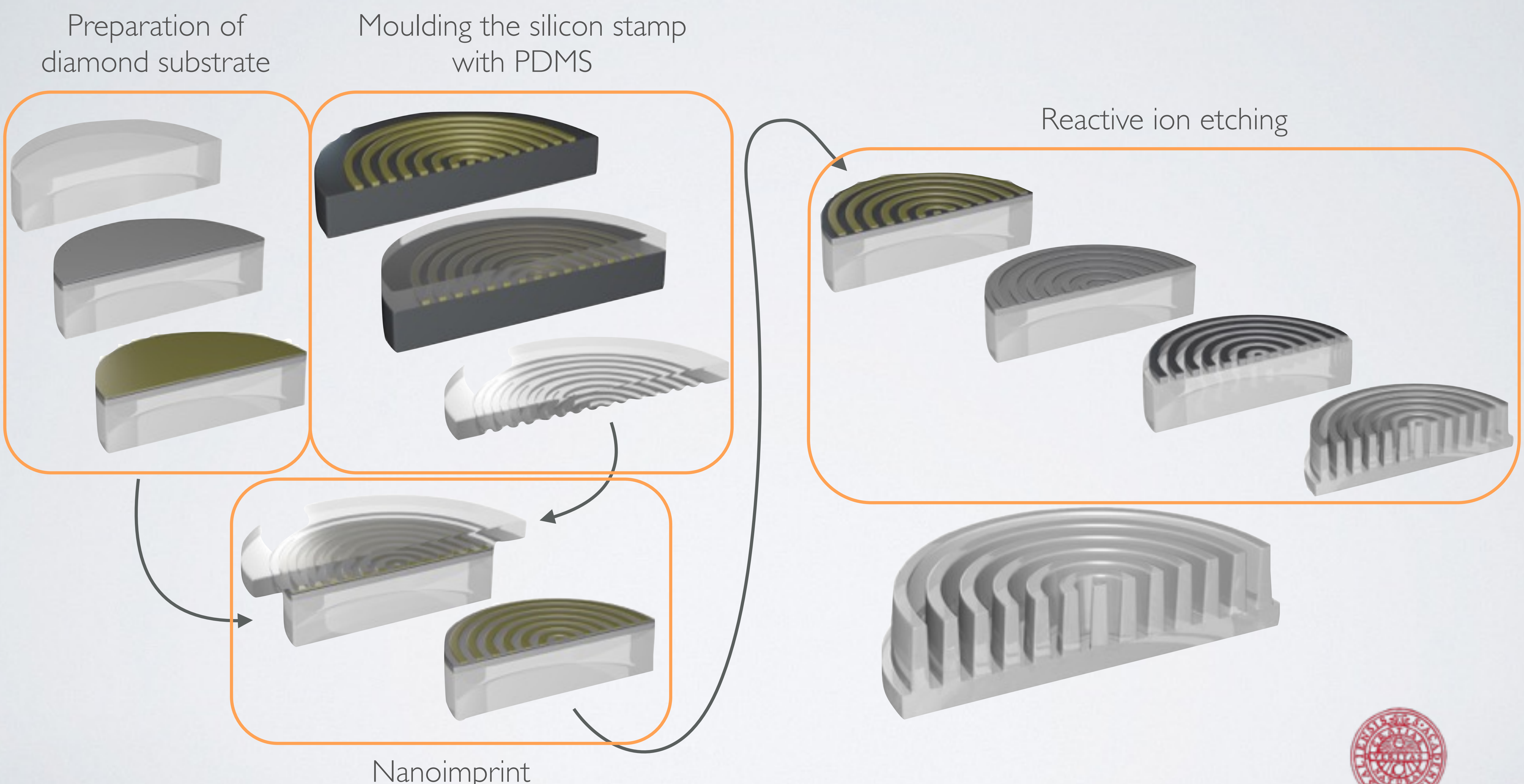
- Rotationally symmetric half-wave plate made of **sub-wavelength** (aka zero-order) gratings



- Small IWA, 360° discovery, can be made achromatic

Mawet et al. 2005

How We Build AGPMs



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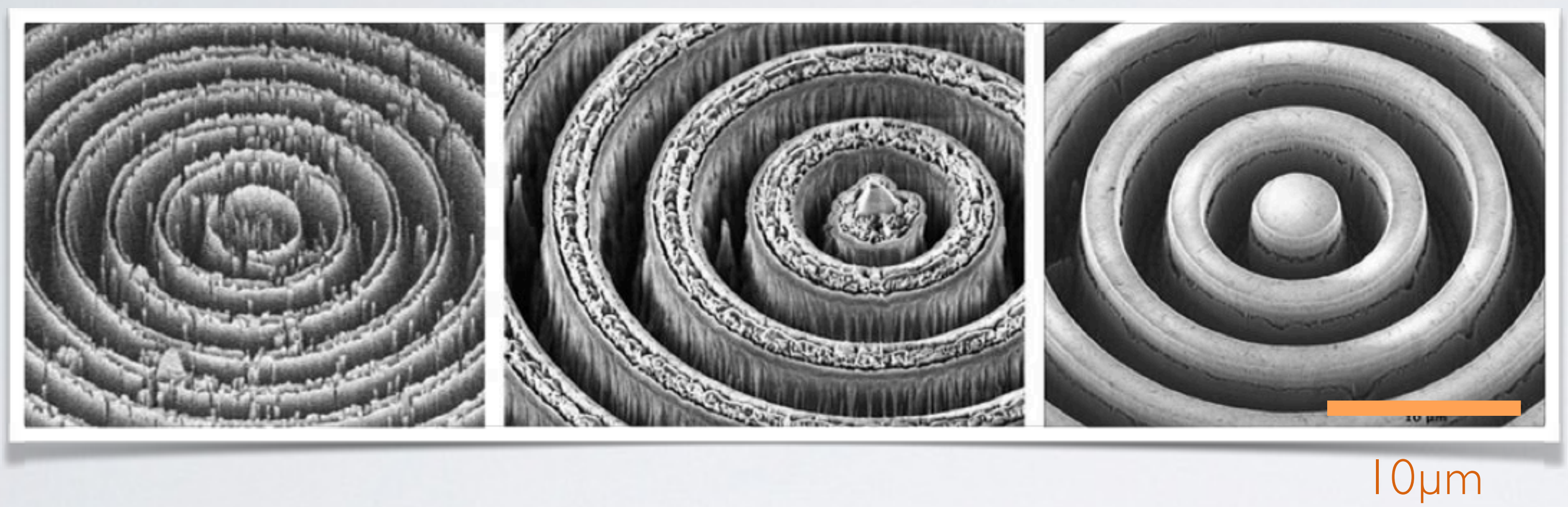
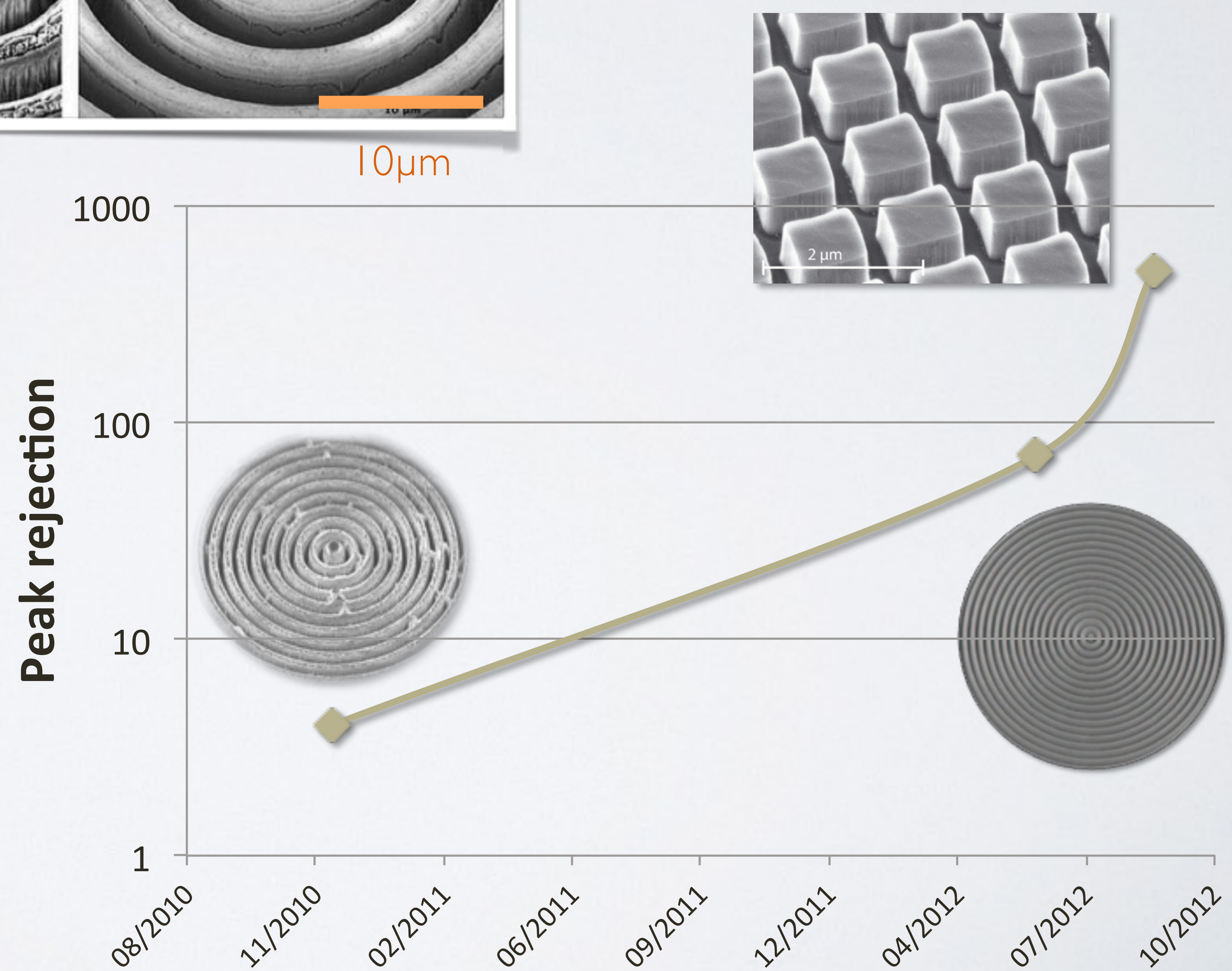
Early Achievements

Nov 2009 Oct 2010 Feb 2012



- First N- and L-band AGPMs
- Peak rejection measured at L band



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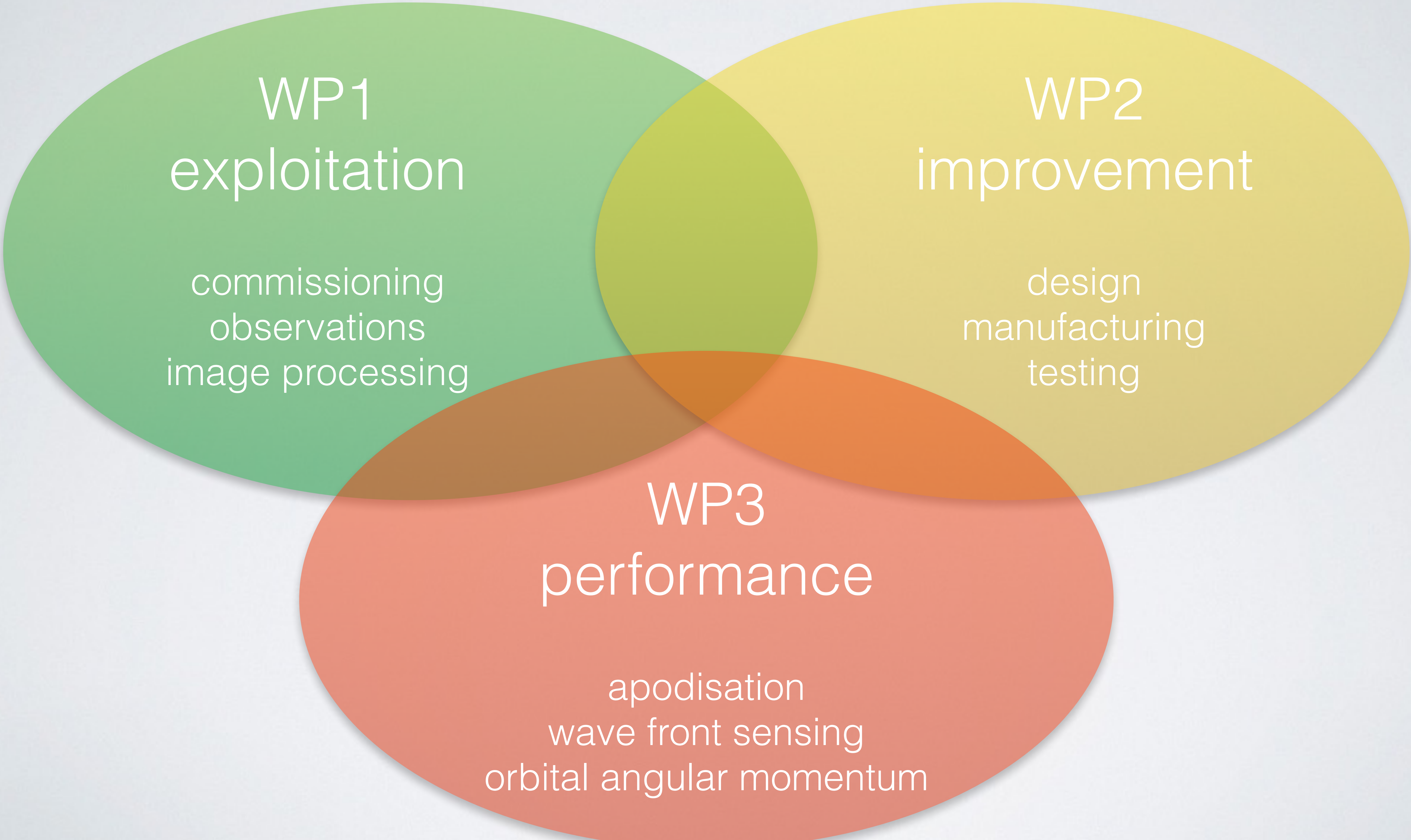
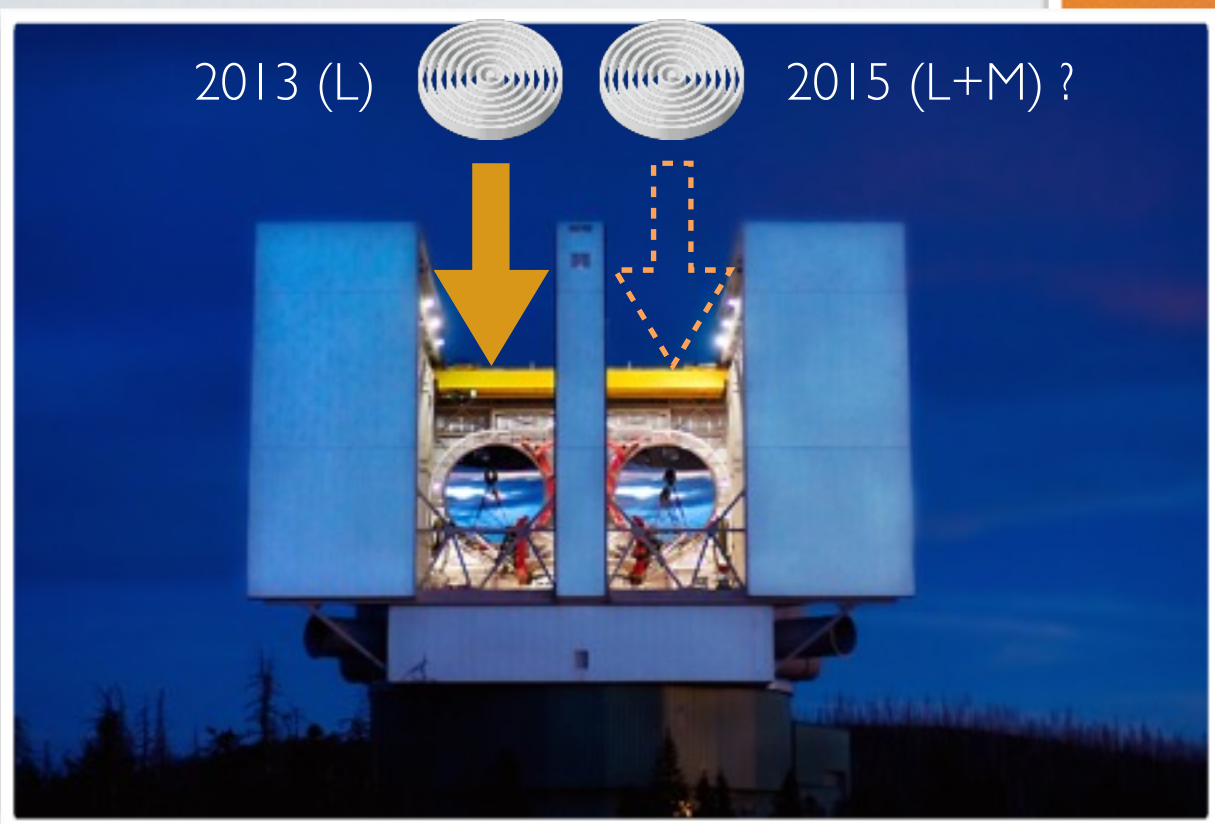
The VORTEX Project

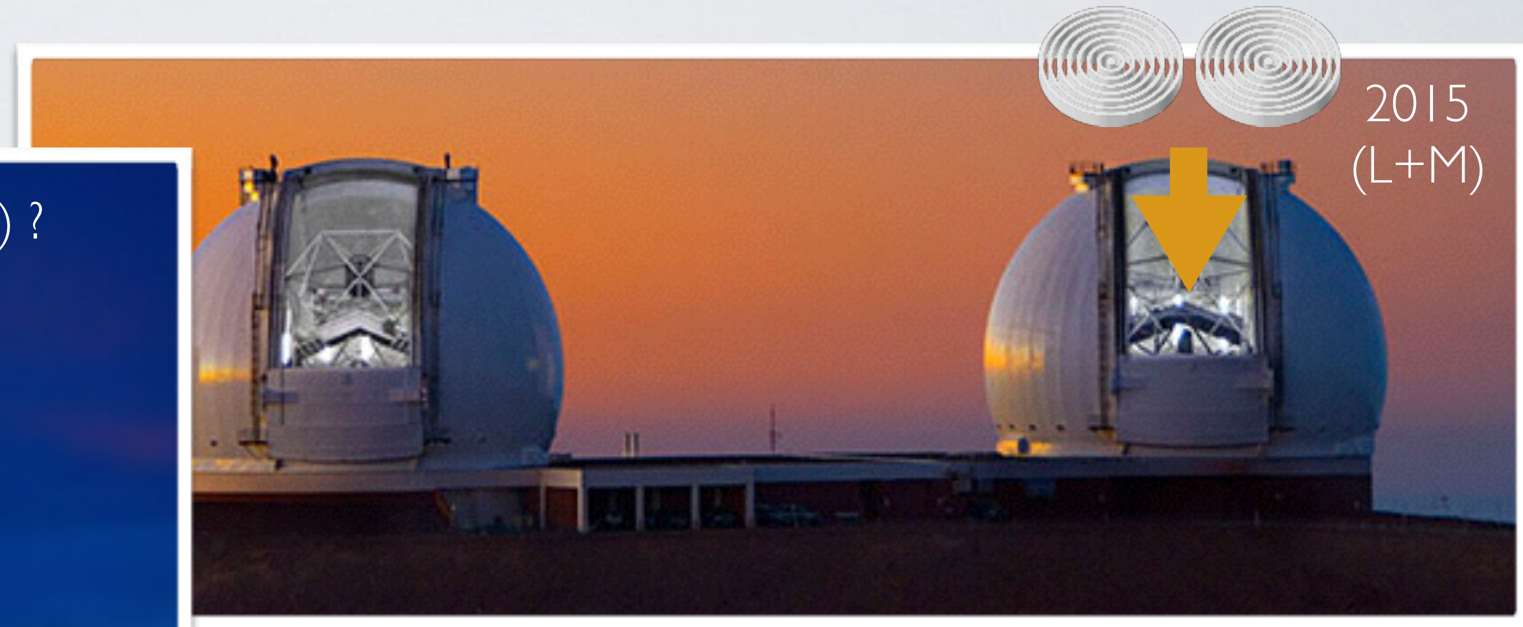


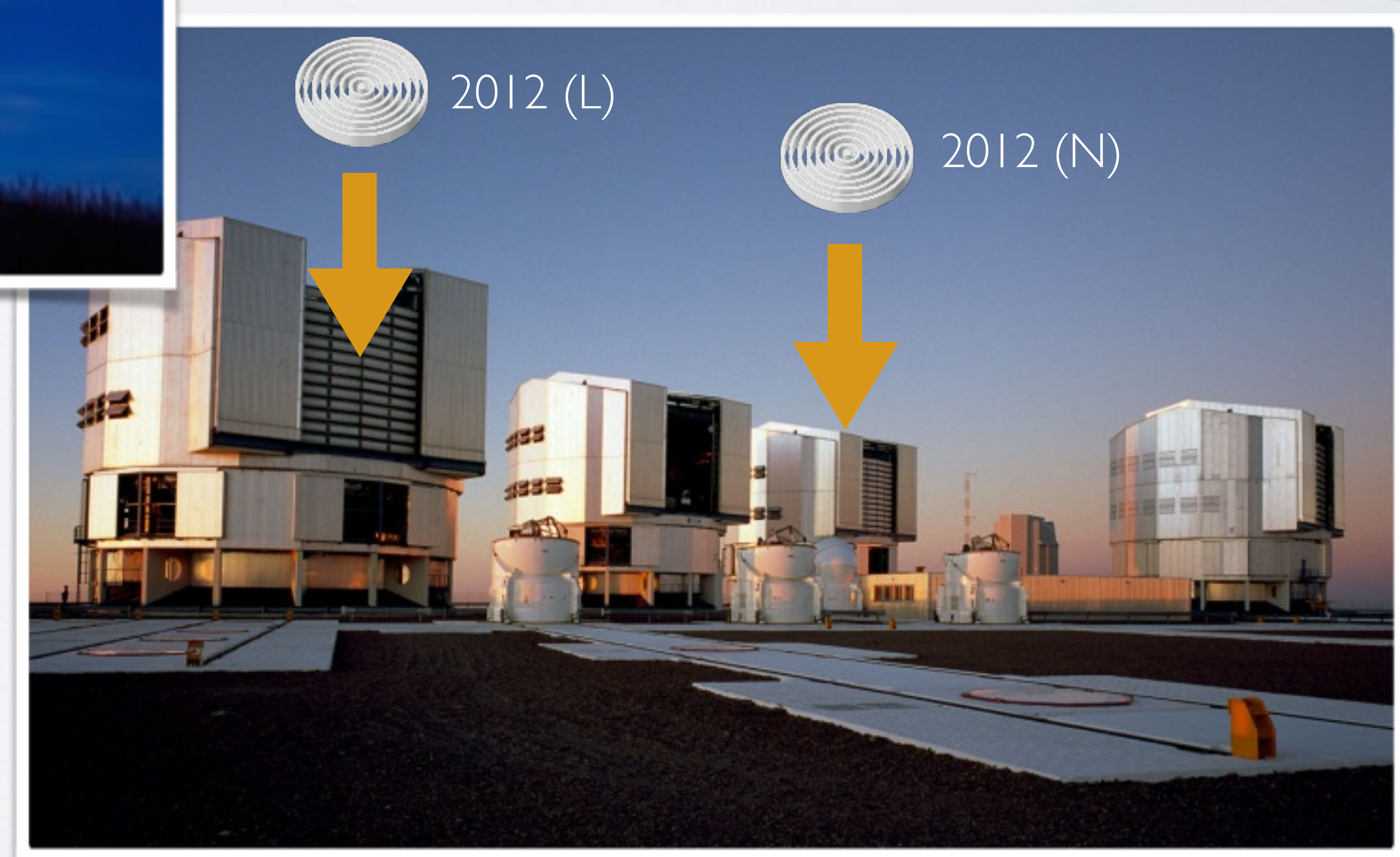
WP1
exploitation

commissioning
observations
image processing

Conquer the World

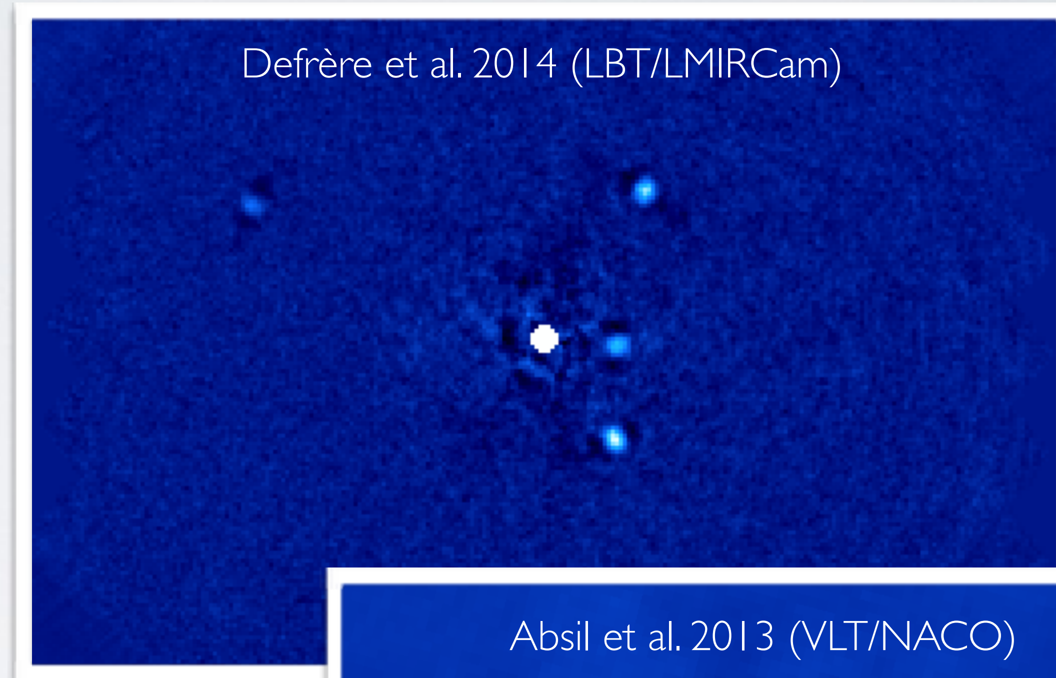


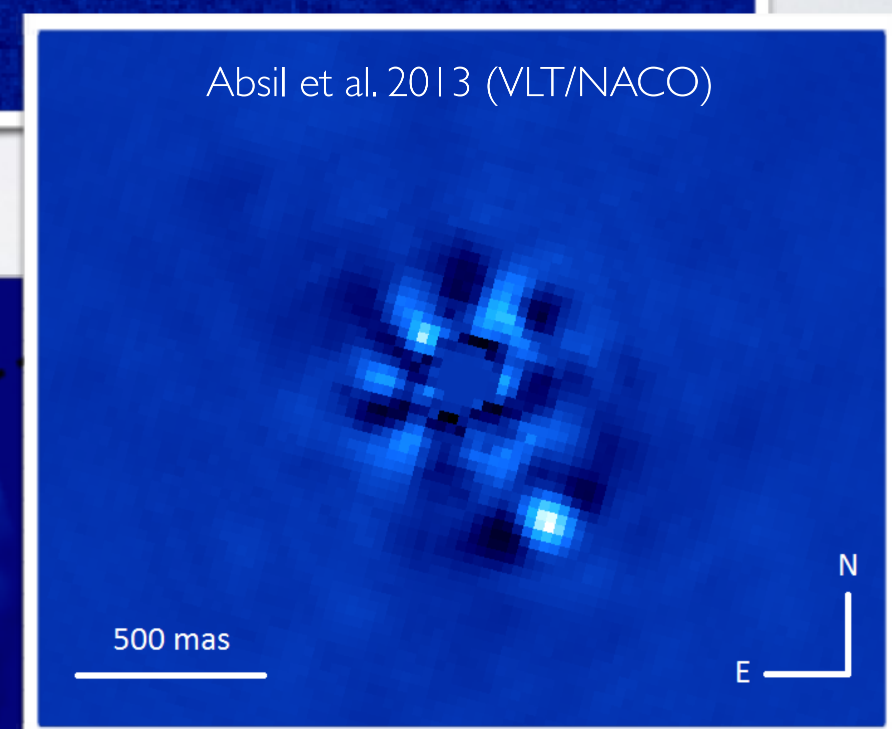


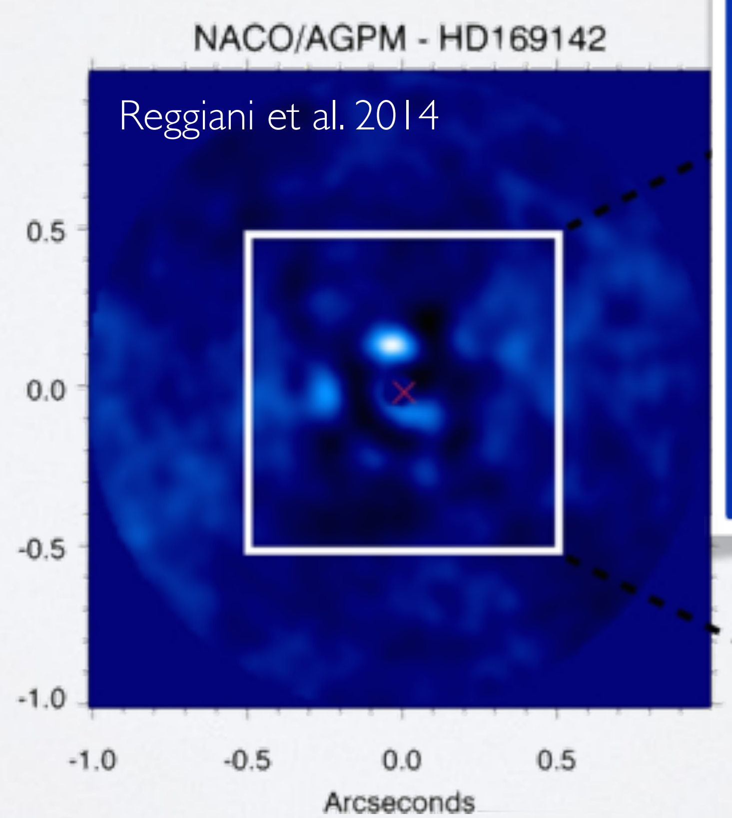


First Observations

- Revisit famous systems
- Dedicated survey (cool dwarfs)
- Transition disks



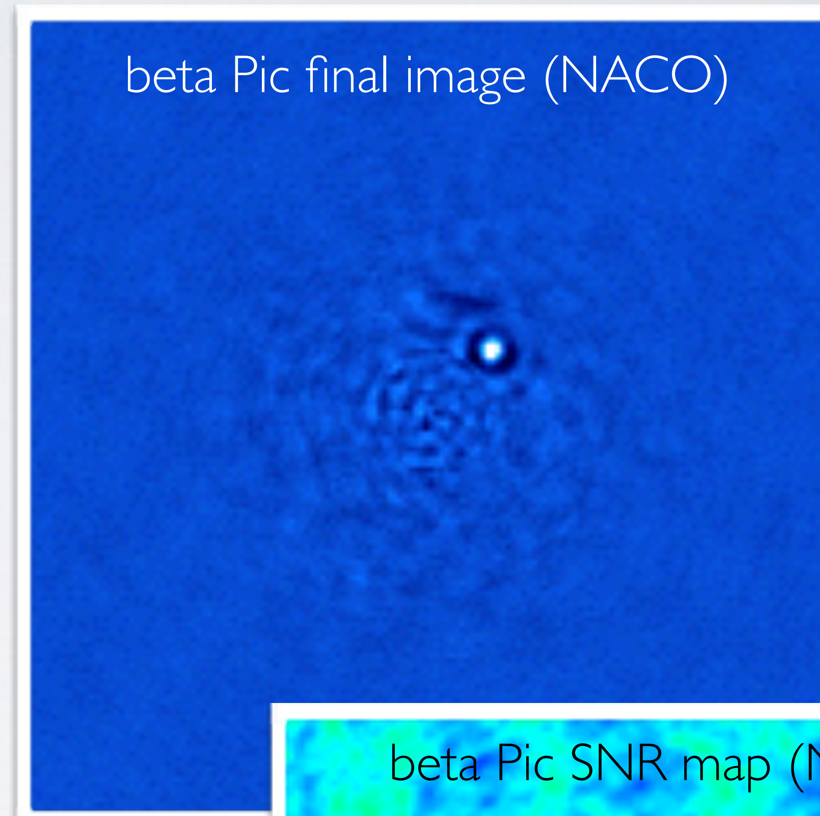


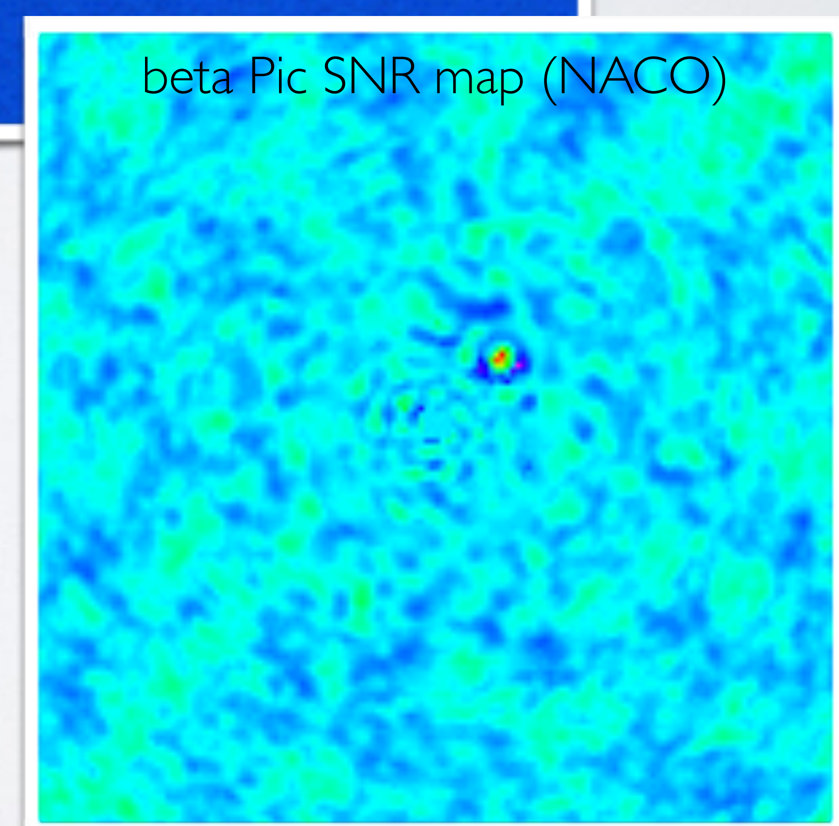


Carlos Gomez

Image Processing

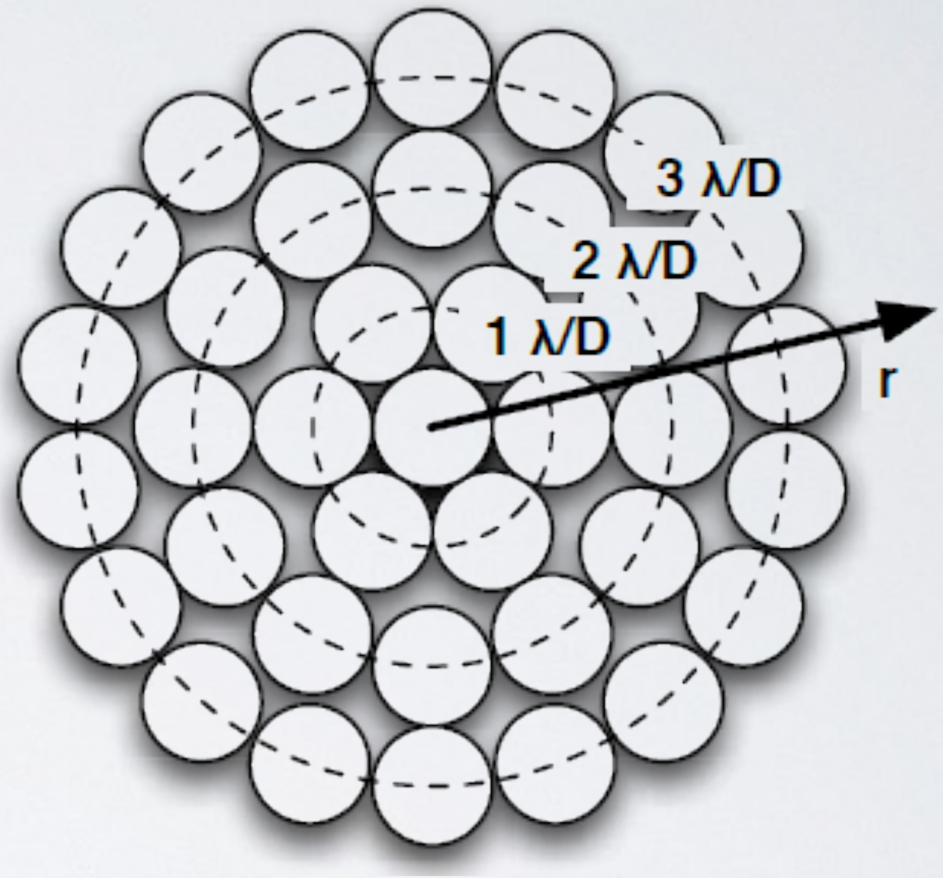
- VORTEX pipeline:
  9k lines python package
- Fast and efficient PCA-based algorithm for ADI/SDI
- Currently testing machine learning techniques + ideas from computer vision field

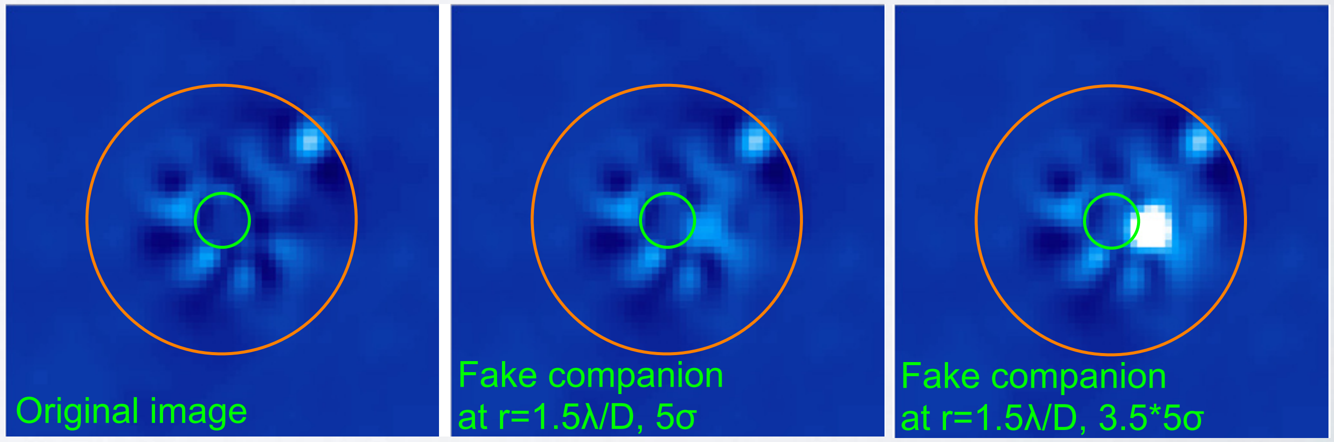




SIGNAL THEORY

- Very small IWA reached with AGPM
- Required revisit of SNR for small sample statistics
- For all the gory details, see Mawet et al. 2014





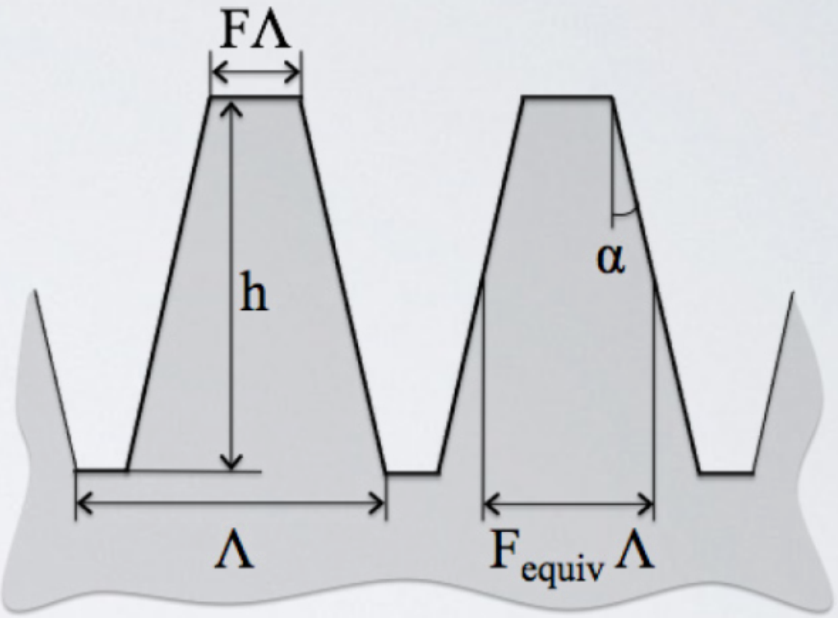
WP2 improvement

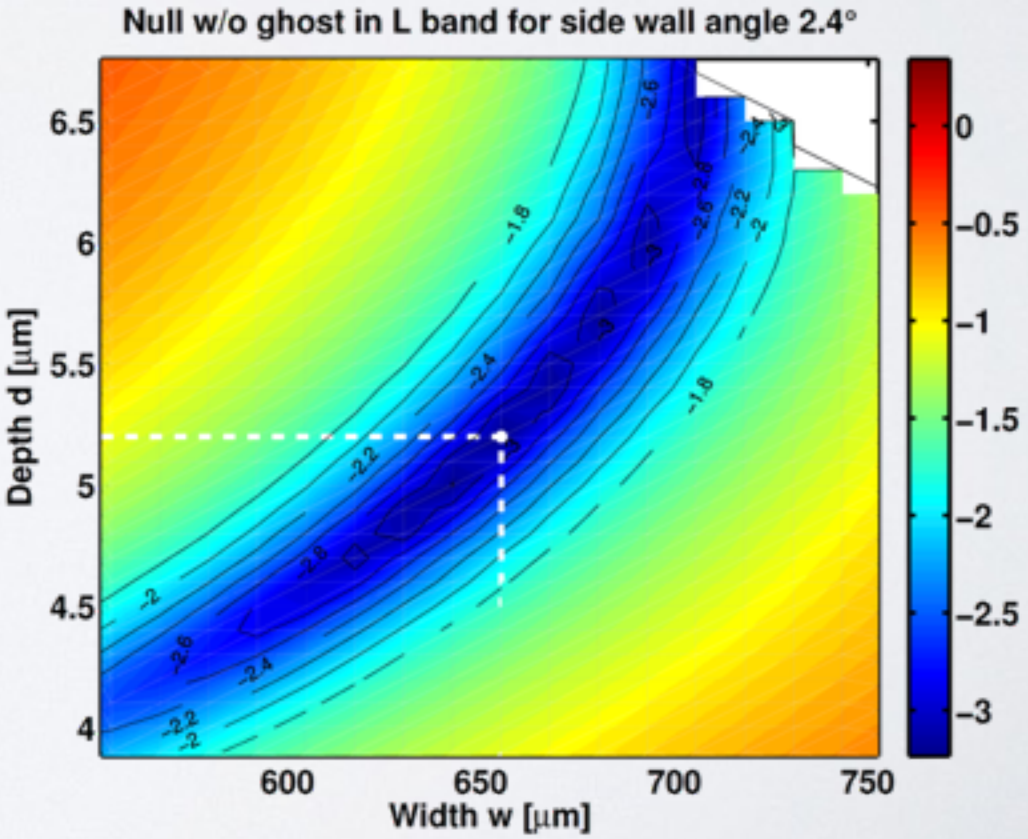
design
manufacturing
testing

Brunella Carlomagno

BETTER MID-IR AGPMS

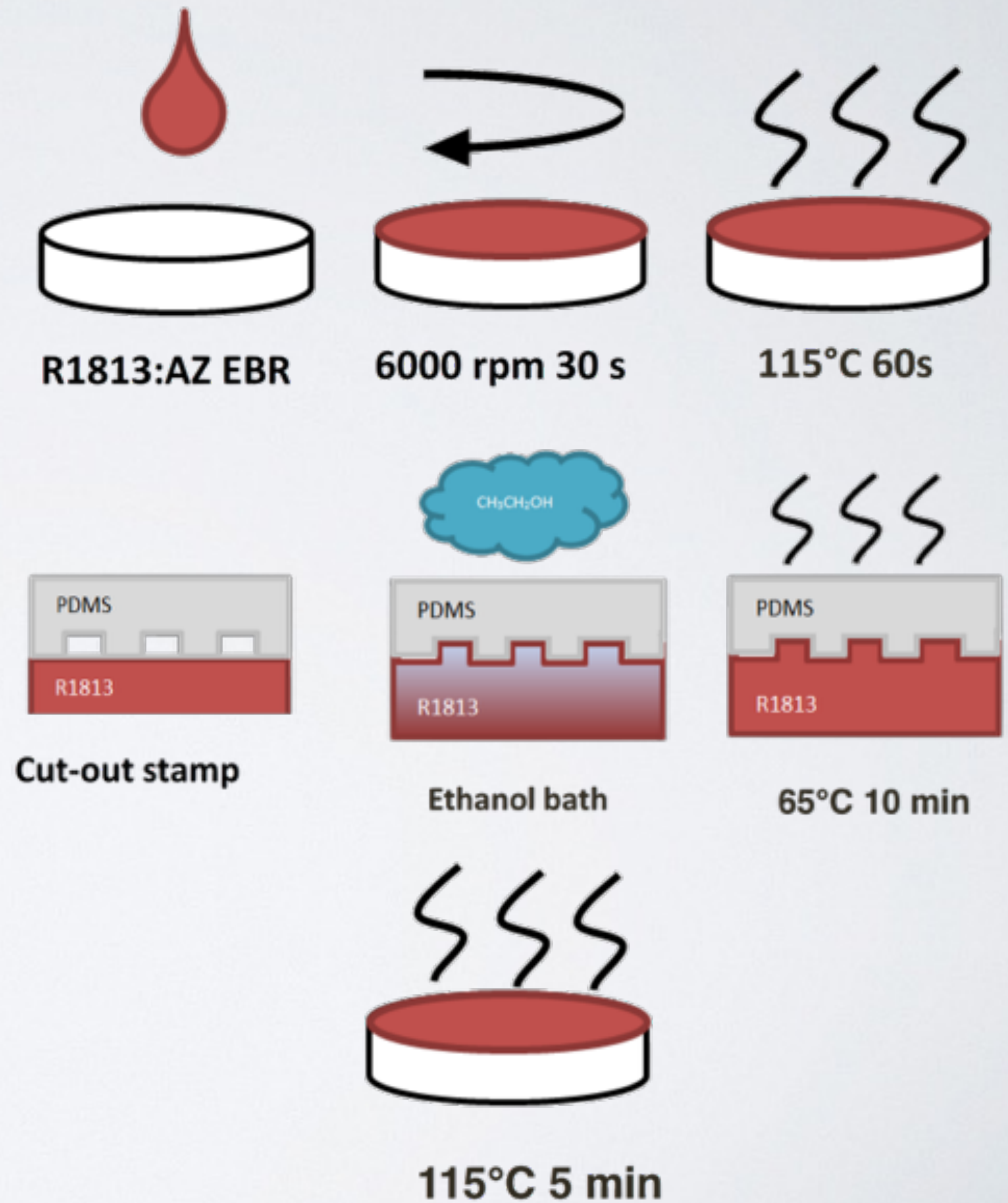
- Rigorous Coupled Wave Analysis to simulate ZOG
- L-band only: optimal peak rejection > 1000:1
- L+M band: optimal peak rejection ~ 500:1
- Goal: EELT/METIS





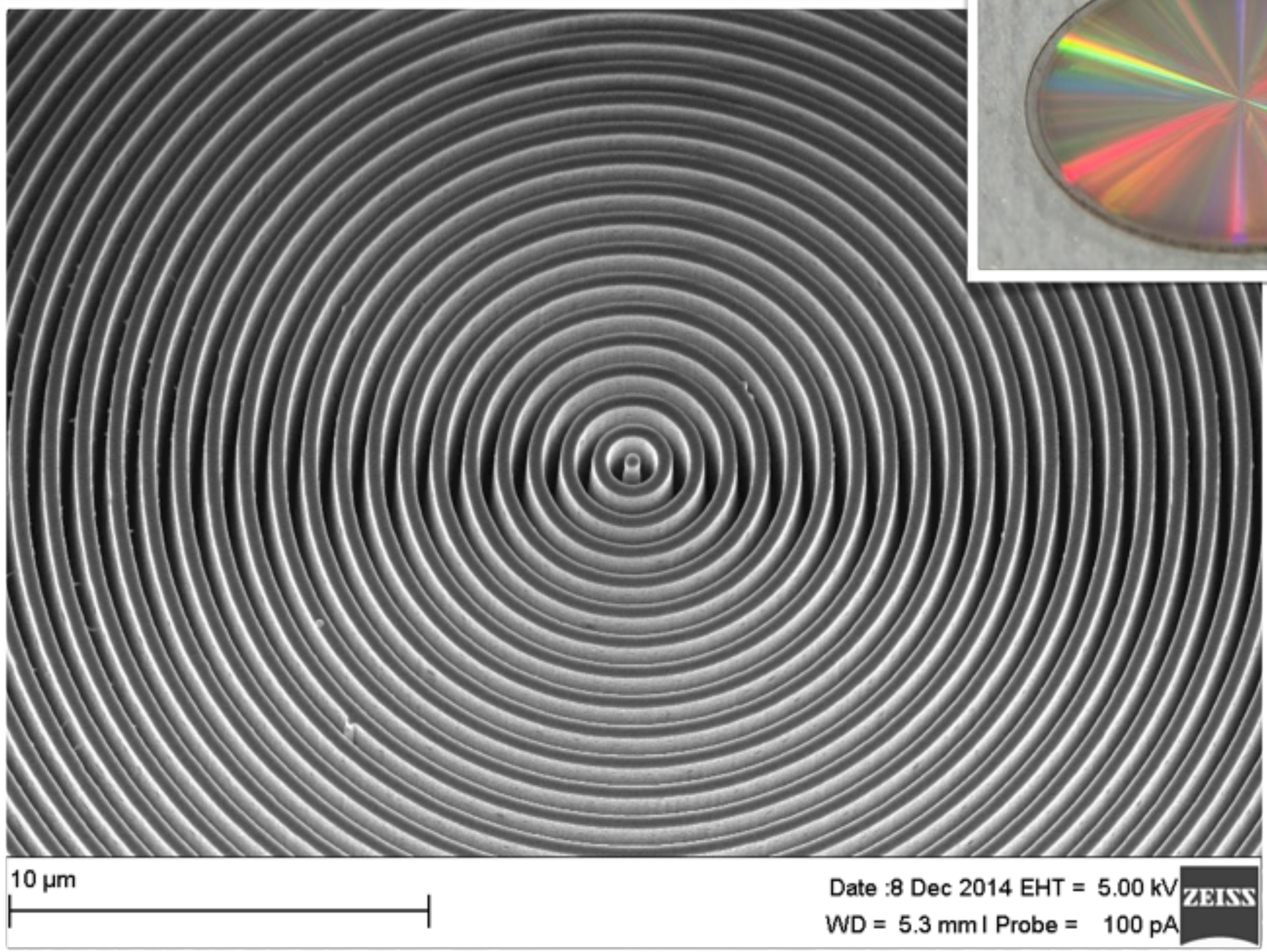
Manufacturing Improvements

- Better pattern transfer with solvent-assisted moulding
- Better control of etch rate
- 600:1 reached in L band, >100:1 in L+M band

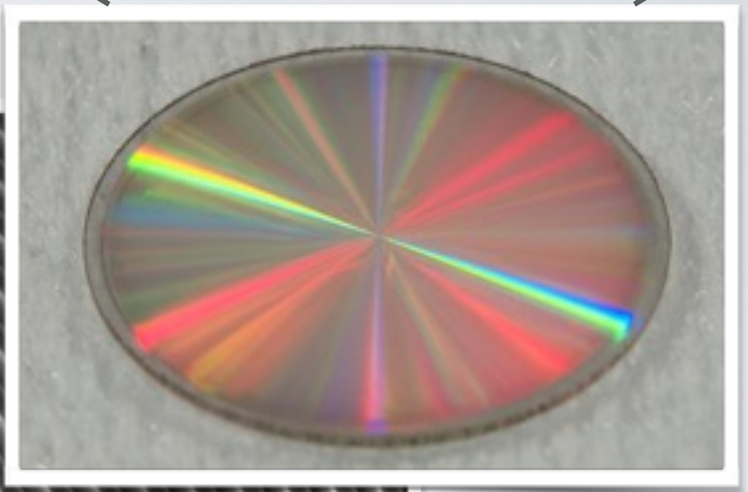


FIRST K-BAND AGPMs

Period = 800nm!!!



10mm



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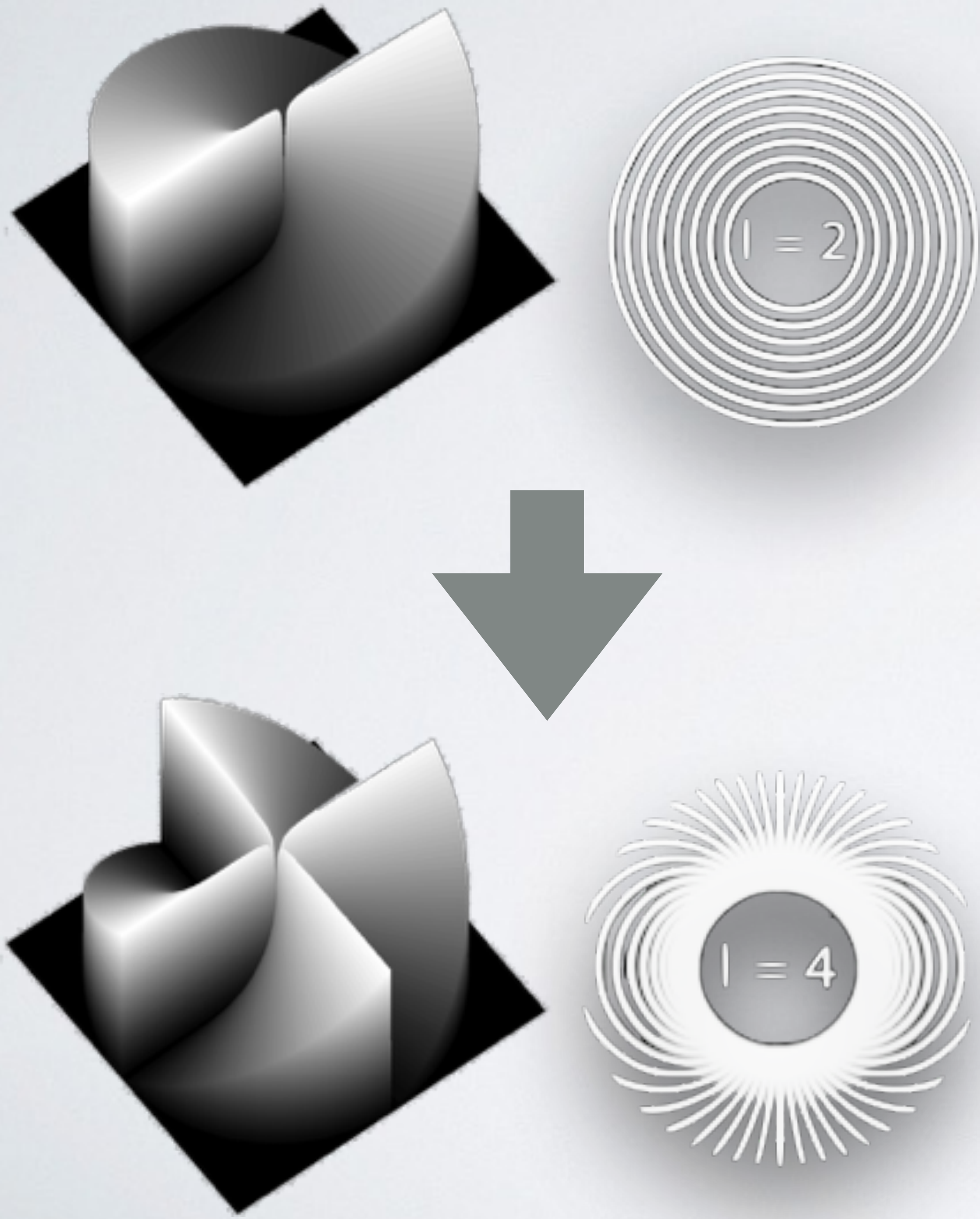
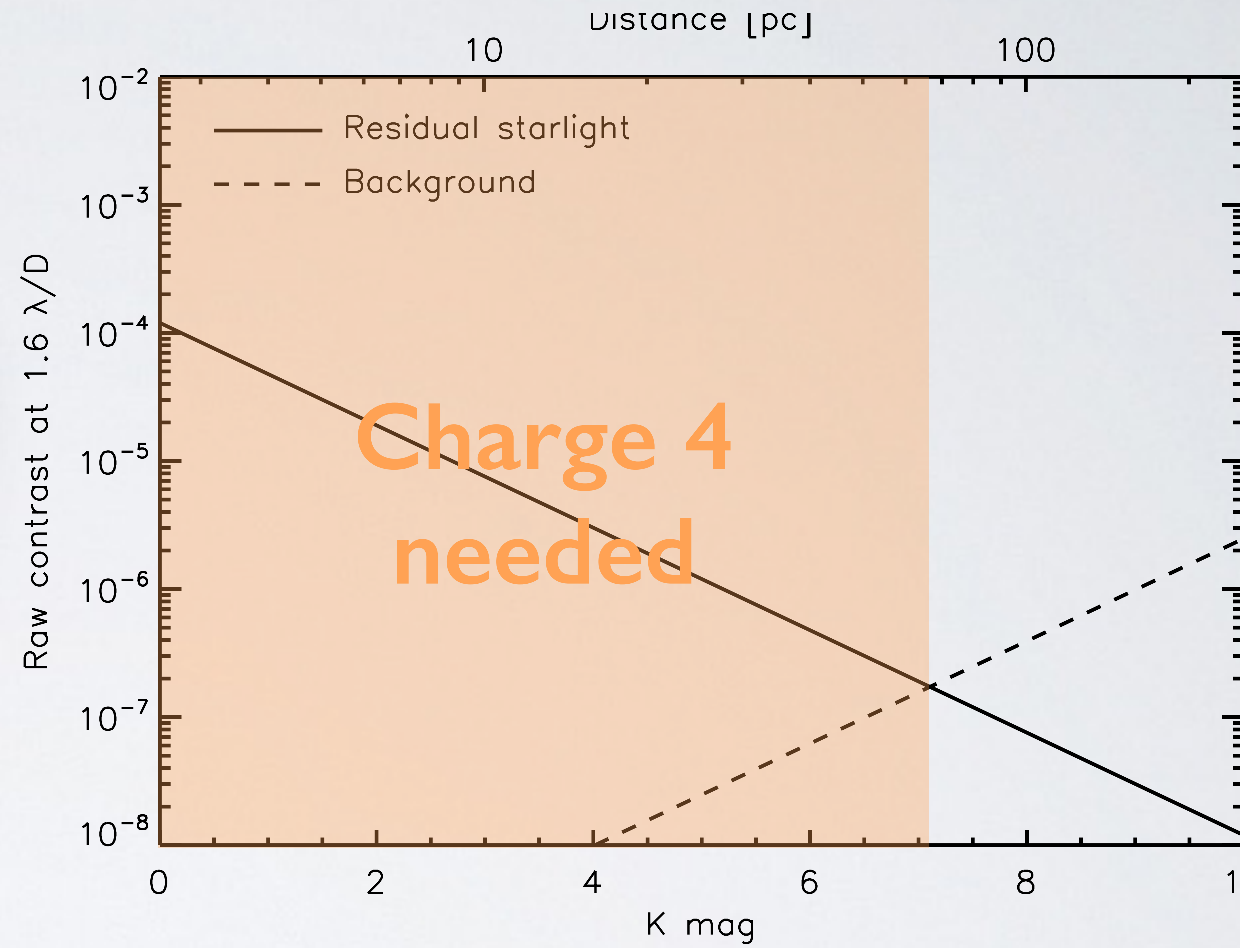
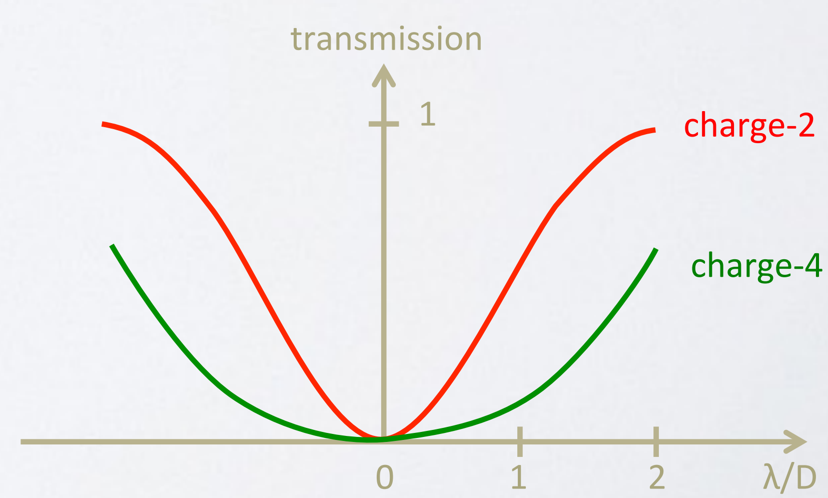
CHARGE-4 VORTEX

Christian Delacroix





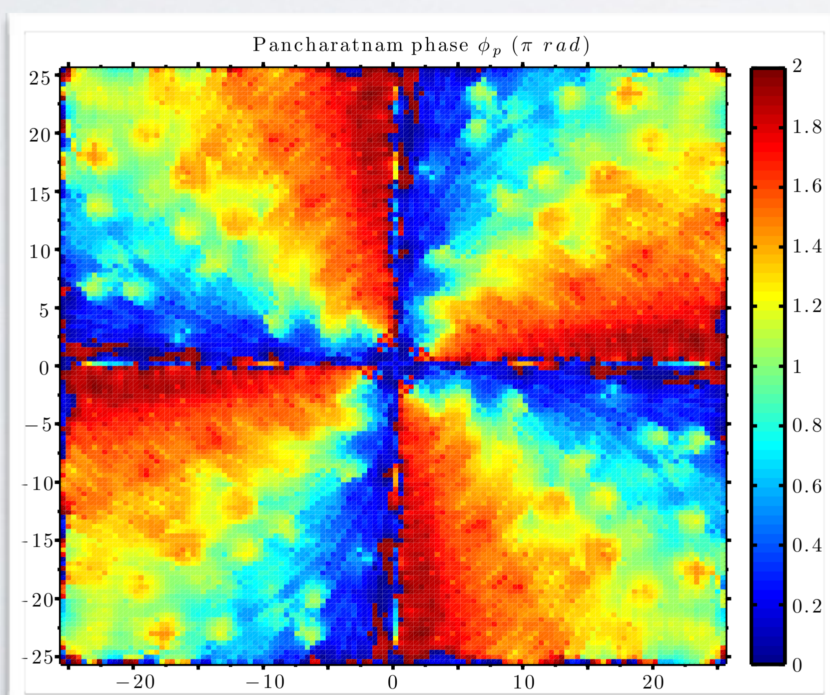


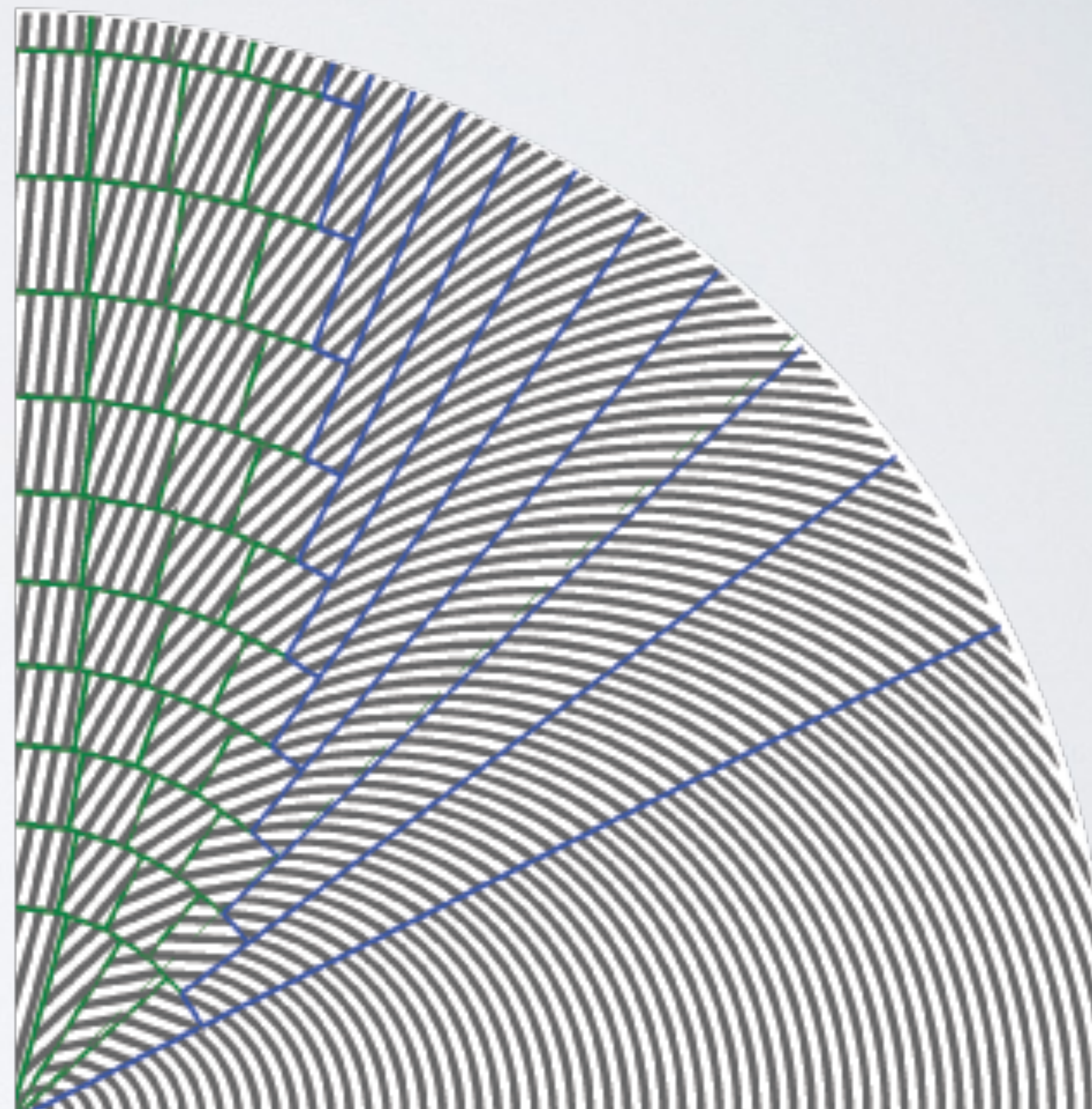
Christian Delacroix

Charge-4 Vortex

- Discretization of the 2D grating pattern, using lines and curves

- 3D FDTD simulations

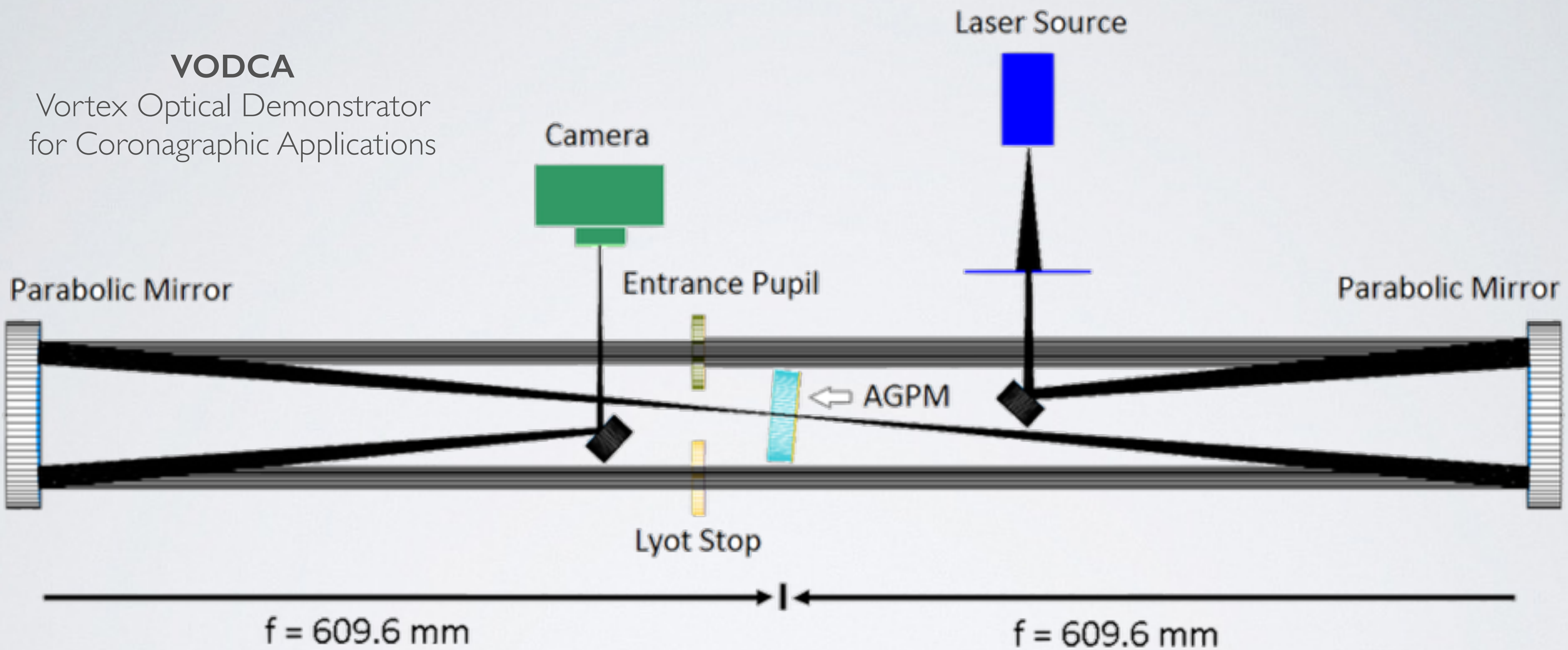




Aïssa Jolivet

PERFORMANCE TESTING

VODCA
Vortex Optical Demonstrator
for Coronagraphic Applications



- All-reflective bench with super-continuum IR source and commercial (FLIR) camera. DM to be added this year.

VORTEX

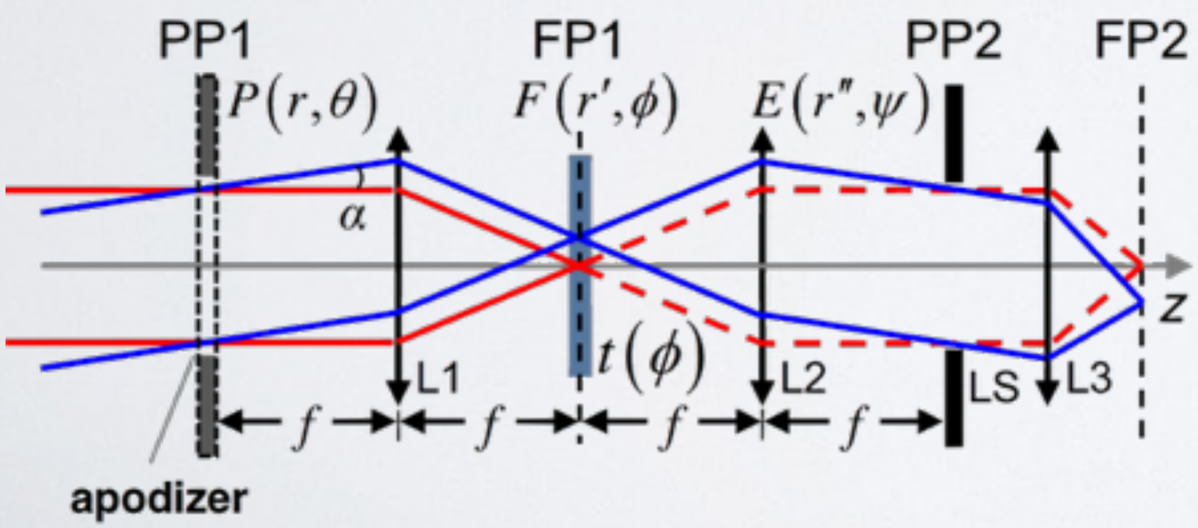
WP3
performance

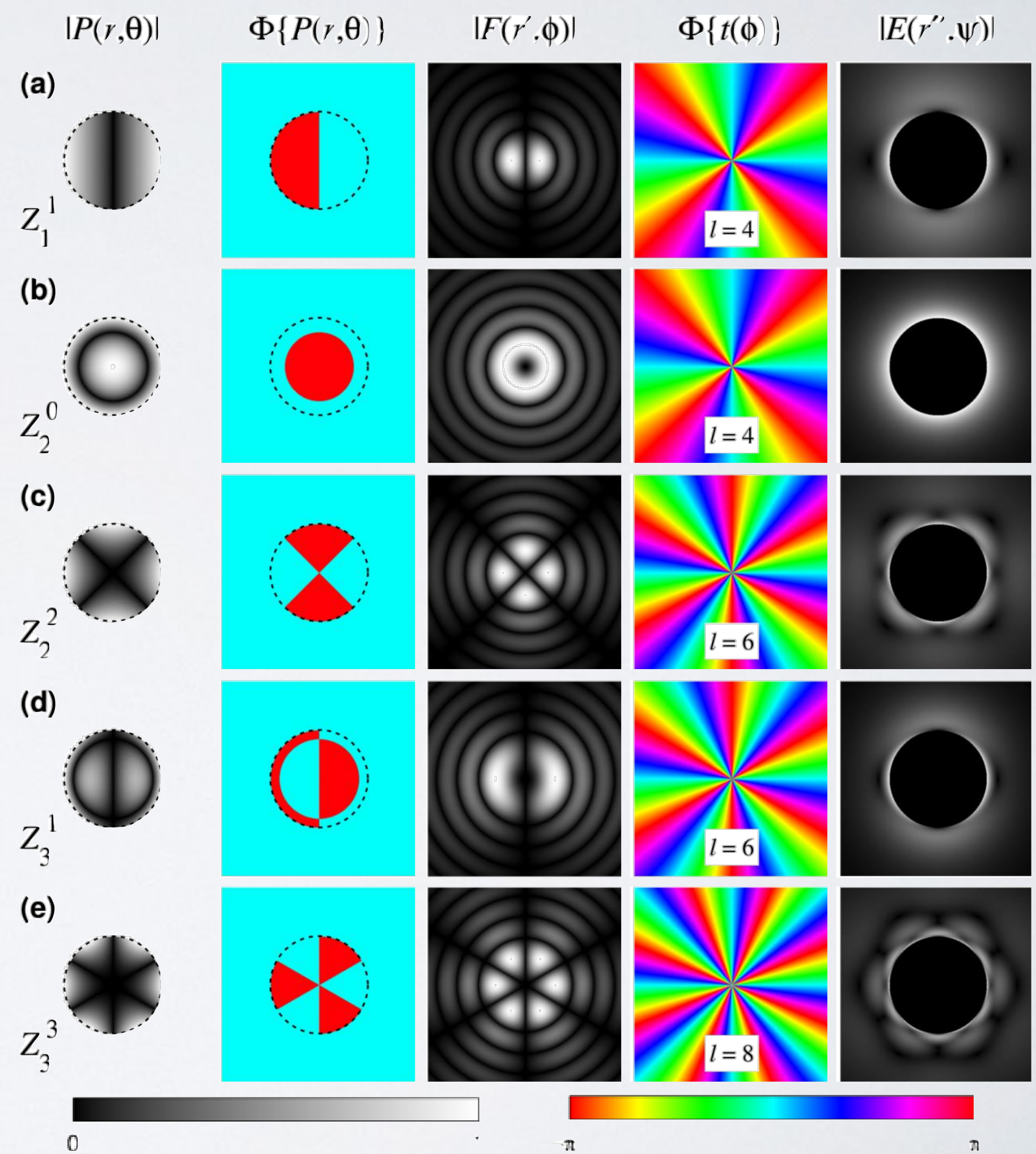
apodisation
wave front sensing
orbital angular momentum

Garreth Ruane

Zernike Amplitude Apodisation

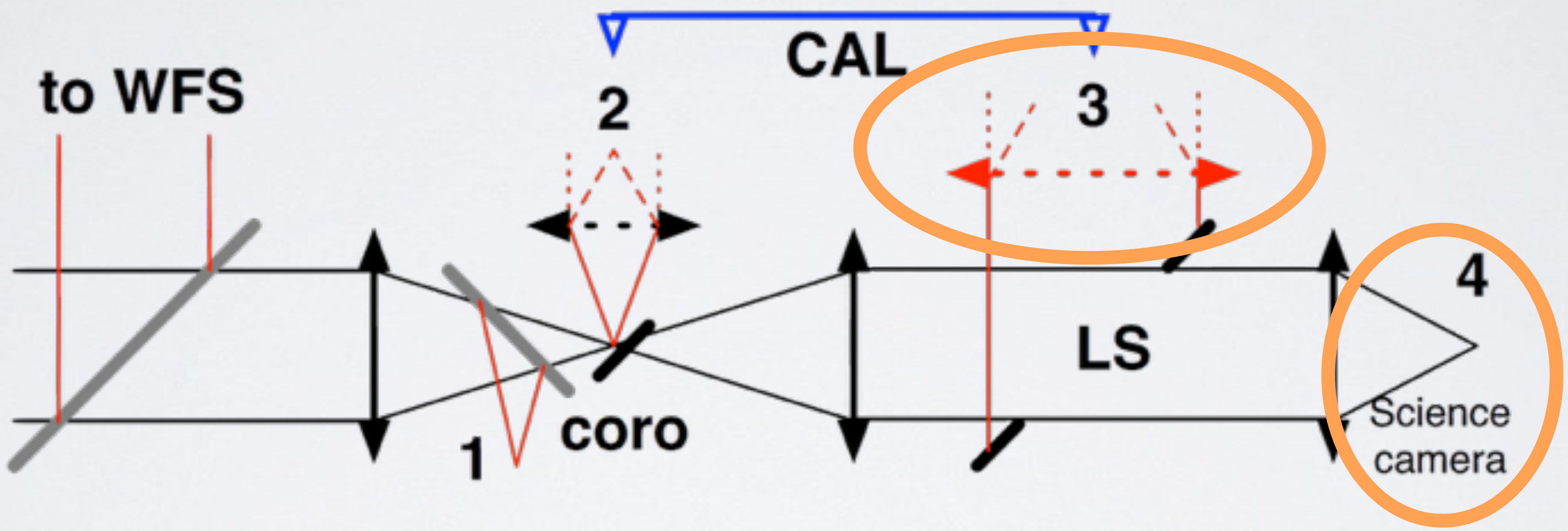
- Preserves the « nodal area » in the pupil plane





Elsa Huby

Post-Vortex Wave Front Sensing



- Wave front sensing at the position of the coronagraph
- Measure (and correct) non-common path aberrations

Elsa Huby

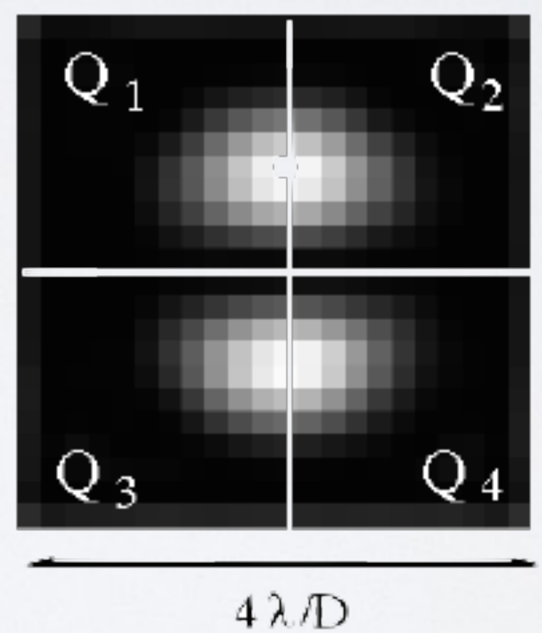
The « 4Q » Method

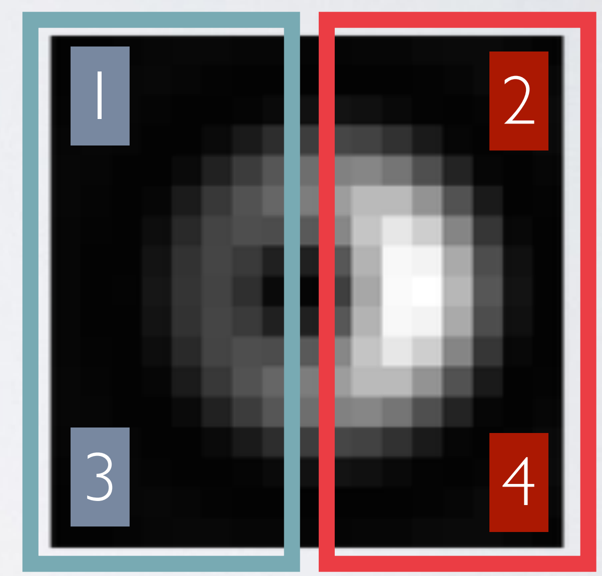
- Differential intensities:

$$\Delta I_x = (I_2 + I_4) - (I_1 + I_3)$$
$$\Delta I_y = (I_1 + I_2) - (I_3 + I_4)$$

- Model:

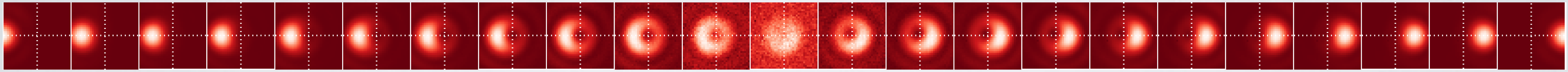
$$\frac{\Delta I_x}{\beta} = T_x^3 + \alpha T_x T_y^2,$$
$$\frac{\Delta I_y}{\beta} = T_y^3 + \alpha T_y T_x^2$$

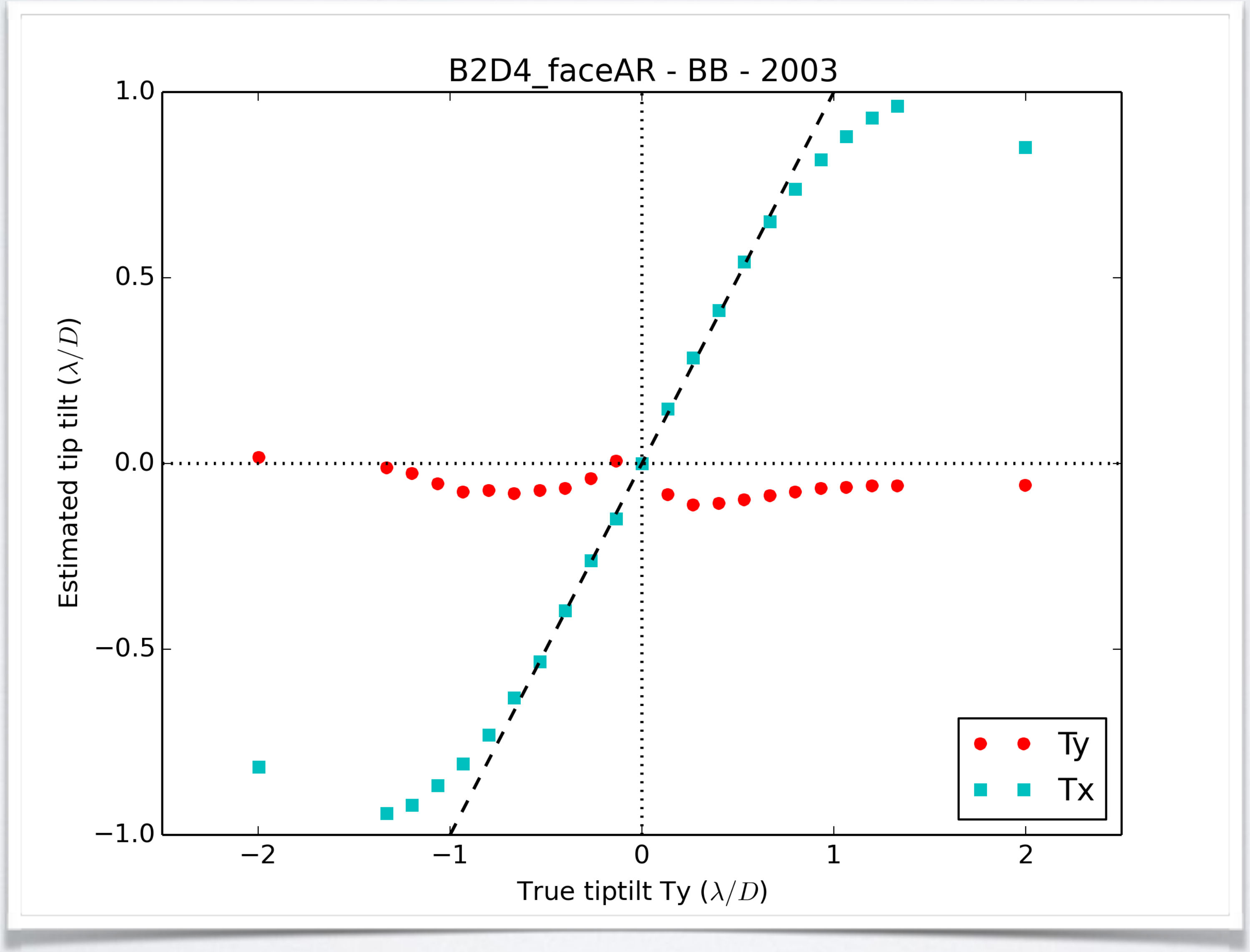




Elsa Huby

4Q Method: Validation





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Elsa Huby

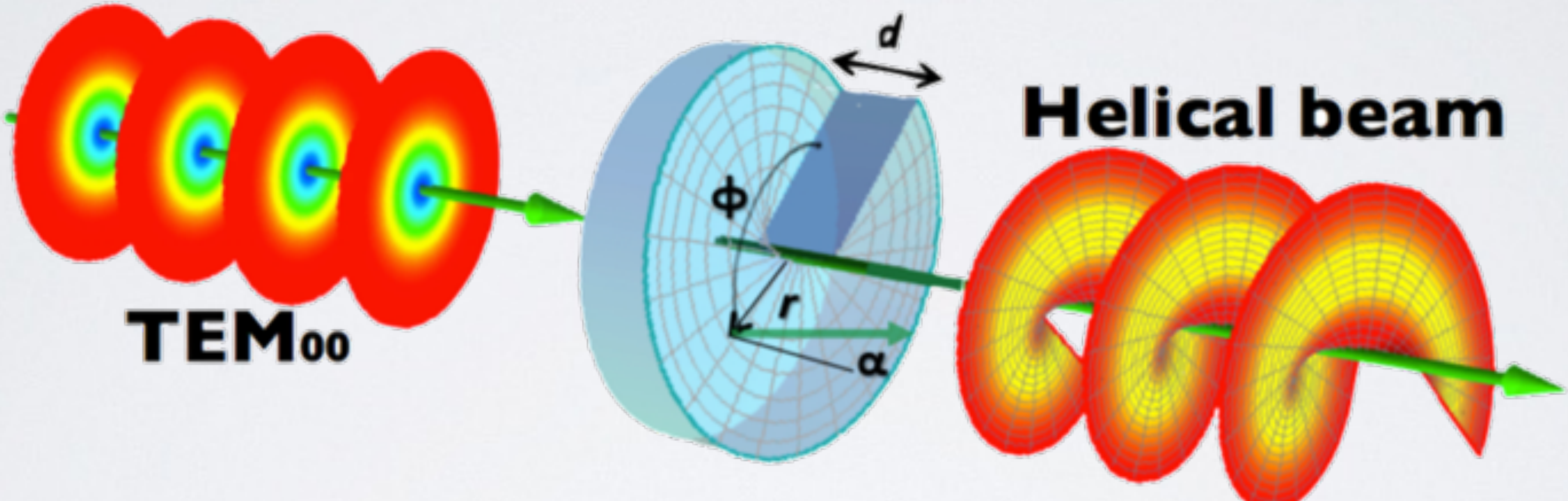
4Q Method: Central Obstruction

Plain pupil

Obstructed pupil

- Breaks the nice (analytical) relationship
- Tip-tilt can still be recovered in a limiting regime and/or with the help of apodisation

Orbital Angular Momentum



Questions?

The VORTEX team, 2014