An Update on the VORTEX Project

Olivier Absil & the VORTEX team
The Vortex Coronagraph in a Nutshell

\[ e^{i\theta} \]

\( l = \text{topological charge (winding number)} \)

\( = \text{height of the screw dislocation} \)
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

Preparation of diamond substrate

Moulding the silicon stamp with PDMS

Nanoimprint

Reactive ion etching
**EARLY ACHIEVEMENTS**

- First N- and L-band AGPMs
- Peak rejection measured at L band
THE VORTEX PROJECT

WP1 exploitation
commissioning
observations
image processing

WP2 improvement
design
manufacturing
testing

WP3 performance
apodisation
wave front sensing
orbital angular momentum
WP1 exploitation
commissioning observations
image processing
Conquer the World
First Observations

- Revisit famous systems
- Dedicated survey (cool dwarfs)
- Transition disks
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
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!!!
**Charge-4 Vortex**

Charge 4 needed
CHARGE-4 VORTEX

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

• 3D FDTD simulations
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.
WP3

performance

apodisation

wave front sensing

orbital angular momentum
Zernike Amplitude Apodisation

- Preserves the « nodal area » in the pupil plane
Post-Vortex Wave Front Sensing

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

\[ \frac{\Delta I_x}{\beta} = T_x^3 + \alpha T_x T_y^2 \]
\[ \frac{\Delta I_y}{\beta} = T_y^3 + \alpha T_y T_x^2 \]
4Q METHOD: VALIDATION

The four quadrant method

Mas et al. 2012

Four quadrant phase mask

Model: VVC

Simulations and analytical derivations show that $\alpha = 1$

Experimental data

Elsa Huby
4Q Method: Central Obstruction

- 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