Development of **FIRST-IR** instrument and study of nulling capabilities

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**Fibered Interferometer for a Single Telescope**

- **High angular resolution**: Interferometry
  - Transform a single telescope into a Fizeau interferometer
  - Take advantage of the already phased beam thanks to AO system

- **High dynamic**: Nulling
  - Use destructive interference to “cancel” the light of the star
    ➡ Reduce significantly the planet/star flux ratio
    ➡ Get rid of photon noise of the star that drown planet flux out

- **Working in the H-Band (1.55\(\mu\)m)** ➡ **Hot Jupiters**

**RECOMBINATION : INTEGRATED OPTIC**
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**RECOMBINATION : INTEGRATED OPTIC**
- Planar waveguides on *silicium chip*
- Single-mode polarization maintaining waveguides
- *stable – compact - easy to integrate*

**NULLER**
- 4 sub-pupils
- 3 ABC combiners → 3 nulls
- 3 ABCD combiners → 3 phases over the nulls
Lyot-based low order wavefront sensor (LLOWFS) for phase mask coronagraphs

Garima Singh, Olivier Guyon, Pierre Baudoz, Frantz Martinache, Nemanja Jovanovic

Principle

\[ I_R(\alpha_x, \alpha_y) - I_0 = \alpha_x S_x + \alpha_y S_y \]

Assuming:
- residual phase error << 1 radian of rms wavefront error in post-AO correction.
- no correlation between low mode aberrations.

Considering only tip-tilt errors \((\alpha_x, \alpha_y)\)

S_x and S_y : response of the sensor to the tip-tilt errors (calibration images).

(Singh et al. 2014, PASP)

LLOWFS implementation on Subaru coronagraphic extreme adaptive optics system (SCExAO)

Coronagraphs
- Vector Vortex (VVC)
- Four quadrant phase mask (FQPM)

Reflective Lyot stop

Reference image

Calibration images (30 nm rms phasemap applied on DM)
- Tip
- Tilt
- Focus
- Oblique Astig
- Right Astig
Closed loop on-sky results with VVC at H band on SCExAO at Subaru Telescope (\(10^{-3}\lambda/D\) closed loop accuracy)

**Calibration Frames on-sky**

(100 nm rms phasemap applied on DM)

- **Reference frame**
- **Tip**
- **Tilt**
- **Focus**
AUTOMATED OPTICAL SYSTEM ALIGNMENT AND LOW-ORDER WAVEFRONT SENSING

Joyce Fang    Cornell University

Method

Geometric Optics:

\[
x_2 = \varepsilon + l \tan \varepsilon' + \left( A + z_{\text{add}} C \right) \left( \frac{x_1 - \varepsilon}{\cos \varepsilon' + \sin \varepsilon \tan \theta_1} \right) + BDz_{\text{add}}(\theta_1 - \varepsilon') \right] \left[ \cos \varepsilon' + \sin \varepsilon' \tan \theta_2 \right]
\]

(1)

\[
\theta_2 = C\left( \frac{x_1 - \varepsilon}{\cos \varepsilon' + \sin \varepsilon' \tan \theta_1} \right) + D(\theta_1 - \varepsilon') + \varepsilon'
\]

(2)

If we want to obtain those parameters of a given system, we will need at least two sets of initial spots \((x_1, y_1)\) and their corresponding final images \((x_2, y_2)\).
Experimental Setup

- The concept is to control the moving lenses and achieve the aligned position by feeding back the image information from the CCD camera. (Both of the moving lenses have 4 DOF, x and y-axis shift, tip and tilt.)
- If the optical system is not perfectly aligned, the CCD image will shift away from the center. The left and right images are simulated by shifting the moving lens 1 and 2 respectively.
- The center of gravity method (COG) can be used to find the shifted distances.
- Moving the lenses independently allows us to break degeneracies in the effects of misalignments of multiple lenses.
Development of a subwavelength grating vortex coronagraph of topological charge 4 (SGVC4)


AGPM lab demonstration
Delacroix et al. 2013

AGPM manufacturing
Forsberg et al. [conf. 9151-44]
From SGVC2 (aka AGPM) … to SGVC4

SGVC4 design: previous works  new design

FDTD 3D-simulations

Don’t miss any VORTEX poster tonight

[conf. 9147-335]
SGVC4
Delacroix et al.

[conf. 9147-346]
Mid-IR AGPM designs for ELT
Carlomagno et al.

[conf. 9148-21]
VODCA – the VORTEX test bench
Jolivet et al.
CubeSat Deformable Mirror Demonstration
Anne Marinan (marinana@mit.edu), Kerri Cahoy

Motivation:
- High-Contrast Imaging in Space
  - Earth-like exoplanet imaging: $10^{-10}$ contrast
- Distortions $\rightarrow$ Speckles and aberrations that ruin contrast
- Wavefront control systems cancel out speckles
  - High actuator density for high spatial-frequency correction
- MEMS mirrors not space-qualified

CubeSat Mission Goals
- Achieve TRL 7 for MEMS DM
- Demonstrate image correction and wavefront sensing algorithms
- Image bright stars and other external objects

Satellite Overview
- 3U CubeSat
- 1.5U Optical Payload
- 1.5U Supporting Bus
- 3-axis stabilized
- COTS components where possible
- Custom electronics interfaces with payload

Mission Status
- Currently in conceptual design phase
- Payload design optimization in progress
- Next milestone: PDR in Fall 2014

This work is funded by a NASA Space Technology Research Fellowship
CubeSat Deformable Mirror Demonstration

**Payload and Experiments**

3 experiment architectures:

- 0 – Internal source + Wavefront sensor
  - Open-loop mirror characterization and closed loop wavefront correction
- 1 – Internal source + Focal plane image:
  - Closed loop correction with focal plane sensor
- 2 – External object + Focal plane image
  - Closed-loop image correction with focal plane sensor

This work is funded by a NASA Space Technology Research Fellowship
A High-Fidelity Solar System Model and High-Contrast Integral Field Spectrograph Prototype for Exoplanet Observations

Haystacks Team: Aki Roberge (PI), Ashlee Wilkins, Maxime Rizzo, Erika Nesvold, Chris Stark, Marc Kuchner, Mike McElwain, Amber Straughn, Vikki Meadows, Ty Robinson, Tommy Wikland, Andrew Lincowski, Brittany Miles

DUST + PLANETS + GALAXIES → Haystacks Data Cube (face-on)
A High-Fidelity Solar System Model and High-Contrast Integral Field Spectrograph Prototype for Exoplanet Observations

PISCES: Fall 2015 delivery to the HCIT

End-to-end testing of high-contrast instrument systems for next-generation direct imaging missions

PISCES Team: Mike McElwain (PI), Marshall Perrin, Qian Gong, Ashlee Wilkins, Karl Stapelfeldt, Tim Brandt, Sally Heap, George Hilton, Jeff Kruk, Dwight Moody, John Trauger