The CGI Flight IFS

Direct Imaging of exoplanets using a coronagraph has become a major field of research both on the ground and in space. Key to the science of direct imaging is the spectroscopic capabilities of the instrument, our ability to extract spectra, and measure the abundance of molecular species such as Methane. To take these spectra, the WFIRST coronagraph instrument (CGI) uses an integral field spectrograph (IFS), which encodes the spectrum into a two-dimensional image on the detector. This results in more efficient detection and characterization of targets, and the spectral information is critical to achieving detection limits below the speckle floor of the imager. The CGI IFS operates in two 18 bands spanning 600nm to 840nm at a nominal spectral resolution of R=50. We present the current science and engineering requirements for the IFS design, the instrument design, anticipated performance, and how the calibration is integrated into the focal plane wavefront control algorithms. We also highlight the role of the Prototype Imaging Spectrograph for Coronagraphic Exoplanet Studies (PISCES) at the JPL High Contrast Imaging Testbed to demonstrate performance and validate calibration methodologies for the flight instrument.

General IFS Design:

- IFS Bandpass: R=5, at 600nm
- Scale: Two sides, 26 channels, 14 lam(D,S,E)
- Control: Two sides, 7 channels, 2.5-5.5 lam(D,S,E)
- Using 'Optimal' estimation of a 3D Gaussian
- Currently working on implementing least-squares extraction
- Working towards higher contrast demonstrations through the next year

High Contrast Demonstration with PISCES:

- IP's Bandpass: R=7, at 600nm
- Scale: Two sides, 26 channels, 14 lam(D,S,E)
- Control: Two sides, 7 channels, 2.5-5.5 lam(D,S,E)
- Using 'Optimal' estimation of a 3D Gaussian
- Currently working on implementing least-squares extraction
- Working towards higher contrast demonstrations through the next year

General Optical Design Specifications:

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Instrument Simulations:

- Baseline differential imaging mode is via reference star subtraction
- Differential images taken and spectra are retrieved via template fitting process
- Example spectra on a fiducial target show anticipated performance using Operating Scenario 5 data
- Performance will evolve, but steps are now in place to work on new operating scenarios
- Example overlay of the IFS FOV overlaid onto HR8799 to show detection area

Optomechanical Design and Trades:

Carried out a trade on a reflective design
- Parfactive: slightly better image quality, likely cheaper, optomechanics/eclipsing bands more difficult to manufacture, more mechanically robust, more difficult packing, sensitive to vibration
- Lenslet Geometry chosen to most optimally pack detector
   - Not limited to detector size, but mitigates coma, astigmatism, etc.
- Requirements driving optomechanics are to keep IFS stable over:
   - Mission lifetime (e.g. > 10 years)
   - Instrument performance (e.g. image blur)
- Imaging: An interferometric image relay, feeding lenslet array

Some On-Orbit Calibration Strategies:

- Example data using PISCES
- Summed probe sets provide a suitable "flat field" for cube calibration
- NO telescope repointing would be required
- Open question: can we recalibrate data cube with a broadband flat?
- Two likely paths forward, both of which should work but not on initial set
- Testing can be done with PISCES and CHARIS

- Shells in the cross-spectral direction exhibit relatively uniform residuals in spectral direction
- Residuals in the spectral direction exhibit "hot spots" from over/under shoot
- Characteristics in broadband data potentially useful for self-calibration of the IFS cube
- Makes calibration approach compatible with wavefront control probing

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- Current Calibration
- Beamlet Calibration
- Sensor Calibration
- Error