GPI INSTRUMENT PAGES

This document presents a snapshot of the GPI Instrument web pages as of the date of the call for letters of intent. Please consult the GPI web pages themselves for up to the minute information.

GPI Home Page

Introduction

The goal of these pages (at the time of the call for Campaign letters of intent, December 2010) is to provide information on GPI's capabilities sufficient to allow PIs to propose projects which could be accomplished with the instrument given its anticipated performance. We provide some detail on the instrument's internal configurations but mainly concentrate on performance aspects. If in any doubt when writing a proposal, please contact the instrument scientist.

Overview of GPI's Capabilities

GPI is an extreme adaptive-optics imaging polarimeter/integral-field spectrometer, which will provide diffraction-limited data between 0.9 and 2.4 microns. The system will provide contrast ratios of 10^7 on companions at separations of 0.2-1 arcsecond in a 1-2 hour observation. The science instrument will provide spectroscopy or dual-beam polarimetry of any object in the field of view. Bright natural guide stars (I<9 mag) are required for optimal performance of the GPI adaptive optics system. GPI will be capable of detecting point sources down to H = 23 mag., with ≥ 5-sigma, in 1 hour (absent photon noise from a bright companion). For more information on achievable contrast, see the Contrast Page.

GPI combines four main optomechanical systems:

- The adaptive optics (AO) system, responsible for fast measurement of the instantaneous wave front, and for providing wave front control via two deformable mirrors.
- The calibration unit (CAL) is a high-accuracy infrared wave front sensor tightly integrated with the coronagraph. It provides precise and accurate measurements of the time-averaged wave front at the science wavelength and coronagraph focal plane, to suppress persistent speckles caused by quasi-static wave front errors in the final image. It also provides pointing and focus sensing to keep the target star centered on the coronagraph with 1mas accuracy and slow low to high-order aberration corrections.
- The coronagraph uses a combination of apodized masks and focal-plane stops to control diffraction and pinned speckles.
- The integral field spectrograph produces the final science image, including simultaneous multiple channels to suppress residual speckle noise in the spectroscopy mode, or polarimetric imaging allowing the determination of the four Stokes parameters.

The primary data product of the IFS is a data cube consisting of slightly more than 200x200 spatial locations, each with typically 18 spectral channels in spectroscopy mode and two spots in each position in polarimetry mode. The final field of view (FOV) is 2.8 arcseconds on a side, with 14 milliarcsecond sampling. A figure showing the expected format of data on the detector is given here.

The Instrument Scientist for GPI is Fredrik Rantakyrö.

How to use these pages

The GPI pages are organized as follows (pages active at the time of the Call for Campaign Proposals are in boldface):

- Status and Availability: Modes available in the current and upcoming semesters; links to news items
- **Default Mode: Most common configuration options**
- **Sensitivity and Overheads: Suggested minimum observation times and details of observing overheads**
- **Contrast curves: Contrast ratio as a function of guide star brightness and separation**
- Calibration: How to calibrate GPI observations
- Observation Preparation: How to configure GPI in the Observing Tool
- Data Format and Reduction: Examples of GPI data and links to data reduction resources
- **Documents: GPI design documents and references**
- GPI Acronyms: Commonly used acronyms particular to GPI

Default Mode Page

Instrument Configuration

The primary user configuration decision is over the coronagraph focal plane stop and pupil mask, the observing wavelength (Y, J, H or one of two filters in the K band) and the desired contrast and inner working distance (size of the Coronagraphic mask). Coronagraph configurations are: direct imaging (for imaging or polarimetric imaging), Coronagraphic (combined with either polarimetric imaging, or spectroscopy). Note that the Y filter is a design goal; you should state clearly if the Y filter is critical to your programme.

The tables below list the properties of the standard GPI coronagraphic configurations. GPI will automatically select appropriate apodizer, focal plane masks, and Lyot stops for each wavelength. In GPI's apodized-pupil Lyot coronagraph, these three are carefully matched to each other - performance would be severely degraded if e.g. the Y-band focal plane mask was used at K band.

Configuration	Filter	Wavelength range (1/2 power bandpass, microns)	Spectral resolution (per 2 pixels)	Coronagraph focal plane mask diameter (mas)
Y-coron	Y	0.95 - 1.14	34-36	156
J-coron	J	1.12 - 1.35	35-39	184
H-coron	H	1.50 - 1.80	44-49	246
K1-coron	K1	1.9 - 2.19	62-70	306
K2-coron	K2	2.13 - 2.4	75-83	306

Notes:

Direct imaging (without coronagraph) is an option for all filters - to specify, use e.g. "K1-direct".

Spectral resolution varies slightly across the detector; typical values are given above. Each individual spectrum is 12-18 pixels long. The coronagraph mask diameter sets a hard limit on the inner working angle, but typically full performance is only achieved ~1 λ/D beyond the mask radius; the contrast curves given in the Contrast page should be used to predict performance at a given radius.

In addition, coronagraph masks are available for a non-redundant aperture masking mode, and a "deep" H band mode that sacrifices inner working distance for better achromatic characterization of planets. These modes may be supported if a case is made; if you feel that you wish to take advantage of a trade between contrast and inner working distance, please contact the instrument scientist.

In polarimetric mode, the light is not spectrally dispersed - the whole waveband is split into two polarization channels.

Configuration	Filter	Wavelength range (1/2 power bandpass, microns)	Coronagraph mask diameter (mas)
Y-coron-pol	Y	0.95 - 1.14	156
J-coron-pol	J	1.12 - 1.35	184
H-coron=pol	H	1.50 - 1.80	246
K1-coron-pol	K1	1.9 - 2.19	306
K2-coron-pol	K2	2.13 - 2.4	306

For your science target, you will need to be able to specify its magnitude both in the I band and in your observing waveband. This information, combined with estimates of r_0 and t_0 from prior, internal, WFS telemetry, is used to pre-configure the AO system, including loop gains, bandwidths, and to select the sub-aperture size for the fast WFS. Wavefront sensors, wavefront controllers, and calibration system all operate autonomously.

In the direct imaging mode (without coronagraph) the CAL unit is not available. Note that the contrast curves are based on the assumption of the use of a coronagraphic mask.

The choice of masks is dictated by your science goals. A full set of possible combinations will ultimately be provided. The tables above give a representative list; in special cases, free mixing of mask combinations may be possible. Please contact the instrument scientist if you feel you need a non-standard combination which is not listed.The links below go to design documents which contain more details. Specific items are discussed in the following list:

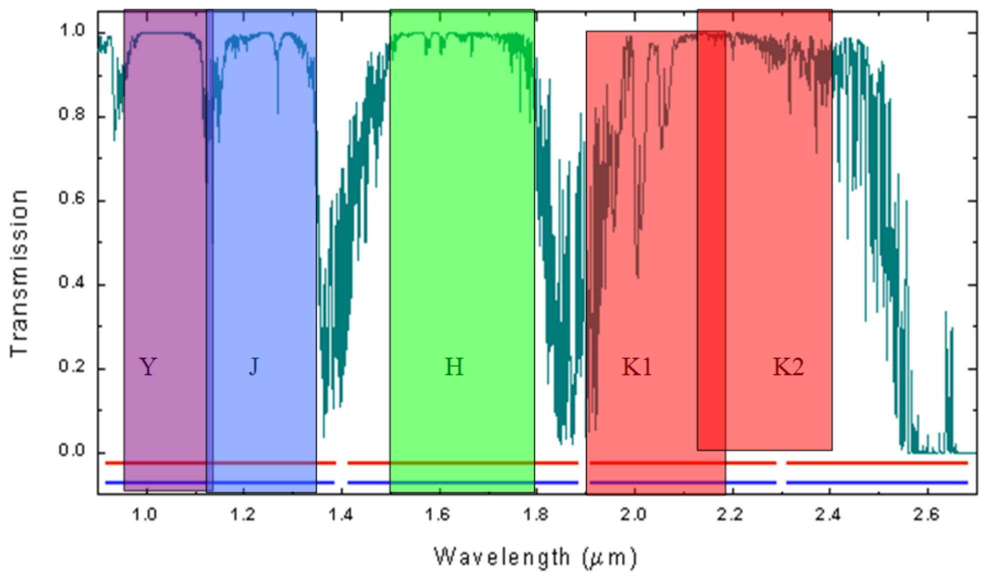
1. Compromise masks for smaller and larger Inner Working Area OCDD Section 8
2. Saturation and brightest observable objects: FPRD Section 5.5.2.3.4 and 5.6.1.4

Science Camera Configuration

The IFS science instrument has few moving parts. The basic parameters are operating wavelength (set by filters) and polarimetry mode selection. The science camera incorporates the following mechanisms:

Cold pupil mask. As described above.

Filter wheels. Blocking filters are used to isolate diffraction orders and to control the background reaching the detector array. These will closely approximate the standard *Y*, *J*, *H* filters, plus two custom filters (*K*1 and *K*2) to span the two-micron window. Filter bandpasses are listed in the tables above, and are shown graphically in the figure below. As stated above, provision of the Y filter is a design goal.



Polarization analyzer. An optional polarizing beam splitter (a Wollaston prism), introduces an angular deflection between ordinary and extraordinary rays and produces two images with orthogonal polarization states on the focal plane array. Simultaneously, an "un-prism" deploys that partially cancels the spectral dispersion of the main prism. Together with an external rotating half-wave plate, the analyzer permits measurement of the Stokes parameters.

Science Detector Configuration

On-chip integration time will be set automatically, by two considerations. First, the integration time must be long enough that speckle noise or photon halo shot noise must dominate over detector read noise and dark current. Second, the on-chip integration time must be sufficiently short that trailing of images does not significantly degrade detectability of faint companions at the outer working distance.

For bright stars, the H2RG will support subarray readout modes allowing very short exposures. In full-readout mode for spectroscopy, the detector will just enter saturation on H magnitudes brigher than 2.

Sensitivity and Overheads Page

Sensitivity

For faint targets, GPI is expected to achieve 5-σ sensitivity at H=23 in one hour in spectroscopic mode. Achieved sensitivity is a function of many parameters, including contrast, inner working distance, brightness of the central star (if any), observing mode (dithered, sky-offset, sky-rotation) and it is not yet possible to provide estimates for all modes. Further details will be made available upon commissioning, but for the purposes of PIs generating proposals for Campaign observing, please assume that you will require a typical observation of at least 1 hour on each science target, irrespective of filter. If you believe that your programme will require significantly more or significantly less than this per target, please state so clearly in your proposal and contact the instrument scientist to confirm that the estimate is appropriate.

Overheads

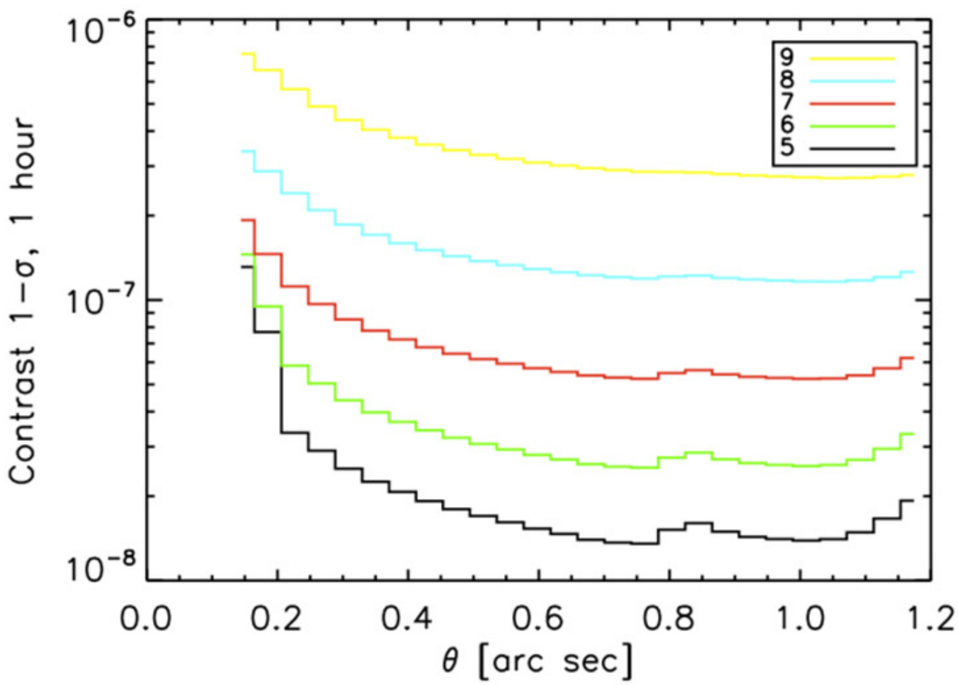
The nominal GPI acquisition time is 10 minutes. This time is expected to apply to both coronagraphic and non-coronagraphic modes when the target is a bright (V <~11), single star, and should be added into your overall time estimate. Fainter targets, or targets in very crowded fields requiring the use of finder charts, may require longer acquisitions. Please note that the field of view is very small; so accurate positions and proper motions will be essential for efficient acquisitions.

The following will be included as baseline calibrations (for baseline telluric standard frequency, see the IR Calibrations page). You do *not* need to account for these in your total requested time:

- PSF standards
- Telluric cancellation standards
- Polarization standards

Contrast Page

Contrast curves for H-band from end-to-end AO and Fresnel simulations of GPI are shown in the figure below. 1-hour observations were assumed, and the contrast is shown per single R~45 spectral channel - the broadband contrast would be higher in proportion to the bandpass. Contrast is a function of both I magnitude (which determines AO performance) and the magnitude at the observing wavelength (which determines photon noise from the starlight halo); curves are given as a function of I magnitude. Contrast on stars brighter than I=5 mag will probably be limited by quasi-static speckle effects, so the I=5 mag curve should be used for all brighter cases.



These curves have only been calculated for H band, with the default apodizer mask. Contrast *vs*. radius will be similar for the J and K1 bands; Y and K2 performance is not yet known. Two other mask options will be available, permitting smaller inner working diameter with lower contrast, or larger inner working diameter with better contrast. These have characteristics which will be determined at the integration & test stage of the instrument project. If you believe that your Campaign proposal would benefit from non-default masks, it will be necessary to state why. Please contact the instrument scientist in this case.

Documents Page

Design Reference Documents

The documents linked to here are detailed design reference works, which contain a wealth of information on the instrument, its capabilities and modes.

- Operational Concepts Definition Document - Science overview, drivers and requirements, observing scenarios
- Functional & Performance Requirements Document - performance requirements at the top level and broken down by subsystem

Project Documents

- GPI Project Web Page - Main page for the GPI project, including links to technical publications