PILOT: OPTICAL CONFIGURATION AND INSTRUMENTATION

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Abstract. PILOT, the Pathfinder for an International Large Optical Telescope, is proposed as a 2.4 m diameter optical/infrared telescope to be located at Dome C, Antarctica. The “strawman” optical configuration and instrument suite for PILOT described here is designed to take advantage of the unique atmospheric characteristics found at this site.

1 Introduction

Above a turbulent surface boundary layer some 30–35 m thick, the free atmospheric turbulence at Dome C has been shown to be exceptional. The median integrated seeing above this layer is typically ~0.3 arcsec (Lawrence et al. 2004; Agabi et al. 2006; Vernin et al. these proceedings), while the coherence time and isoplanatic angle (important parameters for adaptive optics systems) are longer and wider respectively than found at the best mid-latitude sites. The Dome C atmospheric scintillation (important for astrometry and photometry) is also very low (Kenyon et al. 2006). PILOT could take advantage of these atmospheric characteristics by being placed on a ~30 m high tower above the turbulent ground layer. Proposals based on an extension of the design of the 15 m Dutch Open Telescope tower have demonstrated the feasibility of such a structure (Hammerschlag et al. 2006).

In addition to the benign turbulence characteristics, the extremely cold temperatures of the Antarctic plateau atmosphere result in an infrared sky emission and water vapour absorption significantly lower than the best mid-latitude sites (Walden et al. 2005). The low Antarctic plateau surface temperatures result in low telescope thermal emission. Thus, Dome C also offers significant gains in sensitivity for infrared astronomy (Lawrence 2004).

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The combination of unique atmospheric conditions enables a wide range of science programs for a 2 m class Dome C telescope (Burton et al. 2005). The optical design and instrumentation suite for PILOT presented here are designed to achieve good performance across as many of these science programs as possible, by providing the capability for both high resolution imaging in the optical and high sensitivity imaging in the infrared. Each camera is configured to achieve good spatial sampling (at the diffraction or seeing limits) rather than fast (wide-field) survey speed.

2 Telescope optical configuration

The strawman optical design for PILOT shown in Fig. 1 is a modified Gregorian configuration with an f/12 system focal ratio. This design consists of a 2.4 m f/1.5 primary mirror with a Nasmyth focal plane fed through the elevation axis bearing. High Strehl ratio (>0.9 at 1.25 µm) is observed on a spherical focal surface (400 mm outside the elevation fork) out to ~5 arcmin field radius. The beam is vignetted by the axis bearing for fields greater than 28 arcmin diameter. The 28.8 m focal length is chosen as a good match to Nyquist sample the diffraction limit in the thermal infrared, allowing a simple high-throughput camera at these wavelengths. The Gregorian configuration is preferred for adaptive optics correction with a deformable secondary mirror, as this mirror is conjugate to the atmosphere just above the telescope and is easier to align. At this system focal length, however, the secondary mirror is relatively large (550 mm diameter for a 20 arcmin FOV), compared to the 430 mm diameter secondary for an equivalent Ritchey-Chretien design.
### Table 1. PILOT instrument suite camera parameters

<table>
<thead>
<tr>
<th>wavebands</th>
<th>focal ratio</th>
<th>plate scale (arcsec/pixel)</th>
<th>FOV (arcsec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>KLM</td>
<td>f/12</td>
<td>0.13</td>
<td>8.7</td>
</tr>
<tr>
<td>JHK</td>
<td>f/22</td>
<td>0.07</td>
<td>4.7</td>
</tr>
<tr>
<td>V seeing</td>
<td>f/12</td>
<td>0.11</td>
<td>7.3</td>
</tr>
<tr>
<td>V diff lim</td>
<td>f/55</td>
<td>0.023</td>
<td>0.75</td>
</tr>
</tbody>
</table>

### 3 Instrument suite

Major parameters for the PILOT concept design instrument suite presented here are shown in Table 1. The infrared camera uses a single 4k $\times$ 4k mosaic HgCdTe or InSb focal plane array with two possible beam paths, having plate scales appropriate for imaging in either the JHK or KLM bands. A wide field visible camera sampling the natural seeing operates simultaneously with the IR camera. A second high-resolution visible instrument is designed to operate with an adaptive optics system.

The infrared camera envisaged for PILOT is designed for high throughput and low emissivity. The addition of cold baffling inside the dewar, and Narcissus mirrors surrounding the secondary (Gillingham 2002), obviates the need to reimagine the primary onto a cold stop in the pupil plane, thus reducing the number of optical elements. As shown in Fig. 2, the f/12 thermal infrared (2.5–5 μm) camera simply consists of a spherical meniscus lens, which acts as the dewar window, a field flattening lens close to the focal surface, and a filter wheel. This design gives good image quality out to 6 arcmin radius (which represents a corner of the 8.7 arcmin field covered with a 4k $\times$ 4k pixel array). For imaging in the near infrared (1–2.4 μm) windows, a finer plate scale is required to sample the diffraction limit achievable with tip/tilt correction. This is achieved with the addition of a negative doublet (Barlow lens), which increases the focal ratio to f/22 and gives high Strehl (> 0.95) over the 4.7 arcmin field of view.

The wide-field visible instrument for PILOT samples the seeing limit at the f/12 telescope focal ratio via a dichroic in the infrared dewar. An atmospheric dispersion compensating doublet pair and a correcting doublet provide reasonable Strehl for large zenith angles over the 7.3 arcmin field covered at this plate scale by a 4k $\times$ 4k pixel CCD array. The high-resolution visible instrument is designed to operate with an adaptive optics system. With an adaptive secondary mirror alone, near-diffraction limited imaging should be achievable over a small field for some fraction of the time. The camera consists of a negative dispersion compensating achromatic doublet pair, which Nyquist samples diffraction at f/55 with high Strehl over a range of zenith angles out to the edges of the 46 arcsec field covered with a 1k $\times$ 1k pixel CCD array.
Fig. 2. Left: optical layout for near (top) and mid (bottom) infrared cameras. Right: Huygens point spread function for JK and LM bands compared to the 18 μm pixel size.

4 Conclusion

The baseline design for the PILOT optical configuration and instrument suite presented here is motivated by the desire to satisfy many diverse science goals. It is one of many possible final configurations for this telescope, each of which will be investigated and refined during the PILOT design phase, which is funded to begin in January 2007. Other design options include a dedicated wide-field infrared survey telescope with a Cassegrain instrument focus, or a telescope located at ground level equipped with a ground-layer adaptive optics (GLAO) system.

References

Lawrence, J. S., Ashley, M. C. B., Travouillon, T. & Tokovinin, A. 2004, Nat, 431, 278
Gillingham, P.R. 2002, PASA, 19, 301