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PATHFINDER FOR AN INTERNATIONAL LARGE OPTICAL TELESCOPE

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Abstract. PILOT (Pathfinder for an International Large Optical Telescope) is a proposed 2 m class optical/infrared telescope to be sited at Dome C on the Antarctic plateau. Recent site testing results from Dome C have shown remarkable ground level seeing, a large isoplanatic angle, and a long atmospheric coherence time. These factors significantly improve the resolution and increase the capabilities of adaptive optics systems. Additionally, the low sky emission at Dome C gives a significant increase in infrared sensitivity compared to typical mid-latitude sites. PILOT is envisaged as a winterised version of a commercially available 2 m class telescope, with a simple low cost dome (sufficient for the low ground level wind speeds), and a tip-tilt and/or a deformable secondary mirror. A number of science cameras covering the visible to the sub-millimetre are being considered.

1 PILOT resolution

Recent results from Dome C (Lawrence *et al.* 2004) have shown the extraordinary calm turbulence of the atmosphere. With a mean seeing at Dome C of 0.27 arcsec, the PILOT telescope should be capable of taking the highest resolution visible images of any existing ground based telescope. The lack of high altitude turbulence above Dome C results in a wide isoplanatic angle (5.7 arcsec), and the low wind speeds throughout the atmosphere result in a slow atmospheric coherence time (7.9 ms). These factors significantly improve the performance of any Adaptive Optics (AO) system on a telescope sited there. As shown in Figure 1, with tip-tilt correction alone PILOT should be capable of near-diffraction limited imaging for wavelengths longer than $\sim 1.2\mu$m (J band) over a several arcmin field-of-view. A larger mid-latitude telescope with a high order AO system is capable of higher resolution than PILOT at this wavelength. The mid-latitude system, however, will be limited to a very small field of view.

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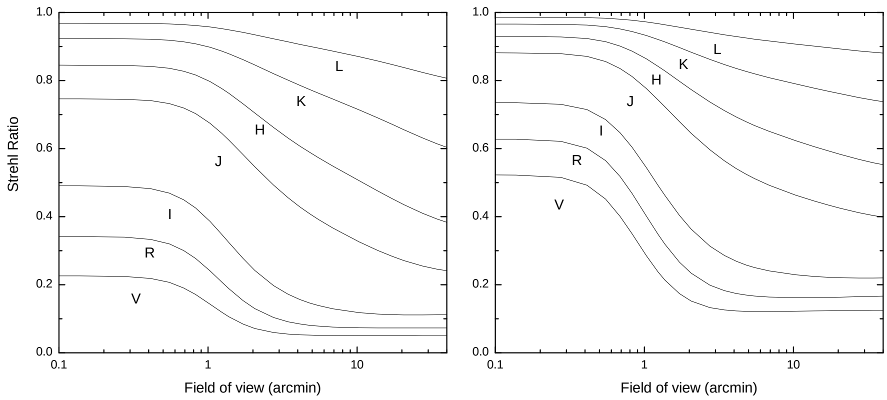

Fig. 1. Strehl ratio for tip-tilt correction as a function of field of view for the PILOT telescope in visible and near infrared wavebands. Left plot shows average Dome C atmospheric conditions, right plot shows 25% quartile Dome C conditions.

Unfavourable atmospheric conditions make visible AO unfeasible from any mid-latitude site. At Dome C, however, tip-tilt correction on PILOT gives improved resolution in the visible over a $\sim$ 40 arcsec field. A relatively low order ($\sim$ 50 actuator) adaptive optics system on PILOT should allow high resolution visible imaging over a wide field if operated as a ground layer compensating system (Ragazzoni *et al.* 2004), or diffraction limited imaging over a narrow field for bright objects.

2 PILOT sensitivity

Three factors increase the sensitivity of a Dome C telescope relative to a mid-latitude telescope. This is illustrated in Figure 2, which compares the limiting magnitudes for PILOT with an 8 m mid-latitude telescope and an 8 m Antarctic telescope. Firstly, the low temperature of the Antarctic plateau atmosphere results in a thermal sky emission orders of magnitude lower than found at typical mid-latitude sites (Chamberlain *et al.* 2000). PILOT thus has an equivalent sensitivity to an 8 m mid-latitude telescope in the near and mid-infrared. Secondly, the low water vapour concentration of the Antarctic atmosphere results in increased atmospheric transmission at wavelengths around water vapour absorption bands. This enhances sensitivity in the mid-infrared and sub-millimetre wavelengths. Thirdly, the better seeing allows an increased spatial sampling of the focal plane, which reduces noise from sky emission. In the visible, seeing-limited point source observations with PILOT can thus reach the same magnitude as a $\sim$ 4 m mid-latitude telescope. If the PILOT resolution is further improved with adaptive optics, the sensitivity in the visible approaches that of the seeing-limited mid-latitude 8 m telescope. The 8 m Antarctic telescope is significantly more sensitive than the mid-latitude telescope in all these wavebands.

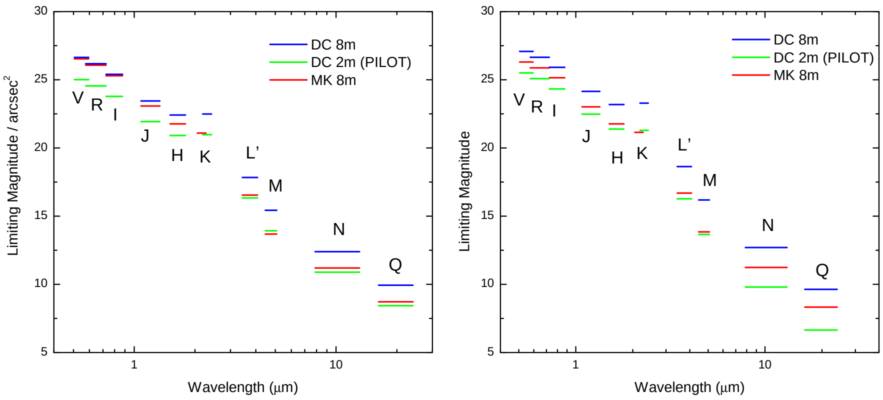

Fig. 2. Extended object (left plot) and point source (right plot) sensitivities, in limiting magnitudes/arcsec^2 and limiting magnitudes respectively, for one hour of integration and a SNR=10 detection for PILOT compared to an 8 m mid-latitude telescope and an 8 m Dome C telescope. For each wavelength the pixel scale is Nyquist sampled at the greater of seeing or diffraction limit.

Table 1. Strawman instrument suite for PILOT

Wavebands	Array size	pixel scale (arcsec)	Field of View (arcmin)
VRI narrow	4K	0.03	2
VRI wide	4K	0.1	6.8
JHK narrow	4K	0.08	5.3
JHK wide	4K	0.30	20.5
KLM	1K	0.23	4
NQ	0.5K	0.7	6
sub-mm	1	30	0.5

3 PILOT instruments

The exact makeup of the PILOT instrumentation suite is yet to be determined. Table 1 shows strawman specifications for possible instruments based on the largest commercially available detector arrays, in order to provide simple camera systems. These instruments provide PILOT with capabilities to perform high spatial resolution visible imaging; high resolution narrow field near-infrared imaging; wide-field, near-infrared whole-sky imaging; high sensitivity, wide-field, diffraction limited mid-infrared imaging; and high sensitivity terahertz detection. Wider field instruments may be also be implemented on PILOT with detector mosaics, which would significantly increase the capabilities for performing sky surveys.

4 PILOT Science

PILOT is envisaged as a general purpose facility that can undertake a range of different astrophysical investigations discussed in detail by (Burton *et al.* 2004), and listed below.

- Our solar system and others:
  - high resolution planetary imaging via selective imaging,
  - wide field photometric follow-up of transiting planet candidates,
  - discs and the early stages of planet formation,
  - planetary microlensing in the inner galaxy.
- Our galaxy and its environment:
  - the earliest stages of massive star formation,
  - stellar seismology,
  - a survey for brown dwarfs,
  - studies of pulsar wind nebulae,
  - searches for obscured AGB stars in the Magellanic clouds,
  - stellar streams and dark matter halos.
- Our universe and its evolution:
  - a survey for supernovae in starbursts,
  - time dealys in gravitational lenses,
  - a deep near-infrared extra-galactic survey,
  - star formation in the early universe,
  - the evolution of galaxy mass and morphology,
  - gamma-ray burst observations,
  - measurement of cosmic shear.

5 Conclusion

The unique atmospheric characteristics of the Dome C site will enable PILOT to make important astronomical discoveries despite its relatively modest size. Additionally, PILOT will serve as a technological testbed for the development of larger astronomical facilities at Dome C in the future.

References

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