Preliminary Technical Analysis and Proposed VAMPIRES Upgrade from November 2014 Observations

BRN 25/11/2014

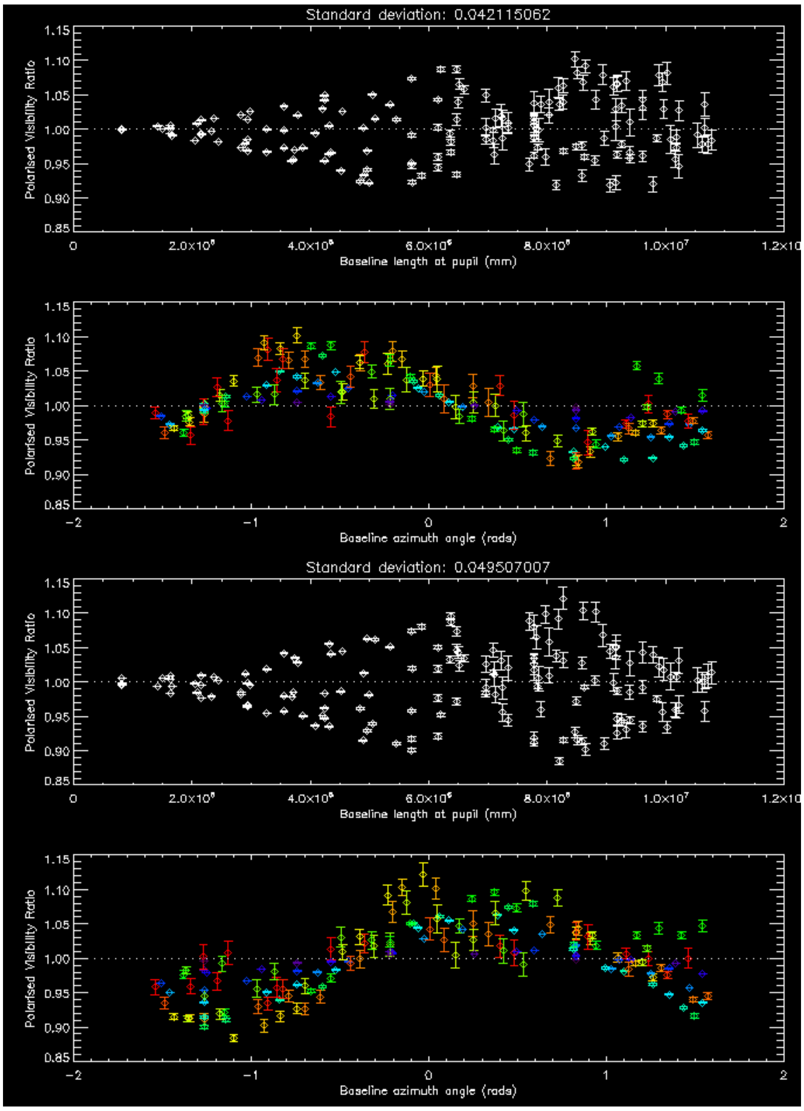
Summary

A major finding from the November 2014 observations was the advantage in precision gained when using AO188's half-wave plate to modulate the polarisation, while applying a static (but wavelength-dependent) correction with VAMPIRES' internal quarter-wave plates.

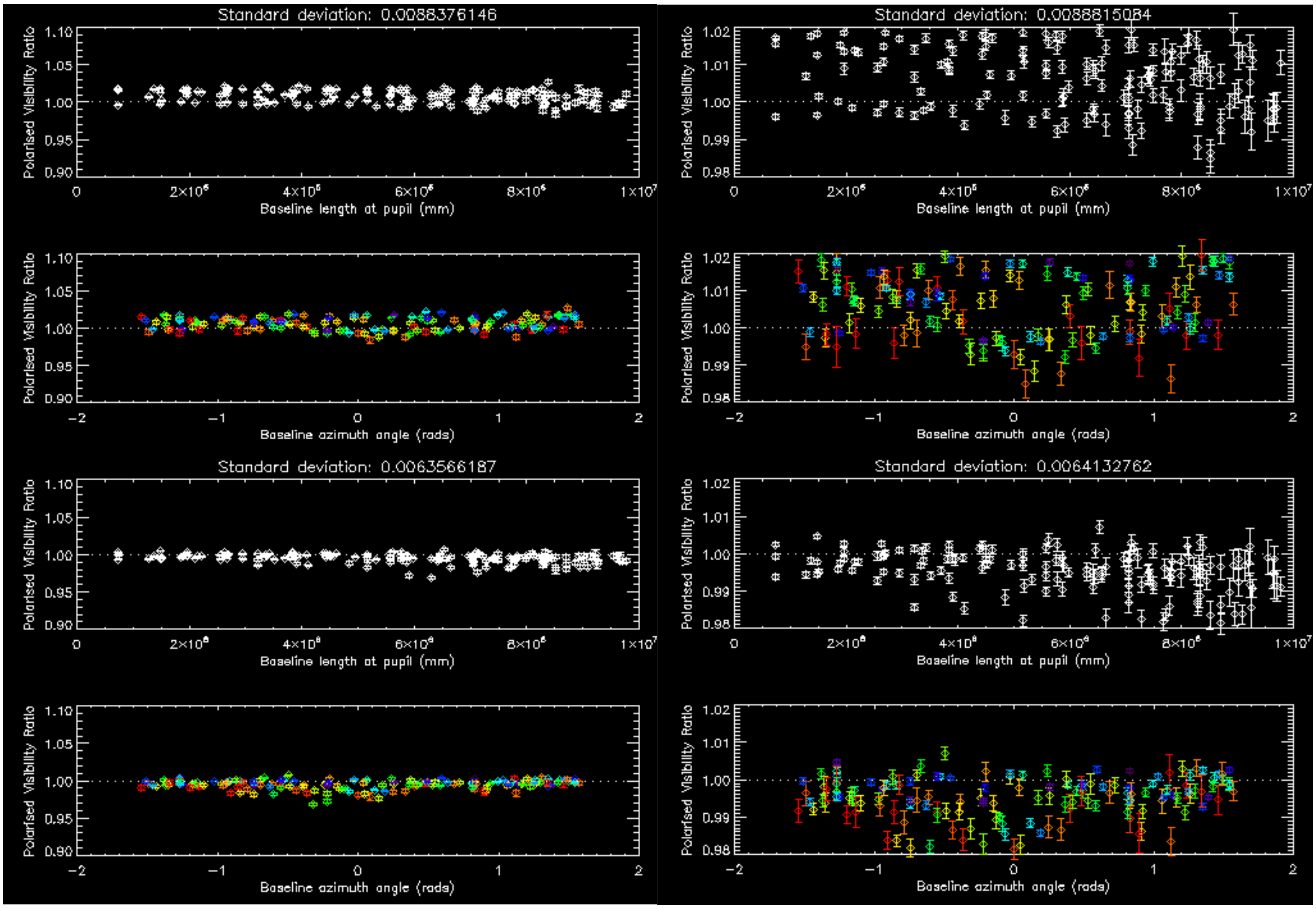
This in turn revealed a new limiting factor in precision, which is believed to be related to anisotropy and wavelength angular dispersion in the Wollaston prism. An upgrade is described here that should correct this problem.

Findings

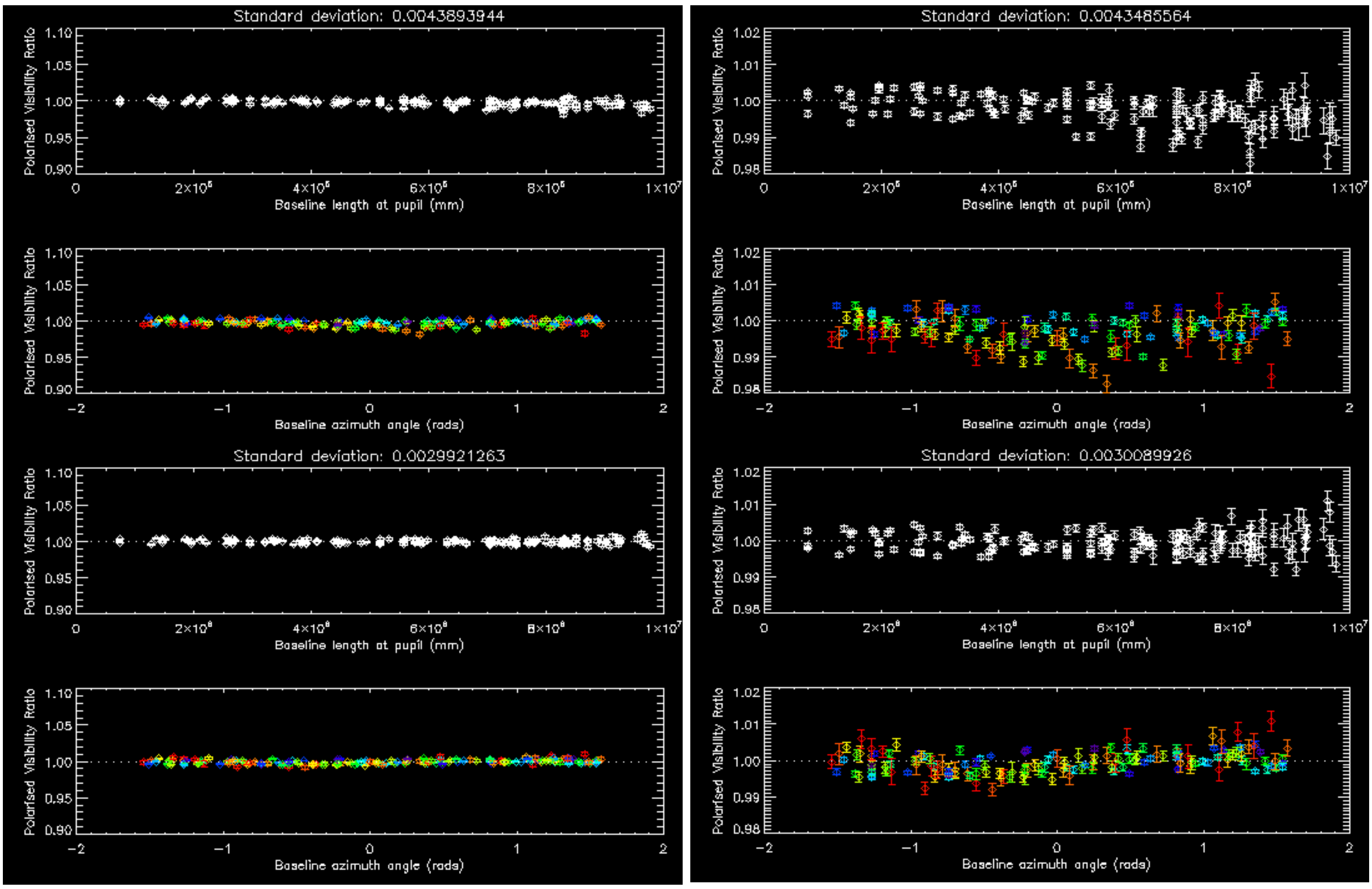
When strong signals are observed, such as those from dusty atmospheres of evolved stars, the existing precision is more than adequate, as demonstrated by the following calibrated signals as observed from alf Ori (note Y axis scale).



Calibration precision is tested by observing an unresolved target, in this case alf Ari. Following is the result when the AO188 half-wave plate is *NOT* used. The right hand plots are a zoomed-in version (note Y scale):



And here is the same star, but *WITH* the AO188 half-wave plate used:



A better than factor of 2 improvement is seen, which is great. But examination on the zoomed-in plot reveals that a residual, sinusoidal signal now dominates. We do not believe this is of an astrophysical origin since this star should not have any such signal.

This type of systematic error has previously been encountered at the VLT using SAMPol. It is believed to be due to the combination of atmospheric dispersion and Wollaston prism dispersion (see SAMPol technical report for further detail).

The upshot is that we wish to replace the Wollaston prism with a wire-grid polariser beam splitter, which offers three advantages:

1. Angular wavelength dispersion is eliminated, which should remove the effects seen above.
2. Anisotropy due to the crystal structure of the Wollaston - also suspected to be a major source of non-common path error - will be removed.
3. The beamsplitter can now be placed in a converging beam, directly before the detector. This greatly reduces non-common path error and results in a true dual-beam polarimeter.

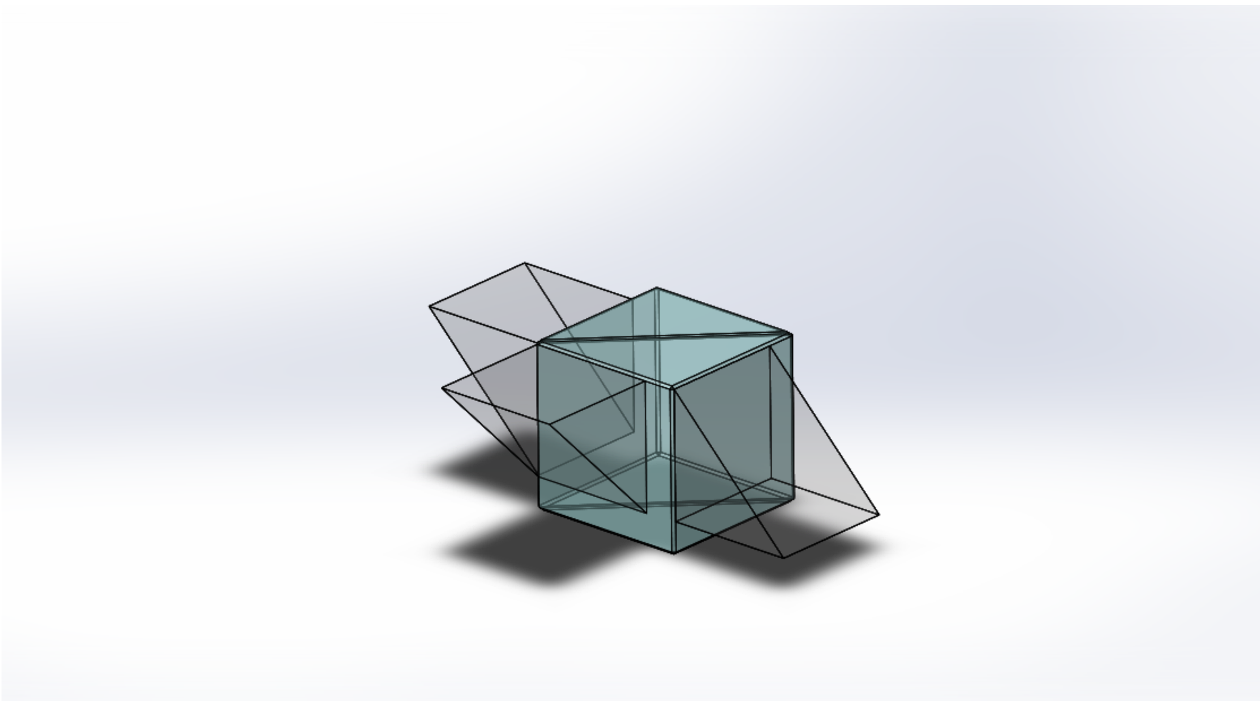
These advantages will significantly improve VAMPIRES' visibility precision to allow detection of the much fainter signals arising from e.g. proptoplanetary disks.

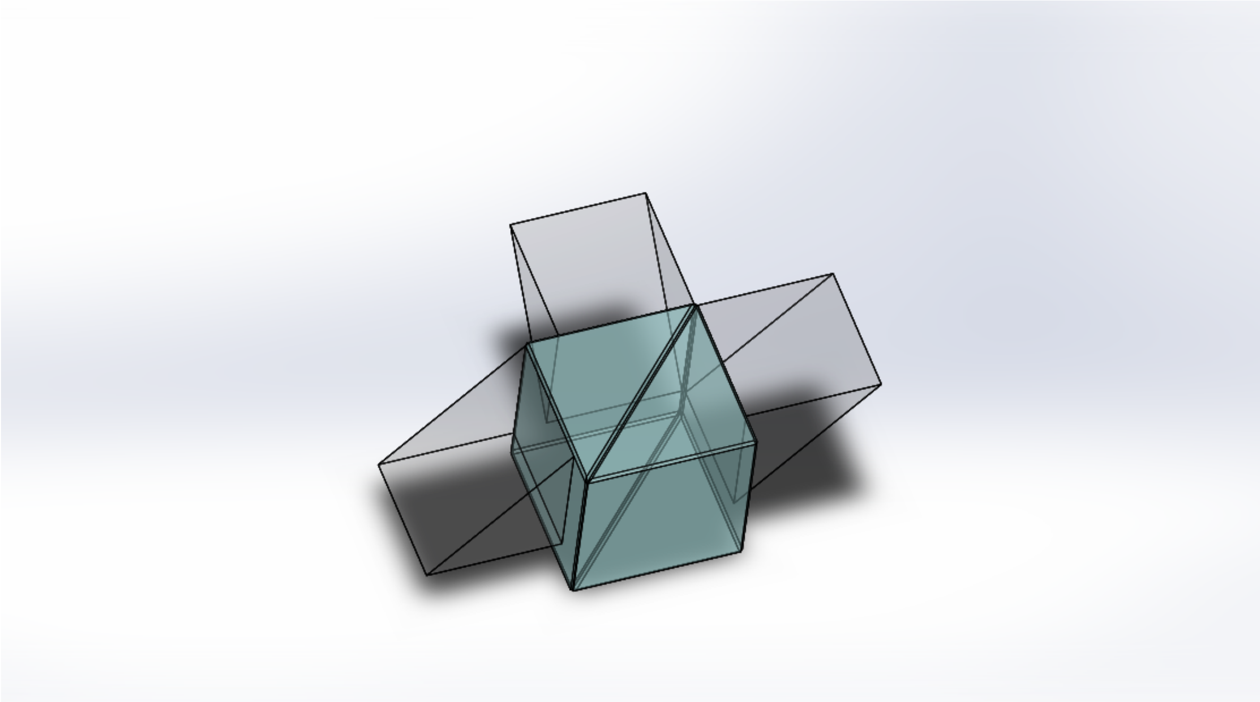
Proposed upgrade

A wire grid beamsplitter cube has minimal sensitivity to angle of incidence and is suitable for use in a converging beam. The aberrations (spherical aberration and chromatic focus) introduced by the glass is predicted by Zemax models to be negligible, due to the slowness of the beam at this point. The beam diameter is approximately 1mm (a the point halfway between Camera Lens 2 and detector) and is converging with a half-angle of 0.49 degrees.

In order for the resulting two beams to strike the detector at normal incidence and with the correct separation, two small right-angle prisms are affixed to the beam cube with optical cement. To avoid the 90 degree beam turn, which may not be possible in the given bench space, a third RA prism is affixed to redirect the resulting two beams in the same direction as the incident beam (but with a lateral offset.)

Images of a proposed design are below:





Ideally the beamsplitter cubes and RA prisms would have widths of 5mm, but the wire grid polariser cube is only available in a half inch size. The pictures above show this cube with 10 mm RA prisms. 5 mm prisms would actually be preferable as this would a) reduce the glass path length and b) provide a flat surface to allow easy mounting on the bench. However it is feared these small sizes might make assembly difficult. Assembly will take place in Sydney at MQ and then the item will be shipped to Hilo.

Installation steps would be as follows:
1. Remove existing Wollaston prism and associated hardware
2. Place the new beamsplitter assembly in the beam halfway between the 2nd camera lens and the detector, such that it is parallel with the bench.
3. The beamsplitter is rotated to be square to the beam by looking at the back-reflection (with the laser) from the incident surface onto camera lens 2.
4. The beamsplitter is translated in x and y to ensure the beam is incident on the correct part of the input glass (which will be marked), which should be good to a couple of millimetres.
5. The beamsplitter is tweaked in its translation in x and y to achieve correct separation of spots on the detector.
6. The beam will now be offset by approximately 20 mm (if 10 mm RA prisms are used). This can either by up-down or left-right, depending on how the cube is mounted. The camera will then need to be shifted accordingly.

To aid in steps 4 and 5 I will try and find some simple stage that can do this.