

Progress report on phase knife stellar coronagraphy at Dome C

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Running title:

Stellar Coronagraphy at Dome C

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Abstract

We report on preliminary on-sky tests of a phase knife stellar coronagraph operated in the visible from the French-Italian Concordia station at Dome C of Antarctica. Laboratory experiments and numerical simulation results are also presented, and the experimental feedback for further observation campaigns is discussed.

Keywords

Astronomical Instrumentation –Stellar Coronagraphy – Concordia Station

1 Introduction

We describe in this article the CORONA experiment (for CORONagraph in Antarctica), which is a precursory prototype of stellar coronagraph designed for Antarctica. The goal of CORONA is to yield experimental feedback for a future more ambitious instrument, equipped with a tip-tilt corrector and an adaptive optics system. We first describe the CORONA instrument itself in Section 2. and the preliminary laboratory tests and numerical simulations in Section 3. Then, we present the result of the first observation campaign in Section 4 and discuss the experimental feedback in Section 5.

2 The CORONA instrument

CORONA is a compact four-quadrant phase mask stellar coronagraph (Rouan *et al.*, 2000), coupled to a commercial 14-inch Schmidt-Cassegrain telescope modified for low-temperature operation. The central obscuration of the telescope is known to alter seriously the coronagraphic efficiency (Riaud *et al.* 2001). Thus, following the suggestion of Lloyd *et al.* (2003), we have added at the telescope entrance a pupil mask with four circular identical sub-apertures. The coronagraph has been designed to have optimal efficiency in the visible with reduced chromatic defects, and to be able to operate in Antarctica. The four-quadrant phase mask is the most critical component in the coronagraph. Ideally, it should produce achromatic phase shifts of 0, π , 0 and π respectively in each quadrant with sharp transitions. In addition, it must be as compact, robust and reliable as possible to withstand without permanent damage the severe conditions encountered in Antarctica, especially during shipping, storage or power failure periods with no thermal control. The retained solution involves a stack of two crossed phase plates. Each phase plate is itself a pair of glass plates placed side by side, with the same thickness but with different refraction indices and dispersion. The optical properties of both glasses and the thickness of the plates are carefully chosen to yield phase shifts close to the desired values, with reduced chromatic variations over the spectral domain of interest, *i.e.* the visible. All the optical components of the coronagraph (phase mask, Lyot stop, lenses, guiding and science camera) are inside an isolated and thermally controlled box.

3 Laboratory tests and numerical simulations

In order to assess the phase mask's ability to withstand low temperatures during shipping, storage or in case of temporary failure of the thermal control, the coronagraphic phase mask was first laboratory tested in France on a specially designed coronagraphic bench, then exposed to Antarctica's atmospheric conditions in November 2004, then finally tested again on the same bench. This has not revealed any alteration of the mask's optical and mechanical properties.

The laboratory tests were performed with a Helium-Neon laser source. With a single circular entrance pupil, the peak attenuation (Bocaletti *et al.*, 2004) has been found around 900. With a four-hole entrance pupil similar to the pupil mask of the CORONA instrument, the peak attenuation was measured around 600.

These experimental data are compatible with the results of numerical simulations incorporating the expected defects of our coronagraphic phase mask (finite size, residual chromaticity in phase shifts).

4 On-sky tests

CORONA's first daytime observation campaign at Dome C ranged from December 5 to December 13, 2005. Only bright stars have been observed: HD 45348 and HD 128620J. Neither auto-guiding nor tip-tilt corrector was available on this preliminary instrument. In addition, the real-time image selection facility did not operate properly. However, rejection ratios of 15 and peak attenuations of 17 have been obtained. The turbulent tip-tilt (although small at Dome C), and the chromatic defects of the phase mask in near UV appear to be the most limiting factors in our first experiment. Thus, our on-sky data should not be compared to our laboratory results (turbulence-free, monochromatic), but rather to other on-sky data. As an example, results of the same order of magnitude were obtained by Boccaletti *et al.* (2004) on the ESO Very Large Telescope with the NACO near-infrared camera and adaptive optics.

The first attempt for night-time observations with CORONA was unsuccessful. Indeed, when the temperature drops down to typical winter values (-65°C), strong trefoil-like aberrations appear, probably due to mechanical tensions within the primary mirror.

5 Conclusion

This first Antarctic observation campaign with CORONA has provided valuable experimental feedback both for future improvements of the instrument, and for other observation projects in Antarctica. The main conclusions are listed below:

- The phase mask appears to withstand Antarctica's conditions without damage.
- Tip-tilt correction is mandatory, even when turbulence is low.
- Modifying an "off-the-shelf" telescope is sufficient for summer observations at Dome C, but some extra care has to be taken for winter coronagraphic observations. The tensions appearing within the primary mirror at very low temperatures have to be eliminated.

Astronomical experiments involving winter observations from Antarctic, and requiring very good and stable image quality have to take into account this last point. That is the reason why it has been chosen to design a dedicated telescope rather than to modify a commercial model, for the more ambitious ASTEP program (Fressin *et al.*, 2005).

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