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# CORONA: FIRST LIGHT AT DOME C OF THE ANTARCTICA PROTOTYPE APKC CORONAGRAPH

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**Abstract.** We present the results of the first light of CORONA obtained during the summer campaign 2005 at Dome C. The CORONA experiment uses an automated 14'' antarctized telescope for its remote operation from the Concordia station. The instrument includes an Achromatized Phase Knife Coronagraph (APKC) with no tip-tilt correction. The high contrast long exposure is obtained from image selection among raw short exposures.

## 1 Principle

### 1.1 CORONA Principle

The coronagraphic bench is mounted on the side of a Celestron 14 telescope. A monitoring camera is directly placed at the focus of the telescope.

The beam passes through a beam-splitter which transmits 80% of the light to the monitoring camera and the remaining 20% of the beam are reflected to the science camera. Behind the beamsplitter, the coronagraphic mask is placed at the focus of the telescope.

### 1.2 Principle of the Achromatic Phase Knife Coronagraph

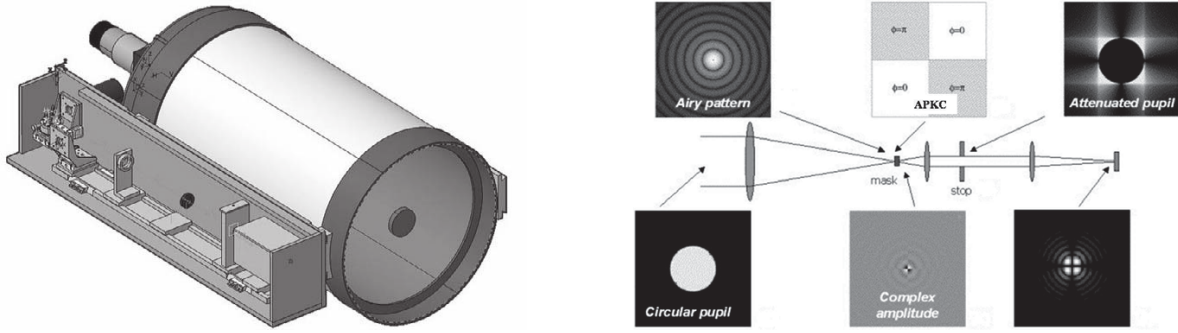
Behind the APKC coronagraphic mask, a relay lens re-images the pupil. An iris diaphragm called Lyot Stop is placed at the relayed pupil plane so as to block the rejected light out of the geometrical pupil. Then a last lens re-images the focal image onto the science camera. In this final focal plane, we can see the famous coronagraphic image which looks like Butterfly's wings.

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**Fig. 1.** (*Left*) CAD view of CORONA and (*right*) principle of the achromatic phase knife coronagraph.

## 2 CORONA Manufacturing

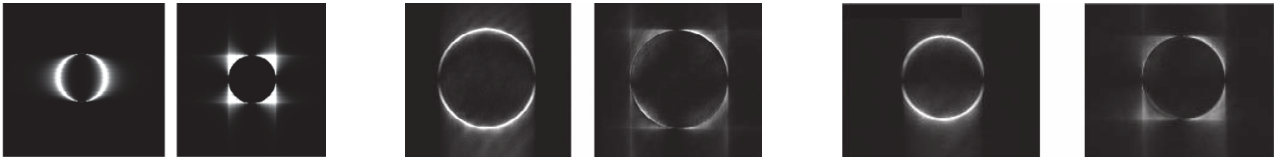
All components of the CORONA experiment were “antarctized”, *i.e.* realized with materials and according to a procedure compatibles with the extreme conditions of Dome C.

### 2.1 Manufacturing of the Telescope and the Bench

The original Celestron’s tube which is made of an aluminium alloy was replaced by a tube made of invar. Invar is a metal alloy whose coefficient of thermal expansion is lower than the aluminium alloy’s coefficient ( $\approx 10^{-6}$  versus  $\approx 12 \times 10^{-6}$ ). The two mirrors of the telescope are also glued leading a special procedure. Finally, each mechanical part is dry-cleaned, then greased. The grease which is used remains viscous up to  $-80$  °C. Furthermore, a system made up of heating resistances is used in order to bring back the cameras’ temperature under the threshold of the normal conditions of use.

### 2.2 Manufacturing of the Coronagraphic Mask

The coronagraphic mask is an assembly of two crossed pairs of phase plates. Each phase plate, called phase knife, has the same thickness but has different refraction indices. The two  $100 \mu\text{m}$  phase knives are blocked between two thick glass blocks. To be manufactured, this kind of complex optics needs multiple assemblings going from adherence to gluing, because the glasses have different indices and densities. An external protection is necessary to avoid penetrations of humidity because of the thickness of the plates: the coronagraphic mask is covered with a flexible glue which withstands  $-70$  °C. The mask is operational after a few weeks drying. Then, the mask has been exposed in November 2004 to Dome C temperatures without any visible alteration appears.



**Fig. 2.** Coronagraphic images in the pupil plane: numerical simulations (*left*), experimental images for an aperture ratio of 106 (*center*) and of 205 (*right*).



**Fig. 3.** Reference image (*left*), Coronagraphic image  $\times 1000$  (*center*) and overage radial profiles (*right*).

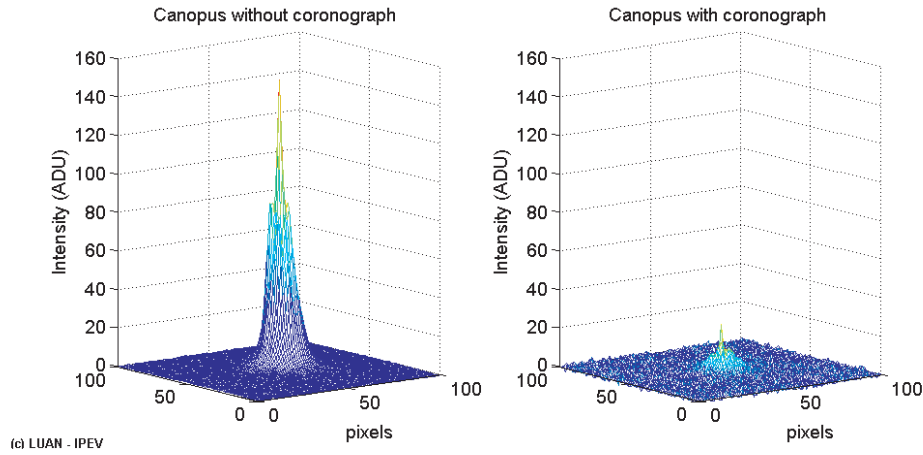
### 3 Laboratory Measurements

The coronagraph has been tested in laboratory to validate the achromatization process. The laboratory first data for a monochromatic light are presented in the two figures below. First, in order to appreciate the good quality of the transition between the phase knives, we performed acquisitions on the conjugated coronagraphic pupil plane for different apertures ratio. The look of experimental images is perfectly consistent with numerical simulations.

Quantitatively, the coronagraphic nulling results attains more than  $10^3$  at least.

### 4 First Light at Dome C

The first observations of Corona at Dome C have been made on the 5th december 2005, 11h (local time). The primary test of Corona on the Antarctic sky have been done on the bright star Canopus (ie alpha Carinae). With a magnitude of  $-1$ , this star is the second brightest star of the sky and is bright enough to be visible in daytime at the focus of a small telescope, with a reasonable contrast. For example with a 20 cm diameter telescope, Canopus is ten times brighter than the sky background. Canopus is not a double star, but its observation permitted to try to collimate the telescope and to verify that the coronagraph is working as expected. Because of the sky background, it was not possible to collimate the telescope on the sky. CORONA is piloted from an igloo located ten meters away from the telescope. As the polar alignment is not sufficient enough, the star is pointed manually. The first images of Canopus are presented in the Figure 4.



**Fig. 4.** 3D view of Canopus (*left*) without and (*right*) with coronagraph.

On these images, the extinction rate is around 11. These results are encouraging, and we expect better since the optics were not yet perfectly collimated.

During the summer, CORONA has also imaged binary stars like AlphaCruX or AlphaCen. The data reduction is in progress.

## 5 Conclusions and Future Prospects

The astronomical dark night officially begun on Tuesday 26th February 2006. We are waiting for data of binary and massive stars taken by our winterer Eric Aristidi. We can nevertheless say that, due to aberrations introduced by the Celestron 14 telescope, CORONA is not diffraction limited by the 14' aperture. These aberrations are caused by tensions of the telescope mirrors. This reveals the limitations of using a telescope bought in the shops, even if it was antarctized. Moreover, we plan to combine this optical system with a high speed, high efficiency photon counting camera which is under realization at LUAN.

The authors would like to thank Gérard Greiss (SEOP, France) for manufacturing the achromatic phase mask, Franck Valbousquet (Optique et Vision, France) for preparing the telescope, Alex Robini from LUAN who manufactured most of the mechanical parts, OCA and ASHRA for supporting the experiments.

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