The International Concordia Explorer Telescope (ICE-T): an Ultimate Transit-Search Experiment for Dome C

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Abstract. ICE-T is a fully robotic telescope for astrophysics and atmospheric research for the Antarctic station Concordia at Dome C. ICE-T consists of two 60cm optical ultra-wide-field Schmidt telescopes and one 18cm narrow-field Maksutov spectrophotometric telescope on a single mount. The dual 60cm will be mainly used for a transit search due to extrasolar planets while the 18-cm will be used for measuring aerosol optical depths. ICE-T is a team effort of the German Alfred-Wegener-Institute for Polar Research, the Italian Universities of Padova and Perugia, the INAF Observatory Catania, and the Catalonian IEEC in Barcelona, Spain, and the AIP with collaboration from the University of New South Wales, Australia and the University of St Andrews, U.K.

ICE-T’s primary science goal is a quantification of the relation between stellar magnetic activity and close-by planets. It is to detect transits from extrasolar planets and provide targets for detailed spectroscopic investigations with large telescopes and interferometers with the ultimate goal to detect few-Earth-mass planets in habitable zones. For the photometric transit method to be effective, two main difficulties need to be overcome. Firstly, the probability that a given star hosts a planet in an edge-on orbit and the transit occurs while the star is being observed is low. Thus, a reasonable detection rate can only be achieved by continuous photometric monitoring of a large sample of stars. Secondly, to monitor a transit requires a high level of photometric precision. Changes in brightness on timescales of a few hours need to be measured to better than 0.5% precision. Dome C with its low level of scintillation noise and its 3-4 months long uninterrupted nights seems to be optimally suited for this task.
Our technical goal with ICE-T is to perform a stellar variability survey in two bandpasses (Sloan g and i) between 9-19th mag. This is because stellar activity (starspots, plages etc.) could mimic a transiting planet, which could be recognized with the help of the two widely-separated bandpasses. A predetermined sky field (Fig. 2, right) would be continuously observed for the entire polar night of approximately 100 “regular nights” for up to four years with a time resolution between 10-600sec, depending on brightness. The expected planet catch has been simulated with updated star count models, the technical ICE-T parameters, and the assumption that every star has a planet (Fig. 1).

Figure 1. Transit detection probability for ICE-T. Left: The expected transit light curves for a 1 Earth radii planet in the habitable zone around a star of radius 0.2-1.2 solar radii and magnitudes between 6-16th mag in V (4 years of observations). The number of detectable transits is indicated at the top of each row. Right: Detail from the Monte Carlo simulation. Cumulative number of planet catches plotted as planet’s radius in Earth radii versus its equilibrium surface temperature in Kelvin (250-350K denotes the habitable zone). The simulation predicts a catch of 44 planets greater than 3 Earth radii.

The optical design of ICE-T is based on a very fast f/1 Wynne-Schmidt system with an entrance aperture of 60cm (Fig. 2, left). The main mirror is 76cm in diameter. Its surface quality specifications are basically monochromatic. The corrector plates are from BK7 and F2, which is available in the required sizes. By allowing the field flattener to be thicker and by allowing the mirror to have a larger asphericity (it is elliptical), the corrector can be very close to the mirror. The field flattener is now intersecting the correctors. The camera can therefore be mounted on the correctors and be accessible from the outside. The filter is a “smart” coating on the CCD entrance lens. The science field of view (FOV) is 12.4° diameter, i.e. a square of 8.8×8.8 degrees can be seen by the 10.3k×10.3k CCDs corresponding to 77 square degrees on the sky.

We are currently favoring a one-degree offset from the field originally proposed by Barbieri et al. (2003) for Eddington (but see also Barbieri (2006) in these proceedings), i.e. centered near the star θ Carinae. This is shown in Fig. 2 (right). It will include the young Open Cluster IC2602 and a total of 100,000 stars down to 16th magnitude. The line-of-sight characteristics are still the same than in the original Barbieri et al. field ($A_V(0-1kpc)=0.78$ mag/kpc).

A 3''/px plate scale results from the 9-µm 10600²-pixel back-illuminated thinned CCDs; the soon largest single CCD devices in the world. We emphasize
that ICE-T is optimized for high-precision photometry with a defocus of 6px (tbc) over an ultra-large FOV. The expected quantum efficiency for the 10k CCDs is similar to the current (thinned) 4k×4k 15-µm devices (up to 95% peak). They can be run in frame transfer with a total of 16 amplifiers. The CCD controllers would be advanced copies of the AIP-Magellan design based on a PCI bus and ported to Linux. The current version - October 2006 - reaches 1 Mpx/port/sec at 4-5 electrons read-out noise and consumes 20W per amplifier during read out. The extension from 4 to 16 amplifiers is still challenging but not a principle problem. We expect 240W consumption for the 16-amplifier version for standard voltages (25V).

We consider only full-frame operation for the CCDs, i.e. no pre-windowing like for space missions. With the two large 10k-chips without binning (a total of 225 million pixels), a single exposure from both telescopes amounts to 450MB. An exceptional 4-month observing night and an optimistic 20% bad-weather loss result in roughly 8.3 million useable seconds. For an integration time of 10sec per telescope in frame-transfer operation, the “nightly” data rate would be 373TB. Combining always 30 of the 10-sec frames and employing lossless compression would lower this to approximately 7TB. Final data pick up would be by physically moving the hard disks and the tapes back to Europe.

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References

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