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Microlensing from Dome-C with an adaptive telescope of 2m class

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Abstract. Dome-C, a local peak in the Antartic plateau, is claimed to be one of the best sites in the world for astronomical purposes. We focus here on the increasing evidence that exceptionally good seeing could be available at visible wavelengths, far exceeding what is available at temperate locations. We propose that searching for microlensing events in and by galactic globular clusters, such as 47-Tuc, using a wide-field, possibly adaptive optics corrected, 2m-class telescope, would produce unique science for a medium technical challenge.

Key words. Astronomy from Antarctic – Microlensing – Adaptive Optics

1. Introduction

Antarctica is known to be an extremely appealing site for astronomical observations ranging from millimiter to microwave because of the low temperature and the extreme dryness (Dall'Oglio & Bernadis 1988; Valenziano 2003). Shifting towards the visible wavelengths, however, proved not to be so rewarding at sites such as the South Pole as one of the key parameters for judging the quality of a site, the seeing, was measured to be relatively high (Loewenstein et al. 1998; Travouillon et al. 2003). This finding, however, has been accompanied by the fact that most of the turbulence occurs because of gravitationaly produced katabatic winds very close the ground.

The situation changes dramatically on domes, isolated peaks on the Antarctic plateau, like Dome-C where an Italian-French base is almost finished and several astronomical activities are currently underway (Candidi & Lori 2003). Recent measurements using a Differental Image Motion Monitor (Aristidi et al. 2003) for the first time suggested the raw seeing during summer above the Dome-C site could be lower than 0.2 arcsec for sub-

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stantial parts of the day when the temperature gradient over the first few hundred metres was reasonably constant. The measurements showed a strong diurnal variation expected during the summer months that would, most likely, disappear during the winter. In addition, the high-altitude turbulence impact on the image quality measured on the ground was determined using a Multi-Aperture Scintillation System (MASS). Measurements summarised in Lawrence et al. (2004) showed a 0.3 arcsec mean value with periods including seeing as low as 0.15 arcsec in the visible. The mean isoplanatic angle, the angle on the sky over which the turbulent effect of the atmosphere is constant, was 6 arcsec with a corresponding mean Greenwood frequency of 8 ms.

There are other reasons making Dome-C unique and extremely appealing from the point of view of optical astronomy. These include the low brightness of the coronal sky, the significant distance from Aurorae, and the high (more than 75 %, Dempsey et al. (2003)) of clear time.

2. An experiment, not a facility

A large facility telescope would require special efforts to be erected on the site, or at least would require some specific, extremely smart and simple design. As work on the site is confined to a few months during the Antarctic summer it is easy to visualise the work needed to construct a telescope like TNG (that was previously engineered in Chile as NTT) is several decades, even assuming the availability of manpower and infrastructures are similar to the ones in temperate regions (a condition very far from the truth). A first step into visible astronomy would be, in our opinion, a telescope that can be built, tested, debugged and only then sent as a complete unit, able to be remotely operated for most of the winter. As conventional commercial containers are usually used for large mass transfer of material to Dome-C by traverse, the size of an non-folding telescope is limited to a 2 m aperture size. It is interesting to note that for transport costs alone the size of a segment of a future Extremely Large Telescope (ELT) will most likely be close to 2 m in size, leading to the possibility to share development results, if not real hardware, under the future ELT framework.

The science rationale for this project requires very careful assessment. In particular we think such a project must be only doable from Dome-C and no other ground-based location and should have a high probability of producing unique science. In addition, we think the powerful capabilities of this telescope will aid the wider scientific community with by-product science when considering the capabilities of a telescope that can produce an image quality of 0.1-0.2 arcsec resolution across a 15 arcmin Field of View(FoV) at a wavelength of 500 nm.

3. Microlensing over a wide field

As microlensing surveys have existed for many years to produce outstanding science we have to push the parameter space. In particular, other to the absence of jumps in photometric data due to the use of different telescopes throughout the world in the existing microlesning searches, the much higher spatial and temporal sampling (0.1 arcsec on 10 s exposures, for example) should allow for such a survey to reach detection limits otherwise not possible from the ground.

The guts of the science case lies in the detection of fast microlensing events in and by globular clusters. This requires the continuous observation of a well defined region of stars over a reasonably large field of view (15 arcmin diameter) with an unprecedented resolution. Continuous observation is made possible thanks to the geographical location of Dome-C close to the South Pole that, at least in the Antarctic winter, provides almost uninterrupted observations. As the crowding in the center of a cluster is large (we use 47-Tuc as a reference example) this can be achieved only through excellent optical quality, of the order of 0.1 to 0.2 arcsec, compatible with the diffraction limited imaging of a 1-2 m class telescope. It is noted that the telescope is not required to provide diffraction limited performance but just to exploit the excellent seeing

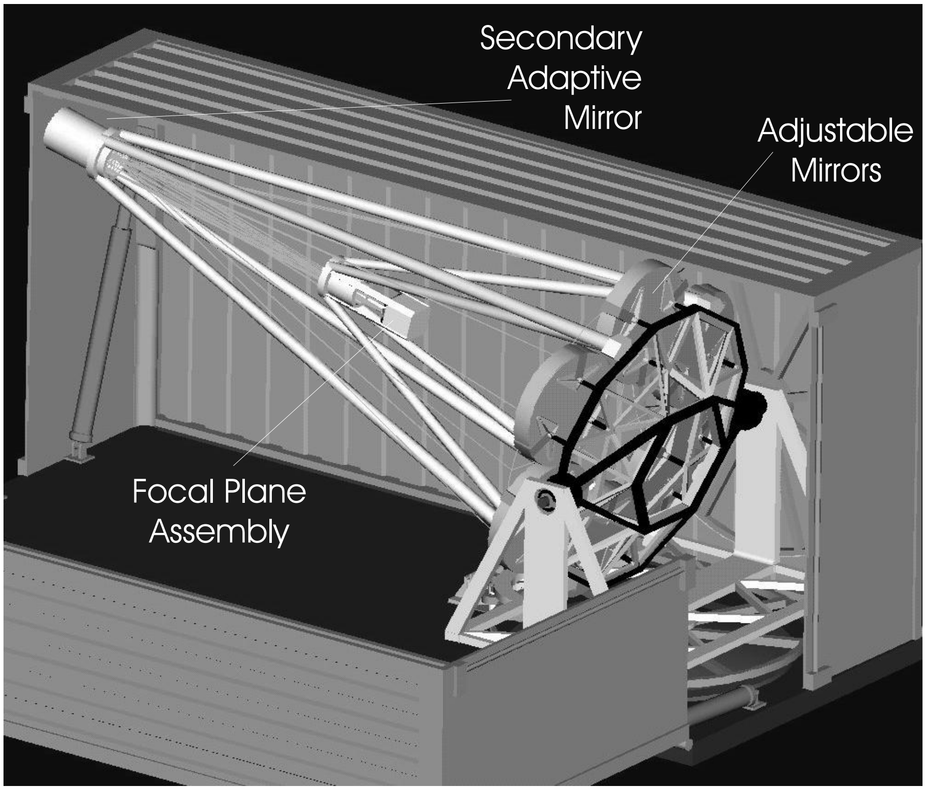

Fig. 1. A schematic view of the current telescope design. A two mirror all-spherical solution is envisaged. The 2 m aperture consists of six, possibly off-the-shelf, mirrors. The trapped foci allow for a compact mounting. Driving of the telescope is accomplished by a direct driven metallic belt with redundancy built-in for reliability in a remote location.

conditions experienced at Dome-C over a wide field.

The scientific outcome can be unique as the microlensing is made on a large number of stars located at a very well known distance (removing some of the ambiguities often occuring in microlensing events), not to mention more exotic possibilities such as self-lensing in the cluster itself. Moreover, there is a by production of huge amounts of lightcurves useful for eclipsing binaries, IMF, deep imaging but to name a few.

We believe a crucial point is to well define the scientific rationale and to then design a precise experiment rather than building a facility instrument. As an example, a series of continuous 10 s exposures does not require a tracking system able to achieve precise encoding for all 360^o of rotation of the telescope axis but just for a small arc, allowing for technical choices that result in a significantly cheaper, faster to realize and reliable design.

A 2 m class telescope at the Dome-C site can achieve a SNR of the order of five up to a magnitude $R \approx 23$ with a 10 s exposure.

4. The telescope design

The telescope design, shown in Fig. 1, is a redesigned and retrofitted Cerenkov Light Ultraviolet Experiment (CLUE, Bartoli et al 1999) structure and therefore will fit into a deployable shipping container. Data can be stored on–board and retrieved during the Antarctic

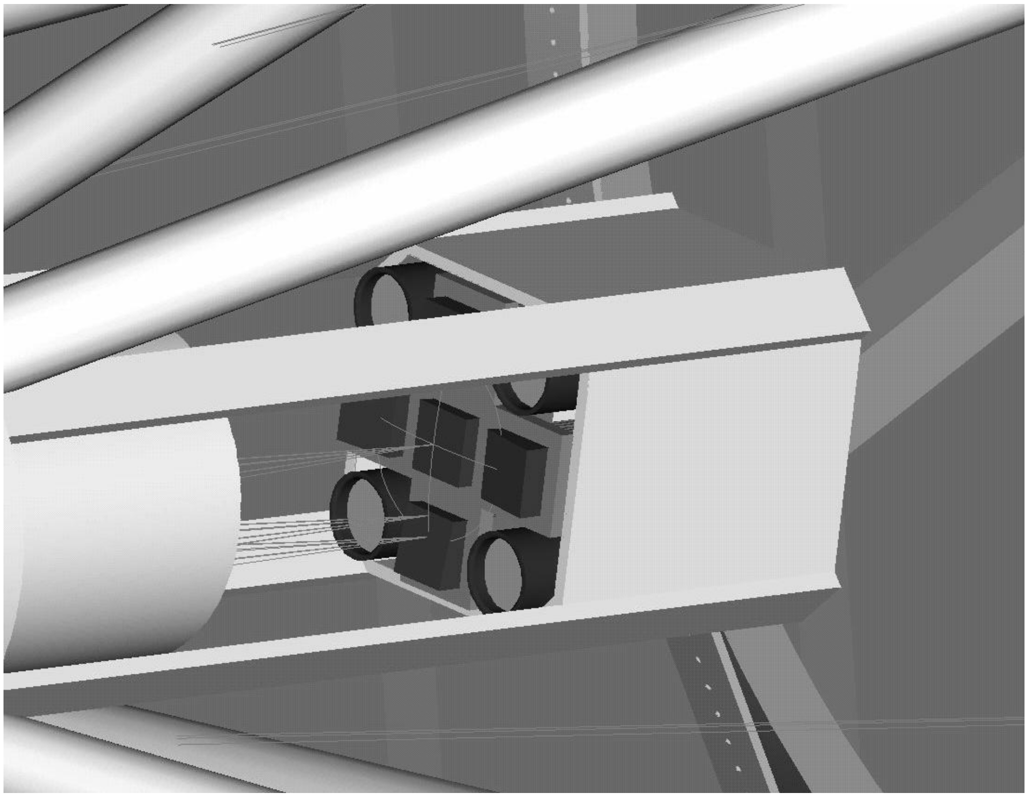

Fig. 2. A possible layout for the focal plane of the telescope. The five CCD chips allow for a total of five 5x5 arcmin square zones centered on the most crowded region of the Globular Cluster. Note they are tilted in order to match the Petzval curvature of the optical design. The four circular Field of View, each roughly 4 to 5 arcmin in diameter, are devoted for Adaptive optics assisted wavefront sensing. They are intended to collect the light of a large number of stars appearing in such areas modulated by a grating.

summer, assuming the Concordia station is not active during the winter.

To make a light, easy to align in a remote controlled or automated environment, we have chosen an all-spherical mirror solution allowing the segmentation of the entrance pupil into a manageable (especially in terms of weight) six mirror configuration with an effective entrance pupil diameter of 2 m. A secondary concave mirror focuses the light to a focal plane unit shown in Fig. 2. Five imaging CCDs are placed in a cross arrangement, each CCD covering 5 arcmin square of sky. The sensors placed at the corners of the field are for adaptive optics purposes and are discussed below. The wide-field correction is made possible by two sets of correcting elements. Close to the telescope pupil are 1-2 Gascoigne plates required to compensate for the introduced spherical aberration. The set of optics just priory to the focal plane correct for the remaining aberrations. All the auxiliary optics are below 200mm in diameter and hence are easy to manufacture, mount and align. Further details of the mirror support and mounting are shown in Fig. 3.

Adaptive optics (AO hereafter)is considered as a viable option. As the required FoV considered for such a camera (15 arcmin in diameter) is huge the role of AO is to remove the

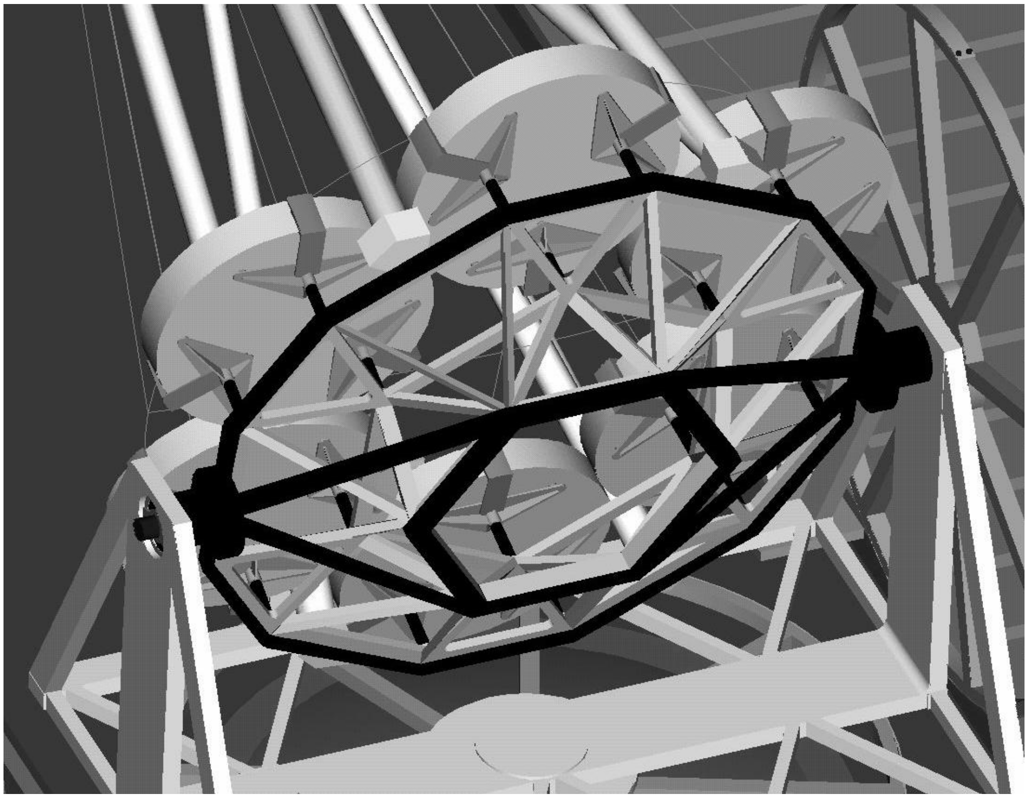

Fig. 3. Details of the mirror cell mounting. As the mirrors employed here are all spherical relative adjustment is easier as a decenter can be matched by a tilt only. If co-phasing is to be considered as an extra, three piezo driven supports could fullfil, in principle, any demands for adjustment of each of the segments of the main telescope entrance pupil.

ground layer turbulence so allowing always the exploitation of the exceptional image quality produced by the virtual abscence of the high altitude turbulence, as shown by the MASS results summarised earlier. The high altitude turbulence will not be strictly zero, of course, so some blurring of the image will remain and the 2 m class telescope will not be always diffraction limited, however, for the purposes of this science case a 0.1-0.2 arcsec resolution across the 15 arcmin FoV is perfectly adequate.

Components for such an AO system remain in the design process, however, a reasonable system can be based on the following. The secondary concave mirror is conjugated to 40 m altitude, perfect for removal of ground layer turbulence. It can be closely based on the smaller prototype for the secondary adaptive mirror of the Large Binocular Telescope (Riccardi et al. 2003). We are currently modelling the wavefront sensing on a combination of modulated grating (Ragazzoni et al. 2004) and curvature sensors, all placed in the focal plane unit covering a total of 1000 stars. This wavefront sensor has the great advantage of containing no moving parts, ideal for increasing the performance reliability that is crucial for remotely operated telescopes.

5. Conclusions

The project, that is currently undergoing the provisional name of the Gregorian Antartic telescope To Observe The Obscure Matter or

Gatto-Tom, is in the advanced phase of optical and mechanical design and will be proposed to PNRA in shortly. As always we greatly benefit from on-going discussions with our French and Australian collegues as a way of sharing our aims with other groups.

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