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AN ADAPTIVE 2M CLASS TELESCOPE FOR A MICROLENSING SEARCH FROM ANTARCTICA

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Abstract. We describe the scientific rationale and the preliminary opto-mechanical design for a 2 m class telescope designed to achieve ground layer correction over a ≈15 arcmin Field of View (FoV) to be located at the Dome-C site. The proposed science case is the detection of microlensing events in and by globular clusters and nearby galaxies that, for a high probability of success, requires exceptional seeing (≈0.2 arcsec or better) and a large target density (the centre of a globular cluster with a corresponding telescope FoV of ≈15 arcmin). This approach can capitalise on some of the unique qualities already observed above the Dome-C site, namely that the atmospheric turbulence is largely limited to a ground layer of small thickness only, a relatively low Greenwood frequency and uniterrupted sky coverage during the winter months for objects such as the globular cluster 47-Tuc. Further to the central science case of microlensing the telescope could provide a technological testbed for future telescopes and, given the unique atmospheric properties witnessed already during previous site testing compaigns, has the chance to provide a large amount of data (based on accurate and continuous light curves lasting several months) for fields of research outside that of microlensing. Details of the specific concepts of adaptive optics to be adopted for this telescope are outlined.

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1 Introduction

The potential for outstanding visible astronomy due to the unique atmospheric properties found above the Dome-C site in Antarctica is well established in literature, as well as numerous papers in this conference. Most notable are the site testing results presented by two groups who, using various instruments for the characterisation of atmospheric properties most important for visible astronomy, have brought to the attention of the world's visible astronomy community the potential of this site.

The results of the site testing campaigns can be summarised as follows. The operation of a Differental Image Motion Monitor (Arisitidi 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 substantial 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. The high-altitude turbulence impact on the image quality measured on the ground was soon after determined using a Multi-Aperture Scintillation System (MASS). Measurements showed a ≈0.3 arcsec mean value with periods including seeing as low as 0.15 arcsec in the visible (Lawrence et al 2004). The mean isoplanatic angle, the angle on the sky over which the turbulent effect of the atmosphere is less than a square radian, was ≈6 arcsec with a corresponding mean Greenwood frequency of ≈8 ms. In addition to the exceptional seeing qualities there are other reasons making Dome-C 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.

We propose an experiment consisting of a 2 m class telescope at Dome-C with a science case the success of which is only possible at a site with similar qualities or better than Dome-C. The proposed science case concerns the detection of microlensing events due to the gravitational lensing of background stars by intervening dark matter. The potential for a staggeringly large field of view with corresponding excellent optical quality offered by the Dome-C site (possibly 15 arcmin field with ≈0.2 arcsec image size across the entire field using Adaptive Optics (AO) ground layer correction only) enables a sufficiently large number of target stars to be observed simultaneously. This increases the chances of witnessing what is in reality a rare event, since crowding is the largest source of uncertainty.

2 Microlensing from Dome-C

As microlensing surveys have existed for many years in order to produce outstanding science we have to push the parameter space. In particular, other than the absence of jumps in photometric data due to the use of different telescopes throughout the world in the existing microlensing searches, the much higher spatial and temporal sampling (0.1 arcsec on 10 s exposures, for example) should allow the proposed 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. However, it is noted that the telescope is not required to provide diffraction limited performance of the full aperture but just to exploit the excellent seeing conditions experienced at Dome-C over a wide field.

The scientific outcome can be unique as the microlensing search is made on a large number of stars located at a well known distance (removing some of the ambiguities often occuring in microlensing events), not to mention the more exotic possibilities such as self-lensing in the cluster itself (Sahu 1994a). Moreover, there is a by production of huge amounts of lightcurves useful for studies of eclipsing binaries, IMF, deep imaging to name but a few.

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.

3 The telescope design

The telescope design shown in Fig.1 is a redesigned and retrofitted Cerenkov Light Ultraviolet Experiment (Bartoli et al 1999) structure designed to fit into a deployable shipping container. Data can be stored on–board and retrieved during the Antarctic summer, assuming the Concordia station is not active during the winter.

To make the design light and 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 relatively easy to manufacture, mount and align. Further details of the mirror support and mounting are shown in Fig.3.

AO at some level is considered unavoidable. As the required FoV considered for such a camera (15 arcmin in diameter) is huge the role of AO is to remove the ground layer turbulence so allowing always the exploitation of the exceptional image quality produced by the virtual absence of the high altitude turbulence, as

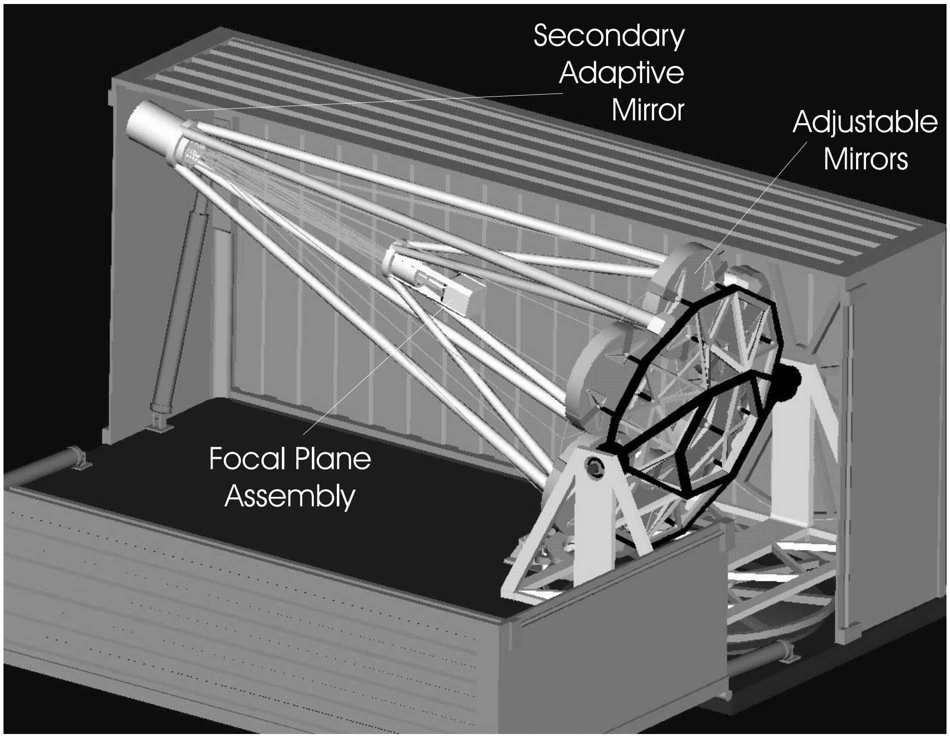

Fig. 1. A layout of the telescope shown inside a standard size shipping container, one of the major influences on the telescope design. The 2 m aperture is composed of 6, 80 cm spherical mirrors co-aligned but not necessarily co-phased (the diffraction limit of a single 80 cm mirror is 0.17 arcsec at 550 nm) is sufficient for achieving the goals of the proposed science case). Spherical mirrors were chosen because of their ease of alignment and resulting large field of view. An adaptive secondary mirror, based on the prototype for the secondary mirror for the LBT project (see text for further details), reflects the primary beam to a group of aberration correcting Gascoigne plates. The beam enters the focal plane assembly, containing an additional group of aberration correcting lenses, and finally to the focal plane array (not shown in this diagram).

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, suitable for the removal of ground layer turbulence. It can be closely based on the smaller prototype for the secondary adap-

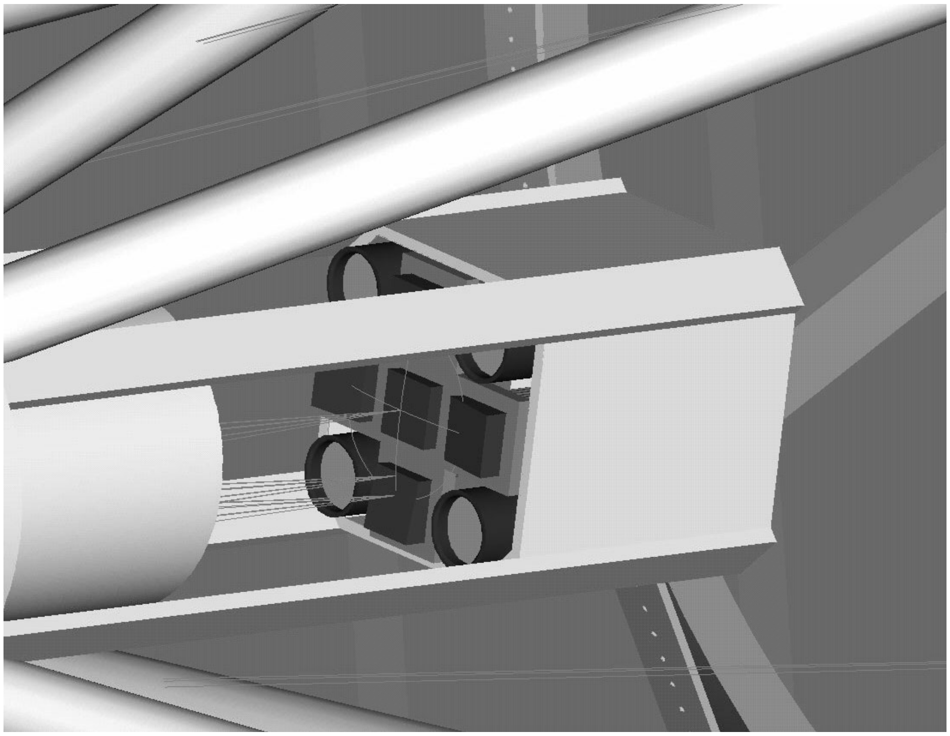

Fig. 2. A possible layout for the focal plane of the telescope. The five CCD chips allow for a total of five 5x5 arcmin square zones centered on the most crowded region of the Globular Cluster. The chips are tilted to match the Petzval curvature of the optical design. The four circular Fields of View at rhe corners of the focal plane unit, each roughly 4 to 5 arcmin in diameter, are devoted to AO assisted ground layer wavefront sensing. Their function is to collect the light of a large number of stars appearing in such areas modulated by a grating.

tive 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 which cover a total of ≈1000 stars. This wavefront sensor has the intended advantage of containing no moving parts, ideal for increasing the performance reliability that is crucial for remotely operated telescopes.

4 Summary and conclusions

We have presented a summary of a 2 m class telescope to be located at the Dome-C site in Antarctica with a primary science case of detecting microlensing events not possible from any other ground based site. The project relies on the advantages

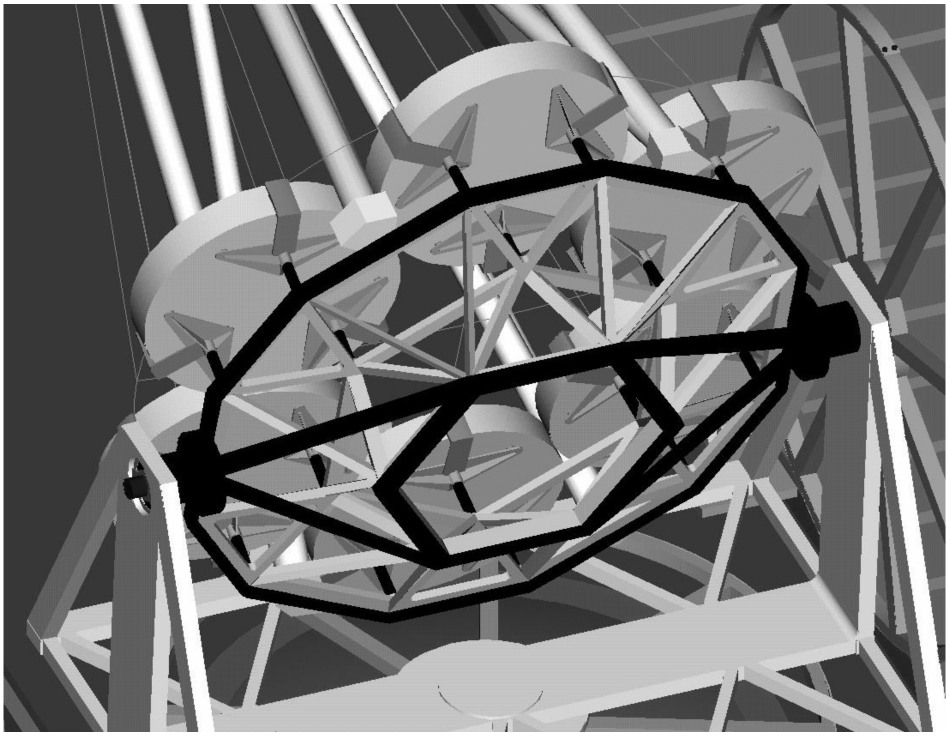

Fig. 3. Details of the mirror cell mounting. As the mirrors employed here are all spherical relative adjustment is easier as a decenter can be matched by a tilt only. If co-phasing is to be considered as an extra, three piezo driven supports could fullfil, in principle, any demands for adjustment of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

of the Dome-C site over temperate locations, namely the continuous coverage possible, the excellent seeing and available wide field after ground layer turbulence removal only. In addition, the telescope offers a technological testbed for future large scale projects such as an Extremely Large Telescope sited at Dome-C, if indeed the seeing and absence of high-altitude turbulence is proved unanimously by long term observations using telescopes of a 2 m class. An extension of the telescope design is the co-phasing of the 6 spherical mirrors to give a diffraction limited performance of a 2 m diameter aperture that could be viewed as a prototype for future interferometry projects aimed to operate at the Dome-C site in the future (Coudè et al 2003).

The project requires the following logisitical needs. A warm pre-test base on the coast of Antarctica is required prior to traverse of the telescope to Dome-C. We require the traverse of a single shipping container and an AASTINO-like mound of snow on which to place the telescope container. Power and, at least, a low-capacity data link are required throughtout the winter. Lastly, logisitcal support at the Dome-C base is required for installation of the telescope prior to the commencement of the winter season.

The schedule and project milestones can be summarised as follows. Following the submission of the project description to INAF we intend to complete the initial design review in approximately 6 months. Components requiring low temperature testing will be identified and tested. We estimate commencement of assembly in approximately 2-3 years and pre-testing of the telescope as a whole in a cold European site, such as existing astronomical facilities in the Alps, for at least 6 months- 1 year. We estimate shipping the telescope, fully tested and assembled, in 3-4 years starting from the culmination of the design review stage.

This small to medium sized project is estimated to cost of the order of 2MEuro. The funding money could be for dual purposes (for the science case described as well as funding a facility for testing ELT components). The project would re-use the designs of exisiting hardware such as the prototype adaptive mirror for the LBT adaptive secondary mirror.

Disadvantages of the Dome-C site should also be noted. These are that only 6 months of the year is available for observations in the visible, that it is a difficult though not impossible working environment and, at least until the Concordia station is manned throughtout the year, that data cannot be retrieved until the first traverse to Dome-C at the beginning of the summer season. For this project it is felt the possible scientific achievement alone far outweighs such disadvantages.

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