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Visible Astronomy as well ? Why not !

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Abstract. It is quite clear that the dry and cold astronomical site of dome C has to be one of the best places on Earth, if not THE best, for infrared and sub millimetric astronomical observations. In comparison with usual observatories located in more usual latitudes, the benefit to be expected in the visible range is a little less obvious. But this benefit does exist indeed. The very long days and nights of the Antarctic plateau provide a unique opportunity for extremely long and nearly uninterrupted observations. Added to the expected reduced amplitude of the stellar scintillation, this makes possible to consider the feasibility of asteroseismic observations that were envisioned only in space so far. Such night time astronomical programmes can be developed very quickly, with moderately sized telescopes, and will benefit of the first winter-over seasons at Concordia. When thinking beyond the first few winters, the unique seeing properties of the site look extremely promising for the combination of interferometry, high performance adaptative optics and stellar coronography, or very high contrast imaging, so that the direct observations of exoplanets must be considered as a possibility for future observations on this site. I briefly review here the first projects and ideas in these directions. As many of these ideas are presented during this "visible" session, you will find details, regarding most of them, in other papers of these proceedings.

Key words. visible astronomy

1. Introduction

Historically speaking, the first successful astronomical observation on the Antarctica plateau was done at South Pole during the 1979/80 summer season. Thanks to the incredible perseverance of Martin Pomerantz (second from left on Figure 1), from Bartol, Gerard Grec and I had the chance of accessing the Amundsen-Scott South Pole station with a very first prototype of the future full disk helioseismic instruments developed for the IRIS network and then for the GOLF space instrument on SOHO. The first uninterrupted measurement of global solar oscillations much longer than one day (6 days non stop, in fact) was obtained during the first week of 1980, and it has since then been regarded as the birthdate of helioseismology, the word itself being used only a year later (Grec 1981) (Grec et al

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Fig. 1. From left to right, Eric Fossat, Martin Pomerantz, Lyman Page and Gerard Grec with the first solar both azimuthal and equatorial telescope that was successfully operated at the geographical South Pole in 1979/1980, providing 6 days of uninterrupted full disk oscillation data

1983). Several other helioseismic missions were then organized, still thanks to the help of Martin Pomerantz, by ourselves and an American group lead by J. Harvey and T. Duvall (Harvey et al 1982).

However, helioseismology was more and more demanding in the extremely long duration of as uninterrupted as possible time series, so that it started to spread around the planet by means of ground based networks first, and of spacecrafts later on. The South Pole station was not able to provide many consecutive months of continuous data, and it became less demanded for this scientific chapter. However, the astronomical properties of the site were studied in much detail and an important night time IR observatory was logically the next step (Roche 2003).

2. The Concordiastro programme

To-day, the South Pole site is certainly one of the best known on Earth for its astronomical properties (Storey 2003). However, if it has indeed proved to be an exceptional site in the infrared and submm ranges, it has also been a little disappointing regarding the seeing in the visible range (Marks et al. 2000). The reason is a 300 to 400 m thick layer of turbulent air due to the fact that the pole is standing on a slope of the polar plateau, even if this slope cannot be felt when looking around at the apparently absolutely horizontal snow desert. This slope is still enough to permit the presence of a katabatic wind coming down from the dome A area, and producing enough turbulence to damage the optical seeing.

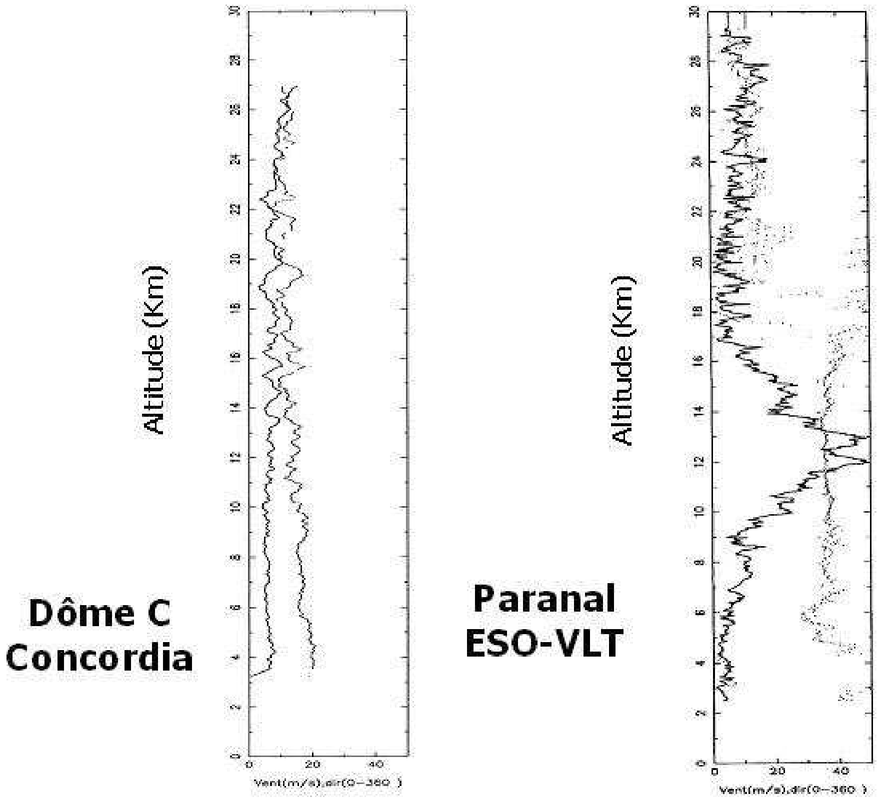

Fig. 2. Left panel: An example of the wind speed profile above the dome C site, up to about 27 km in this case (left curve), with also the wind direction on the right curve. It shows that the maximum wind speed at any altitude above the site is of the order of 10 m/s. Right panel: For comparison, the same wind speed profile measured above the Chilean site of Cerro Paranal, shows the standard jet stream between altitudes of 10 and 15 kms. Courtesy M. Azouit

The dome C site is a dome, and is consequently supposed to be free from katabatic wind. Indeed, the surface wind statistical values are of the order of 6 m/s at South Pole against only 2.6 m/s at dome C. The difference has a very significant impact on the amount of flying snow, and even more important on the amount of turbulence disturbing astronomical images. Another important issue for astronomers is the frequent absence of high speed wind even at high altitude (see Fig. 2). If this can be confirmed at night on a long term basis, it will have really tremendous consequences for optical and near infrared astronomy: indeed, it could imply the absence of any turbulent layers other than the moderate one very near the snow surface. On one hand multiconjugate adaptative optics would then not be required, and on the other hand the stellar scintillation produced by high altitude turbulence would be reduced, possibly enough for making feasible asteroseismic measurements of very faint stellar oscillations. These are generally regarded as inaccessible from the ground because of the scintillation limitation.

Along these ideas, the Concordiastro programme was proposed to both French and Italian polar Institutes in 1999, when it became clear that the Concordia station was really being erected and would become available within only a few more years. This programme aims at measuring the atmospheric seeing quality of the site by many different ways, including in situ radio-soundings and direct optical measurements of quality of the stellar image provided by a telescope. The programme was first funded in 2000, and at the time of the Capri meeting, three summer campaigns have already been organized. They were mostly devoted to daily radio-soundings by means of meteorological stratospheric balloons, and during one month of the last campaign, to the first DIMM measurements ever made at dome C and ever made in permanent sunlight on the star Canopus (Aristidi 2003). During the first accessible winters, a DIMM first and a GSM then (Martin et al. 1994) will be operated to provide as many as possible seeing parameters all night long. Stratospheric radio-soundings will also be done if (financially) possible on at least a weekly basis, and the possibility of organizing a Scidar (Vernin et al. 1973) campaign is also being considered. The solar part of this site testing efforts is in the hands of the OAC group at Napoli, and will include high resolution full disk solar imaging (Moretti et al. 2003).

Another important parameter of the site qualification is the cloud cover statistics, that is not outstanding at South Pole, the sky being covered by more or less thin cirrus clouds nearly 50 percent of time. The precise statistics is not known yet at dome C, but it begins to appear that it will be much better, and even possibly outstanding. The Aastino (Lawrence 2003) and Icecam Australian programmes (Travouillon 2003) are now measuring it at night. Of course, if the seeing night time is really exceptional thanks to the slow winds, with an outstanding cloud cover statistics, the site can then be regarded as the best in the world not only in infrared but also for visible astronomy as well.

Fig. 3. This wooden platform is the first of two that will support, at 6m above the ice surface, the series of small telescopes of the Concordiastro programme, making site testing on one of them and astroseismology on the other one. Photo K. Agabi

3. Asteroseismology, stars and giant planets

The first night time astronomy programme that comes to mind in the visible range is the stellar continuation of the pioneer work made with Pomerantz 24 years ago. Helioseismology has become to-day a mature science, while asteroseismology, that intends to do the same on distant solar-type stars, is still at its very beginning. You can read more details on this topic in another paper (Kurtz 2003).

Along this line, the Concordiastro programme contains the first step of asteroseismic measurements to be conducted at Concordia, namely the double star Alpha Centauri (Grec and Renaud 2003). Solar-type oscillations have recently been detected in Doppler shift measurements with a large telescope on the brightest component of this double star (Bouchy and Carrier 2002). As I already mentioned, asteroseismology is expected to be extremely difficult for ground based observations made in photometry, so that at least

Fig. 4. The surface of Jupiter clearly shows the presence of turbulent motions (including the great red spot) that can be noisy enough, in the real acoustic sense of the word, to imply the presence of resonant acoustic vibrations of all the planet body. Photo Voyager, NASA

two important space projects will be partly devoted to it. The French Corot instrument (Baglin et al. 1998) is supposed to fly within the next two or three years, while the more ambitious Eddington European project is in the ESA package for 2008/2013 (Favata et al. 2000). These space missions intend to measure as many stars as possible, so that they will avoid the brightest of them for the simple reason that they are too bright and an instrument cannot be tuned for both bright and faint stars. As generally speaking, the brightest stars are also our nearest neighbors, they are extremely interesting, and they represent an ideal target for the dome C ground based site, provided the scintillation level confirms that it is indeed significantly lower than anywhere else. Alpha Centauri will be measured during the first accessible night, in 2005.

However, the stars are not the only night time objects that can show pulsations. In parallel to the selection of a few bright stars, the asteroseismological programme that is planned for the first winter-over campaigns at Concordia includes the planet Jupiter. Jupiter is not a star, but it is also a non standard planet, as it has no solid ground, being made mostly of Hydrogen and Helium, as the Sun and most stars. As it is visibly extremely turbulent (see photo), it has been shown already that these noisy subsurface layers must generate enough acoustic energy for producing resonant acoustic vibrations, exactly as the subsurface convection is doing the same in the Sun (Schmider et al. 1991). Consequently, an asteroseismic study of the deep internal structure of Jupiter is also possible, under the name of Jovian seismology (Voronstov et al. 1976), (Mosser et al. 1991). As this deep internal structure is poorly known in fact, this research appears to be very important for the general understanding of the planets and planetary systems formation (Guillot 1998). For this purpose, a specific instrument has been developed at Nice. This instrument is named "Sympa", for SIsmometre IMageur a Prismes Accoles (Schmider et al. 2002). It is a very compact Mach-Zender interferometer, that makes interferometric images of the planet. They give access to acoustic resonant modes of degrees comprised between zero and 20 to 30 depending on the atmospheric turbulence. This range should be adequate for obtaining a good enough vertical resolution in the inversion of frequencies for reconstructing the Jovian interior model.

Now, in 2003, Jupiter is standing relatively high in the Northern hemisphere sky. Its continuous observation is only possible by means of coordinating several observations, using then several instruments at different longitudes. Then, Jupiter will quickly move towards the Southern hemisphere, and for a few years starting in 2006, it will be permanently visible from the dome C. That year will correspond to the second winter-over at the Concordia station, so that the Jupiter programme appears to be very well suited for an optimal deployment at Concordia.

4. Then, what's next?

Clearly, what will happen then, after the first asteroseismic night time campaigns, will depend on the final site testing results, that will will make the site more or less strongly attractive to visible light astronomers, for counterbalancing the difficulty inherent to the geographical situation. The first priority during these first few winter-over campaigns, then, remains without doubt the site testing that must provide extensive, robust and convincing results.

Then, if one assumes that the seeing properties will be consistent with their present expectation in term of Fried parameter, isoplanetic angle and wavefront coherence time, one cannot avoid thinking of large scale astronomical projects involving either very large apertures or long distance interferometry, or both, and with high performance adaptative optics operated in near IR. If you join the IR site quality, with its prospects in high angular resolution and high contrast imaging, the search for direct exoplanet observations is obviously the scientific target that comes to mind. The scientific community involved in this direction has been participating for the first time to this Concordia workshop, thus significantly raising the general optimism on the future of astronomy on the site. The Concordia potentialities in this direction are developed in another session of these proceedings.

Now, between the first night time campaigns with modestly sized telescopes and the very ambitious prospects regarding possible ELT (Extremely Large Telescopes), there is some room and some need for intermediate size projects. We have a few of such projects presented in these proceedings, such as a wide field visible and near IR telescope (Viotti et al. 2003) or a very light robotic 1 to 1.5 m telescope (Boer 2003). An interesting idea, with a scientific scope that goes beyond astronomy, is the measurement of the moon Earthshine for monitoring the climate change on Earth through the albedo long term variation (Chou 2003).

5. Conclusions

This meeting at Capri was not the first one organized around the astronomical prospects at Concordia. However, it has clearly been the broadest, the most international, and all participants have felt that it indicated a very sharp step upwards in these prospects. So I will not include any conclusion in this paper, as any such attempt will be made obsolete very soon, as we all hope.

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