Mem. S.A.It. Suppl. Vol. 2, 92

Memorie della
Supplementi

Infrared Wide Field Spectro-imagery at Dôme C

N. Epchtein[1,2]

[1] Observatoire de la Côte d'Azur, Département Fresnel, 06304 Nice Cedex, France. e-mail: epchtein@obs-nice.fr

[2] CNRS UMR 6528

Abstract. Dôme C is probably the only site on Earth where to perform efficiently large scale broad band and spectro-imaging surveys in the thermal infrared. The largest gain in sensitivity with respect to the best conventional sites occurs between 2.3 and 5.5 μm . I review briefly some of the outstanding astronomical programmes that could be performed with a wide field spectro-imager equipped with a $4k \times 4k$ arrays attached to a 2-3 meter class telescope in the framework of the CONCORDIA international platform.

Key words. Infrared – Survey – Antarctica

1. Introduction

Wide field imaging in the thermal infrared ($\lambda > 2.3\mu$m) is one of the astronomical areas that would greatly benefit of the atmospheric conditions that prevail in the Antarctica Plateau. This spectral range is essential to investigate the physical properties of the interstellar medium and the extreme phases of stellar evolution, the birth of stars and their ultimate stage of evolution on the asymptotic giant branch (AGB). It is also of considerable interest for extragalactic and cosmology programs. A pioneering work has been undertaken in this domain by Burton et al. (2000) during the nineties using the SPIREX facility, a 60 cm telescope equipped with an infrared camera housing an *Aladdin* type 1024 × 1024 InSb array operated at the South Pole station. Excellent images with a pixel size of 0.6" were performed of the large complex nebula NGC 6334 in the L and M broad band filters as well as in a series of narrow band filters centered on the H_2 line at 2.42 μm , the PAH feature at 3.3 μm and the $Br\alpha$ line at 4.05 μm . These results demonstrated the extraordinary gain in sensitivity provided by the exceptional atmospheric conditions and environment of Antarctica. According to the recent results (see *e.g.,* Walden & Storey, Calisse *et al.*, in this volume) obtained with various sky monitoring instruments, the site of Dme C exhibits even better conditions, in particular thanks to the highest altitude and the quasi absence of katabatic winds that strongly hamper the observations from the Pole itself. Unfortunately the SPIREX operations ended up in 1999. It is therefore extremely appealing to proceed now with a simi-

Send offprint requests to: N. Epchtein
Correspondence to: OCA, boulevard de l'Observatoire, 06304 Nice Cedex, France

lar more performant equipment from Dme C, such as the Italian Robotic Antarctica Infrared Telescope (IRAIT) (Tosti *et al.*, 2003) that would prolong and consolidate the former results and provide a real evaluation of the quality of the new site in the field of near and mid infrared imaging. Development of larger facilities in this site would logically rely on the results obtained with a modest size and relatively low cost instrument.

2. The unique infrared observing conditions in Antarctica

Many campaigns of site testing have been performed at the South Pole to study the infrared properties (Phillips et al., 1999) or the turbulence (e.g. Travouillon et al., 2003), they are just starting at Dôme C, namely with the launch of sounding balloon by the University of Nice (UNSA) and the set up by the University of New South Wales (UNSW) of the automated station AASTINO (see Storey *et al.*, in this volume) that started a first winter-over campaign in 2003. The major advantages of the Antarctica conditions for infrared observations are well known and have been detailed in several contribution in this volume, namely, *i)* a low amount of water vapour (less than 200 μm of precipitable water vapour is frequent), *ii)* a very low sky brightness, *iii)* the possibility of cooling down passively the main mirror and the focal instrument to -60C (or even less), *iv)* a low content of aerosols which appears to be a major cause of extinction in the near infrared (Hidas et al., 2000). These exceptional atmospheric conditions lead to the outstanding result that *"for wide field imaging an Antarctic 2 meter telescope has similar sensitivity in the thermal infrared to that of an 8 meter on a good infrared site such as Mauna Kea, but has potentially a much wider field of view"* (Burton et al., 2001) These conditions make Dôme C a unique site on Earth to survey very large areas of the sky, if not the all–sky observable, in the near and mid–IR thermal bands (*i.e.,* K_{dark}, L', M' N, Q).

Large scale surveys require repetitive observations during a long elapse of time and are perfectly suited to a robotic telescope. Useless to say that the extremely long dark time in polar sites is also a great advantage to perform long range surveys. Therefore, Dôme C is likely to be the best and probably only place on Earth where to extend towards longer wavelengths the recently completed 2 μm sky surveys, 2MASS (Skrutskie et al. 1998) and DENIS (Epchtein et al., 1998, 1999).

3. Wide–field broad–band surveys in the 2-5 μm range

3.1. Quest of very low mass-stars

Large scale digital sky surveys such as DENIS, 2MASS, SDSS have proven to be extremely useful tools to investigate the statistical properties of the stellar populations, the galactic structure, and the general interstellar extinction. Thanks to its completeness, DENIS discovered the first sample of the formerly hypothetical brown dwarfs (Delfosse et al., 1997) and the new class of extremely low mass stars (the so called "L–type" stars). This was followed by a harvest of discoveries made by DENIS, 2MASS (*e.g.,* Kirkpatrick *et al.*, 2000) and SDSS (Hawley *et al.*, 2002), and the detection of the first so called "T-class" stars that exhibit methane absorption bands at 1.3, 1.6 and 2.2 μm . Besides the discovery of field-brown dwarfs, the deep near IR surveys revealed a large number of young low mass stars in regions of recent star formation such as the Chamaeleon cloud (*e.g.,* Cambrésy *et al.*, 1998, Vuong *et al.*, 2001). All–sky near infrared surveys have therefore conspicuously contributed to our knowledge of the Initial Mass Function toward the low mass end. An extension of these surveys limited to the K_{short}band (with a cut-off at 2.3 μm), because of the prohibitive sky and instrumental emission, is essential to complete the sampling toward even lower mass objects whose surface temperature ranges between 500 and 1000 K. These stars, brown dwarfs and *free–floating* planets are so faint below 2 μm that they will hardly be detected by the very deep surveys that VISTA (Emerson, 2001) plans to perform. It is only by exploring very large areas of the sky in the L' and M' bands and perhaps beyond that one could single out these still missing objects. Moreover, above 2.5 μm , the interstellar extinction and the dust extinction in the cores of Large Molecular Clouds are much lower. Extremely extinguished young objects will be unveiled in star forming regions only at these wavelengths.

3.2. AGB star populations of the Galaxy and the Magellanic Clouds

Infrared colour–colour and colour–magnitude diagrams are extremely useful for the classification of stars surrounded by circumstellar dust shells, a phenomenon that is due to the mass loss of gas and dust during the asymptotic giant branch (AGB) late phase of stellar evolution. For instance, Epchtein et al. (1987) developed a method that allows to separate carbon-rich and oxygen-rich dust envelopes just on the basis of their infrared colours. Moreover, Le Bertre and Winters (1998) showed that there is a good correlation between the mass loss rate and the index $K - L$. Since AGB stars are the main provider of heavy elements to the interstellar medium, it is important to make complete census of these stars in the galactic disk. The extension of the earlier 2 μm surveys to longer wavelengths, and especially in the L band is therefore crucial for the detection of the most extreme AGB stars that suffer the largest mass loss rate and their chemical classification.

The Magellanic Clouds (MCs) are ideal targets for the study of red giants and AGB stars, because their distance is well determined. The 2 μm surveys have already collected photometric data for a large number of AGB stars in the MCs (Delmotte et al., 2002) but the densest dust and gas envelopes have probably escaped detection, because they are too red and their maximum of emission lie in the 3-10 μm range. We propose as a first priority to make a complete broad band survey of the MCs in this range.

Finally, a survey of the galactic bulge and inner galactic disk would be of utmost interest in complement to the ISOGAL programme (Omont et al.,1999) and studies of the galactic structure.

4. Wide field spectro-imaging surveys in the 2-5 μm range

Perhaps even more promising in Antarctica is the possibility of mapping significant areas of the sky in spectral features that are difficult to observe from a conventional site, albeit they do not require the spatial conditions. Among the numerous observing programmes that could be performed, I shall limit myself to the mapping of the dense interstellar medium in the molecular hydrogen lines and dust features.

4.1. A survey of the excited dense ISM in the molecular hydrogen lines

Molecular hydrogen (H_2) is the most abundant molecule in our Galaxy and in the Universe. A large part of the missing baryonic matter might be in the form of still undetected huge amounts of this molecule. Unfortunately, H_2can be detected only through UV vibration lines (space conditions required) and the rotation and vibration–rotation lines in the mid and near–infrared, respectively. A large number of lines exists in the 2–3 μm range, notably the (1-0) S(1) line at 2.12 μm which is relatively easy to measure from the ground (*e.g.,* Habart *et al.*, 2003). These lines are seen in regions of high excitation (strong UV field, shock, Photodissociation regions, etc..). The rotation lines, at 9, 12 and 17, 28 μm for the ortho and para-hydrogen, respectively could probably be observed from the ground in the exceptional conditions of Antarctica - except perhaps the 28 μm line that coincides with a strong atmospheric water vapour band. One priority of an Antarctica infrared telescope would certainly be a deep survey of the major Giant Molecular Clouds and Dark Clouds of the Southern Hemisphere such as ρ Oph, the Chamaeleon complex, the Coalsack, the Carina, Lupus and RCrA clouds (Cambrésy , 1999), both in the rot–vibration lines between 2 and 3 μm , and possibly in the 9, 12 and 17 μm rotation lines, in connection with the planned H2EX mission (a space mission recently proposed to ESA to survey the rotation lines in the Galaxy and several large nearby spiral galaxies).

4.2. Dust, ice grains and PAH features in the ISM

The 2-10 μm domain is very rich in spectral features that originate in the stretching and bending modes of dust and ice grains (solid water, ammoniac). They produce characteristic emission and absorption features in the spectra of thick envelopes that surround massive Young Stellar Objects such as W33A (Gibb *et al.*, 2000; Taban et al., 2003), Planetary, proto-Planetary Nebulae, Herbig AE/Be stars (van Kerckhoven *et al.*, 2002) , etc... Most of them have been revealed by the SWS on board the ISO mission, but some important features can be observed from dry ground based sites and *a fortiori* from Dme C. Main dust/ice/PAH spectral signatures that could be mapped with a spectro–imager in excellent conditions from Dôme C are the PAH at 3.3 μm , NH_3, near 2.21 μm , the 3.43, 3.53 μm (C–H bonds) attributed to nanodiamonds (hydrogeneated diamonds) (van Kerckhoven *et al.*, 2002) already discovered in comets by Lewis et al. (1989)

5. Future instrumental developments for the thermal IR at Dome C

After the completion of IRAIT that will demonstrate the real quality of the site, I consider urgent to design, build and operate a wide field imaging telescope of reasonable size (2-3 meter class) that would complete the 2 μm deep surveys proposed with the VISTA facility at Paranal. This telescope should be equipped with the largest and most performant focal plane arrays available to day, such as the $4k \times 4k$ arrays manufactured by Rockwell (Hawaii RG2) made of 4 buttable 2k arrays. This would typically cover $30' \times 30'$ fields with a pixel size of 0.5 $''$compatible with the diffraction figure of a 2.5 meter telescope in the 3-5 μm range. Another camera could be dedicated to the longer wavelengths (8 to 30 μm).

An integral field spectrograph should be added to perform the line surveys in the 2-5 μm window. Considering the low background condition of Dôme C and the multiplex advantage, I support the idea of adding to the camera an Imaging Fourier Transform spectrograph (IFTS) covering the 2-5.5 μm range with a spectral resolution of ≈ 5000 (see poster by J.P. Maillard *et al.*at this conference and Wurtz et al. 2002).

6. Conclusion

The CONCORDIA station is now a reality and astronomers are now seriously contemplating the installation of large facilities at Dôme C for the infrared, millimeter and submillimeter region. The site is particularly well suited to surveying large areas of the sky - may be the all southern sky - in the K_{dark}, L' and M' bands. The only challenging project is the WISE space mission, now in phase A study at NASA, that plans to cover the all–sky with am actively cooled 50 cm telescope in the 3.5, 4.6, 12 and 25 μm bands. However, an Antarctica survey done with a 2 meter (or more) telescope would provide a comparable sensitivity in the 3-5 μm range but with a much better spatial resolution.

Besides, the spectro-imaging capability provided by an imaging Fourier transform spectrometer would considerably enhance the interest of the Antarctic project with respect to WISE.

References

Burton M.G., Ashley M.C.B., Marks R.D., *et al.*, 2000, ApJ 542, 359

Burton M.G., Storey J.W.V., Ashley M.C.B., 2001, PASA 18, 158

Cambrésy L., Copet E., Epchtein N., *et al.*, 1998, A&A, 338, 977

Cambrésy L., 1999, A&A, 345, 965

Delmotte N., Loup C., Egret D., *et al.*, 2002, A&A, 396,143

Delfosse X., Tinney C.G., Forveille T., *et al.*, 1997,A&A 327, L25

Emerson J.P., 2001, Proc. ASP Conf. Ser. 232, 339

Epchtein N., Le Bertre T., Lépine J.R.D., *et al.*, 1987, A&A Supp 71, 39

Epchtein N., 1998, Proc. 3rd Euroconf. on Near IR Surveys, ASSL series 230, 3, Kluwer Ac. Pub.

Epchtein N., Deul E., Derriere S., *et al.*, 1999, A&A, 349, 236

Gibb E.L., Whittet D.C.B., Schutte W.A., 2000, ApJ 536, 347

Habart E., Boulanger F., Verstraete L., *et al.*, 2003, A&A, 397, 623

Hawley S.L., Covey K.R., Knapp G.R., *et al.*, 2002, AJ 123, 3409

Hidas M.G., Burton M.G., Chamberlain M.A., Storey J.W.V., 2000, PASA, 17, 260

Kirkpatrick J.D., Reid I.N., Liebert J., *et al.*, 2000, AJ 120, 447

Le Bertre T., Winters J.M., 1998, A&A 334, 173

Lewis R.S., Anders, E., Draine B.T., 1989, Nature 339, 117

Omont A. Ganesh S., Alard C., *et al.*, 1999, A&A 348, 755

html:¡/A¿" not implemented xdvi: special-phillips Phillips A., Burton M.G., Ashley M.C.B., *et al.*, 1999, ApJ, 527, 1009

Skrutskie *et al.*, 1998, Proc. 3rd Euroconf. on Near IR Surveys, ASSL series 230, 11, Kluwer Ac. Pub.

Taban I.M., Schutte W.A., Pontoppidan K.M., van Dischoek E.F., 2003, A&A, 399,

Tosti G., Busso M., Ciprini S., 2003, Mem. S.A.It. 74, 37

Travouillon, T., Ashley M.C.B., Burton M.G., *et al.*, 2003, A&A, 400, 1163

Van Kerckhoven C., Tielens A.G.G.M., Waelkens C., 2002, A&A, 384, 568

Vuong M.H., Cambrésy L., Epchtein N., 2001, A&A, 379, 208

Wurtz R., Wishnow E.H., Blais-Ouellette S., *et al.*, 2002, ASP Conf. Ser. 280, 139