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The meaning and the significance of a mid-ir antarctic experiment at Concordia Station

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Abstract. Several discussions have been introduced in these years about the general importance of the Antarctic Site of Dome C for the conduction of infrared astronomical measures, especially in view of the completion in the next few years, of the French-Italian Scientific Station on the Antarctic Plateau. In this presentation I would like to focalize the importance of a creation of a facility aimed, in particular, at making a survey study in the mid-ir frequency range at Dome C. I would present and discuss the hypothesis of an observing campaign at 10 and 20 microns examining some peculiar aspects: from the importance of performing the first experiment of this kind in antarctica, to the specific scientific interest in this domain, to the opportunity of defining the technical objectives of the instrumentation, up to the future prospects that can be opened by this experiment for the future of Infrared Astronomy from Antarctica.

Key words. IR Astronomy, Mid-ir, Survey Telescope

1. Introduction

As the time when the Concordia Antarctic Scientific Station at Dome C will become operative is approaching, all the discussions of the last years about the scientific use of the Station have to be directed towards the identification of possible and suitable commitments for the development of Astronomy in Antarctica. In fact this was the declared purpose of the Meeting held in Capri, aimed to determine the strategy for a stable astronomical observing activity on the High Antarctic Plateau. In this context, I would try to illustrate in more details, with respect to the previous interventions [1,2,3,4] on the theme, the reasons and the prospects in favour of a soon observing facility for the mid-ir range of wavelengths at Dome C. Starting from the Site characteristics, some advantages will be put in evidence that will ensure a scientific success for different programs in Astronomy in different fields and in particular in the mid-ir domain. I would like to dwell upon the intrinsic reasons of supporting warmly the mid-ir observing range with respect to others (optical and near-ir), even if they present less technical difficulties and presumably better individual results. I would also try to convert the disadvantage in operating in such an extreme site and hence in an automatic way, almost without human intervention, into a favourable prospect of adopting a new observing concept (almost of standard use in space astronomy), that will bring access to par-

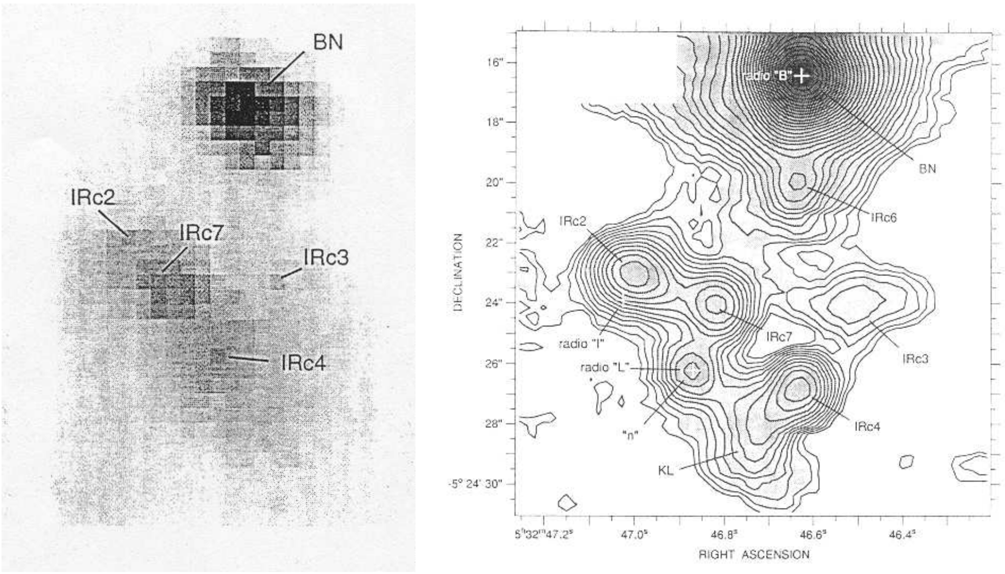

Fig. 1. The comparison of two different images at different spacial resolution of the same (BN/KL) region taken with two different telescopes; 1.5m(Tirgo)[8] at Gornergrat and 3.0m (IRTF) at Mauna Kea[9]

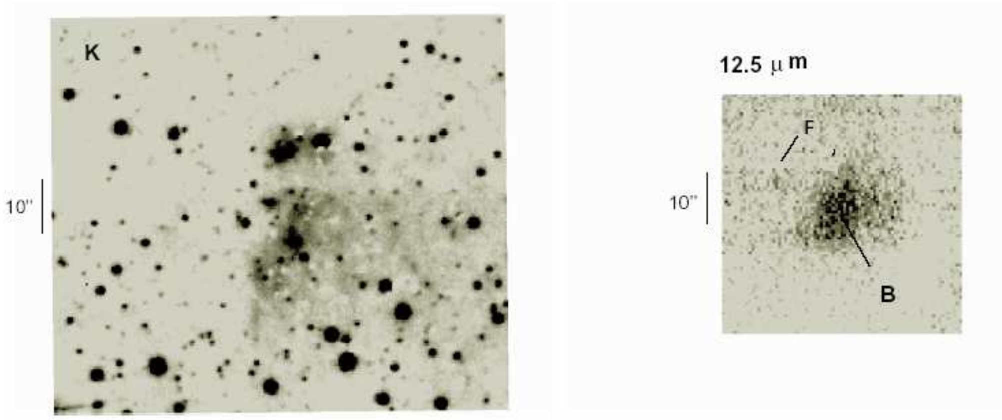

Fig. 2. Comparing images in the near and mid-ir taken with telescope of the same class. The Airy disc is respectively 0.7arc sec and 4.3 arcsec[10].

ticular interesting astronomical data, with the maximum of efficiency. But, mainly, I would underline the necessity of obtaining mid-ir high angular resolution data at very high sensitivity that will be comparable in morphological details with astronomical data of the other nearby domains, at a level so high and unrivalled with respect to the present and future ground-based facilities. It is important to ensure a strong basis of scientific objectives for the programs that will spend and utilize all the huge quantity of observing time that this facility would apparently give. I would lastly present a realistic concrete proposal for a simplified structure for a large antarctic Telescope operating in a non-conventional mode, to permit the realization of this program in a very reliable way, at maximum efficiency, without presenting unsurmountable financial difficulties.

2. ADVANTAGES FOR ASTRONOMY DUE TO THE SITE CONDITIONS.

Even if the specific characteristic parameters are not yet completely achieved quantitatively and statistically for Dome C, we can surely say that the conditions offered (in winter and in summer), absolutely speaking, guarantee that the site is one of the best on earth, considering that the comparison can be done only with other different Antarctic Sites on the Plateau, not yet explored and qualified. Paying attention particularly to astronomical implications for the thermal ir domain, here is a list of some advantages present at Dome C:

1)Ambient Conditions[5,6] - Low soil temperature that minimizes the thermal emission from the telescope. - Low sky temperatures (gradient determined by athmospheric leyers) and integrated effect that determine the sky emission. - High sky transparency due to the height of the site and the combined effects of pressure, temperature and humidity. - Peculiar high local pressure (that is reflacting in the athmosphere components) and a drastic reduction of precipitable water vapour in the sky) etc. etc.

2) Almost absence of wind: This is in favour of a perfect thermalisation and of the stability of parametres. This particular is also of capital importance in the planning of a telescope installation (mostly if it is of large diameter); normally we need a very complex, heavy and strong structure of the enclosure to resist to all kind of storms. This is not the case

3) Stability of principal parameters: There will be very low gradient in the principal parameters due to the small turbolences in the atmosphere and, most of the time, to the lack of diurnal alternance.

4) Polar conditions for Astronomical Observations There is here a double advantage : first you have the maximum field of circumpolar objects of the southern emisphere (particularly rich of peculiar interesting regions of our galaxy etc. etc.) visible continuously for very long time . The second advantage refers to the structure of the mounting of the telescope (expecially if it is large) that here at the pole became a natural alt-azimuthal mount. The terrestrial rotation is driving the azimuth movement suggesting the use of a drift-scan observing mode.

5) The Cloud Cover of the Sky: This is a good recent surprise derived from the measurements made last year and that are now automatically recorded by the AASTINO[7] experiment. The results for the moment describe an extremely high percentage of perfectly clear sky that will assure a huge amount of observing time. We expect that statistical data will confirm this tendency.

6)Turning a disadvantage into an advantage: We would have the possibility to experience here a new concept of observing strategy, that I expect will be developed more and more in modern astronomy and has already been used with succes in space astronomy. The necessity of operating in automatic way (due to site conditions) with simple and reliable operations practically without human intervention, obliges us to set up an optimized telescope and instrument for a particular observing domain, without any compromise derived by the faculty of using multi mode or multi bands or multi instrument opportunities.This means that it is still possible to change the configuration but only after a long period of programmed measures on the optimized structure. This would be the only way to use simultaneously a couple of very different telescopes set up for measurements in the near and the mid-ir that produce comparable results as I will discuss hereafter.

3. MID-IR MEASUREMENTS.

When observing in different bands of the e.m. spectrum we often have results difficult to utilize together if they are not comparable one with another in term of sensitivity or spatial resolution. This is one of the points emphasized by modern astrophysics: the association between data at different wavelength (first of all, for example, the construction of the SED) is of great power in understanding the physical phenomena which dominate some peculiar regions of the sky. Instead, the normal situation until now is that (but for some exceptions) mid-ir measures offer data from ground, space and from the Surveys obtained, of relatively poor quality due to different reasons: Physical limitations of measures (presence of bgr and diffraction); the need of a great amount of observing time to collect acceptable data; very few good available instruments at disposal; not much time allocated at important telescopes; poor angular resolution obtained also with medium class telescopes and with space telescopes (sensitivity cannot do anything against confusion); and also the future situation will not be much promising for mid-ir data improvement. In order to invert the tendency we would need a dedicated telescope usable only in this domain and this could be the prerogative of the Antarctic ir Astronomy. We would need the possibility of use different telescopes for different wavelengths having the appropriate sensitivity and angular resolution and possibly at the same time. In this way it is possible to collect high precision morphological pictures of the aggregated and diffused matter in order to clarify the different phases of evolutionary processes of formation.

In fig.1 the importance of angular resolution is emphasized by looking at images of the same region taken with a 1.5 m (Tirgo) or with e 3.0 m (IRFT) telescopes. Note that in the detailed picture where the FWHM is about 1 arcsec, the problem discussed is still the coincidence or not of the mid-ir peaks with the radio sources detected thet is of the order of the obtained resolution. In fig.2 a comparison of a near-ir and a mid-ir field of the same region is shown taken with different telescopes but of the same class; a) 2.35m Du Pont at Las Campanas and b) 2.12m at S.Pedro Martir Observatory. As you can see the mid-ir picture will result penalized.

4. ANGULAR RESOLUTION AND FIELD OF VIEW IN THE MID-IR.

Let's have a look at the problem of angular resolution and field of view we can expect for different Telescopes at Dome C. The hypothesis formulated these last years were:
1. The project of a small Telescope[11] of 80 cm of aperture that seems to me unavoidable to "break the ice" for the beginning of an astronomical observing program at Dome C and to face all the technical and logistic problems associated.
2. The proposals of a more or less standard of the 2.0 m Class Telescope[12] for the near and mid-ir.
3. The project proposed by myself and collaborators for a non-conventional Large Antarctic Survey Telescope of the 8m Class devoted in principle to mid-ir observations.
We would like to analise what kind of results are expected in terms of angular resolution and field of view, taking into account the present situation of near and mid ir commercial detectors at disposal. The following Table I could be built: From Table 1 you can see that the only possibility to have an angular resolution in the sub arcsec range is to consider a Telescope of diameter between 1 and 2 meter for the near ir and a telescope in the 8m Class for the mid-ir. We adopted two kind of sampling criterium one corresponding to Nyquist (A22), and an overestimated sampling (A4). Note that as these criterum are the same for the 3 telescopes, there result the same numbers for the optical parameteres. Our proposal is to adopt an F/30 80cm telescope for the near ir and an F/12, 8m telescope Class for the mid-ir. The total fov is reported in the

Telesc.	80cm				2.00 mt				8.00 mt			
λ	2.2um		10.0um		2.2um		10.0um		2.2um		10.0um	
Detector	InSb		Si:As		InSb		Si:As		InSb		Si :As	
n. pix	1024		512		1024		512		1024		512	
size (mm)	0.027 mm		0.05 mm		0.027 mm		0.05 mm		0.027 mm		0.05 mm	
Airy ”	1.38 ”		6.28 ”		0.55 ”		2.51”		0.138”		0.628”	
Sampling criter.	A/2.8	A/4	A/2.8	A/4	A/2.8	A/4	A/2.8	A/4	A/2.8	A/4	A/2.8	A/4
Pix Fov arsec	0.49 arsec	0.34 arsec	2.22 arsec	1.57 arsec	0.19 arsec	0.14 arsec	0.89 arsec	0.63 arsec	0.049 arsec	0.034 arsec	0.222 arsec	0.157 arsec
FOV ”	8’.36	5’.8	18’.9	13’.4	3’.31	2’.34	7’.57	5’.35	50”.2	35”.0	1’.9	1’.3
F/	F/12				F/12				F/12			
G	0.84	0.59	2.06	1.46	0.85	0.59	2.06	1.46	0.84	0.59	2.06	1.46
ϕ P.F. mm	35	23	74	53	34	23	75	53	34	23	75	53
F/	F/20				F/20				F/20			
G	1.41	0.96	3.44	2.44	1.41	0.96	3.44	2.44	1.41	0.96	3.44	2.44
ϕ P.F. mm	55	38	124	88	55	39	124	88	55	39	124	89
F/	F/30				F/30				F/30			
G	2.11	1.48	5.18	3.66	2.11	1.48	5.18	3.66	2.11	1.48	5.18	3.66
ϕ P.F. mm	82	58	187	132	82	58	188	133	83	58	188	132

Table 1: The results for the parameters concerning the angular resolution and the fied of view for three telescopes proposed. In the bottom you can see the kind of demagnification G of the optical system and the sze of the field diaphrgm in the focal plane.

Table and you can see how relative is the concept of wide field and how opposite is to the request ofangular resolution.

5. SCIENTIFIC OBJECTIVES FOR THE MID-IR.

There must be very strong reasons to make a request such as the one proposed for a small near-ir telescope and a large one for the mid-ir to be put in the best site on earth together; and in fact the purpose of the proposed Antarctic Observatory it is not to have another nice observing facility, but to produce the best possible association of instruments that will give a very powerful way of investigation, superior to the present status of potential production of data even from the new class of very large telescopes. The proposed telescopes are intended to study all the regions of the southern sky where the morphological aspect plays an important role in the comprehension of the physical phenomena ruling the aggregated or diffused matter, producing programs concerned with observing and understanding the origins and evolution of stars and planetary systems, of galaxies and of the Universe itself. To make some examples of research programs let me first remind what kind of physical conditions the near and the mid-ir will be able to study. As you go towards higher temperatures (shorter wavelengths) you are examining in general stars as point sources, so you don't need the highest degree of spatial resolution excepts some particular local situation; you would rather have a very large field of view to examine at the same time a large portion of the sky. In this domain you have very developed detectors, easy to use, with large area and low noise. But when you want to study the situation in the early phases, when the matter and the cold gas present in one region began to aggregate with the rise of temperature, you need the maximim resolution and sensitivity to see with sufficient details the evolution of the diffuse matter that often is masking more evolved processes imbedded. And the same happens in the last phases, when the old star is beginning its disgregation and the matter tends to become again a diffuse cold ingredient of the universe.

Unfortunately at this wavelength range detectors become difficult to manage, noisier, of limited dimensions and more expensive and present physical limits (diffraction limits and bgr immersion) that make their use rather difficult. The creation of the Observatory proposed for simultaneous observations of peculiar regions of the Southern Emisphere will be an inexhaustible mine of astronomical unrivalled data. The Southern Sky is particularly favourable for this systematic program of observations due to the presence of the Galactic Center with a high concentration of Molecular Clouds and for the presence of the two nearby Galaxies (Large and Small Magellanic Clouds) and many other peculiar and important regions. The number of Dark Clouds and Molecular Clouds catalogued in the Southern Emisphere is more than one thousand and a high correlation with protostellar objects has been observed in these regions at different evolutionary stages. As an example of research programs that a Large Antarctic Survey Telescope could face , let us mention:

a) Mid-ir Surveys of Southern Dark Clouds and of Giant Molecular Clouds (GMC). The ideal environment for the study of low-mass star formation lay in Dark Clouds and in Giant Molecular Clouds that contain a relevant number of embedded young stellar sources that is the first step for a statistical study of low-mass star formation by correlating the overall characteristic of the Dark Clouds derived from radio observations and from the measured properties of YSO's obtained from mid and near IR data. Some important cases to be mentioned are the Camalion Dark Cloud Complex or the NGC 6334 Giant Molecular Cloud which contain at least seven distinct sites of massive star formation distributed in more than 2 degrees where the acquisition of thermal dust imaging in the mid-ir at high spatial resolution could be of crucial importance.

b) Compact and Ultracompact HII Regions. They represent one of the first evolutionary stages of high mass stars and are embedded in dense nuclei of GMC often associated to OH and H2O Masers. Radio observations, and mm and sub mm measures, revealed different morphologies. The aim would be to extend these measures in the mid-ir at high resolution to study the distribution and the mixing of dust and gas and to reveal the presence of a dust disk around a forming star of high luminosity.

c) High resolution imaging of circumstellar envelopes in Young Stars and in AGB Stars. Envelopes around Young Stellar objects are formed in presence of dust disks or tori and in many cases are perturbated by collimated molecular outflows. It is important to obtain the spatial distribution of the dust around the central source because it results that temporal variations in mass loss rate give rise to complex radial density profiles. AGB Stars, the precursors of Planetary Nebulae, show a very wide range of symmetries that evolve in the transition from the AGB to the PN phase.

d) Planetary Nebulae. They represent the last phase of the AGB Star evolution. It is possible to study the material ejected in the last periods of the life of the star and from the morphology to establish the evolutionary phase and to make a comparison between the galactic PN and those in the Magellanic Clouds.

e) Planetary systems and their evolution around nearby Stars. A very intensive and important study that requires measures in the mid-ir with very high spatial resolution is concentrated on the search of circumstellar structures of nearby main-sequence stars within 10 pc from the sun to detect the presence of planetary systems and their evolution.

6. THE PROPOSAL OF A FUTURE LARGE ANTARCTIC SURVEY TELESCOPE FOR THE MID-IR AT DOME C.

The present status of the French-Italian Base at Dome C shows the two towers, each one with an height of 13 mt and a diameter of 17, almost completed; they are called "the Quiet" (the sleeping area) and "the Noisy" (the working area) and have identical characteristics and are situated on a large shelf of chemically compacted snow. We propose the growth in the next future of a third tower that will be called "The Cold" , meaning that even the interior will be in thermal equilibrium with the ambient, intended to give hospitality to the proposed Large Antarctic Telescope (GTA) . In Fig.3 a sketch of a possible configuration of the Cold Tower with the aperture oriented along the meridian line is proposed. The Telescope mounting will be strongly simplified by its installation in the proximity of the geographic pole: an equatorial mount becomes a perfect alt-az mount when used at the polar latitude without the problem of the rotation of the field and the control of both axes in time To obtain an even more simple operating structure, we think of configuring a drift-scan instrument meaning that the telescope exploits the earth rotation to reach every position in the sky without moving.

This operating mode can offer interesting advantages on the telescope structure, on the active control of the primary segments, on the control of the tube flections and surely on the overall image quality. Under the assumption made for the mounting and the pointing of the telescope, the tracking mechanism becomes rather particular. After having tried to follow the hypothesis, nevertheless faisible, of pure drift-scan observations that introduces complicated devices for the freezing of the image under measure for a short time for integration purposes, and a strong waste of time in the continuosly pointing procedures, we decided to propose an intermediate situation that can produce strong benefits to the telescope structure, to its reliable operation and to the high resolution quality of the collected images. The presence of a huge background signal even in antarctica makes the integration time of a single frame of the order of few msec. If you integrate a certain number of such elementary measure using for example the shift and add technique in an automatic way you can reduce statistically in principle the measure noise by the factor of. This is true only if you have high stability conditions, atherwise the S/N ratio doesen't improve anymore. In practice there is an average time of total integration that it is no longer than some tens of minutes. So, if you observe always in the same direction you need at the maximum only few minutes for the total integration of the measure. By consequence the choice operated consists in a limited tracking mechanism only for the duration from 15 min before the meridian to about 15 min after it. This means a rotation of about 7.5 arc degrees and a quite linear tracking mechanism not at all sophisticated in the case of large bidimensional focal plane arrays.

7. CONCLUSIONS

Starting from the possible advantages offered by the Dome C site for infrared Astronomy, we examined the activities that will take strong benefit in observational astronomy, emphasizing the possibility of using a new highly specialized concept of automatic observations, using the maximum efficiency offered by the local observing conditions. We gave a justification to the thesis of concentrating the efforts on the mid-ir domain, giving relief to the obtainable results in angular resolution and in sensitivity, in order to produce comparable superposition of data in the near and in the mid-ir. After reminding the scientific motivations in the field of star formation, we offered an example of a simplified structure for the future Observatory. It should consist in a couple of ir telescopes: the first is a small 80 cm dedicated to the near-ir and the second will be a 8m class large telescope, with a non conventional structure and used in a quasi-drift-scan mode, to operate for the scanning of peculiar regions of the southern hemisphere sky at sub-arcsec angular resolution with an unrivalled sensitivity in the mid-ir spectral range.

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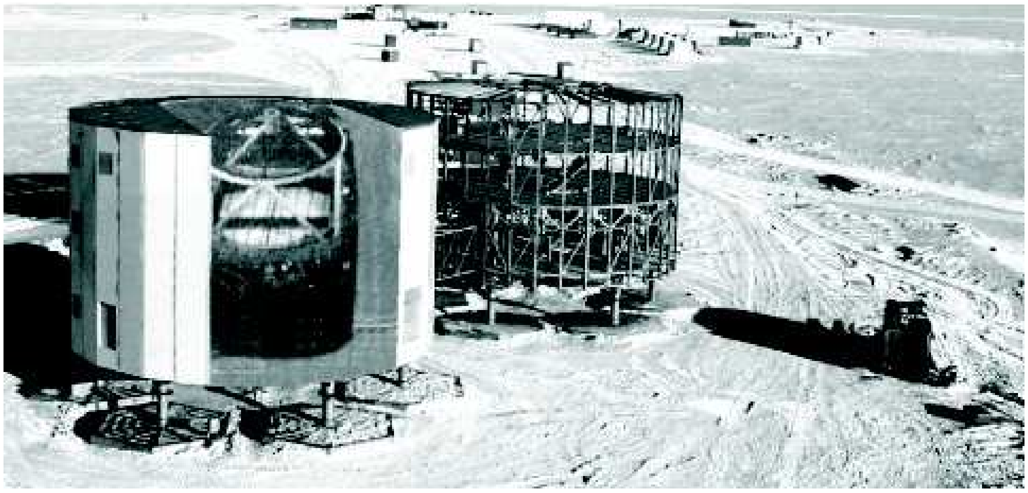

Fig. 3. A sketch of the new Tower at Dome C that will host the Large Antarctic IR Telescope (GTA).

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