

# Infrared instrumentation for Dome C: conceptual design

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**Abstract** We have started a conceptual design study for both a near-infrared (NIR) wide-field camera and a mid-infrared (MIR) camera-spectrograph for a 2m-class telescope at Dome C, Antarctica. The main scientific drivers are the characterisation of young embedded objects, the evolution of crystalline silicates in circumstellar disks and the observation of exoplanet secondary transits. Both instrument concepts pretend to exploit the unique features of Dome C: superb seeing, low temperature, improved infrared transmission, reduced sky background and increased atmospheric stability. Two preliminary concepts are presented here. The NIR instrument would cover the wavelength range  $0.9\text{-}5.5\text{ }\mu\text{m}$  and would be optimized for the K, L and M bands. The MIR instrument would observe in the range  $7\text{-}40\text{ }\mu\text{m}$  and would be optimized for the Q window, including the extended portion ( $25\text{-}40\text{ }\mu\text{m}$ ) only observable from Antarctica.

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## 1 Dome C: the astronomical site

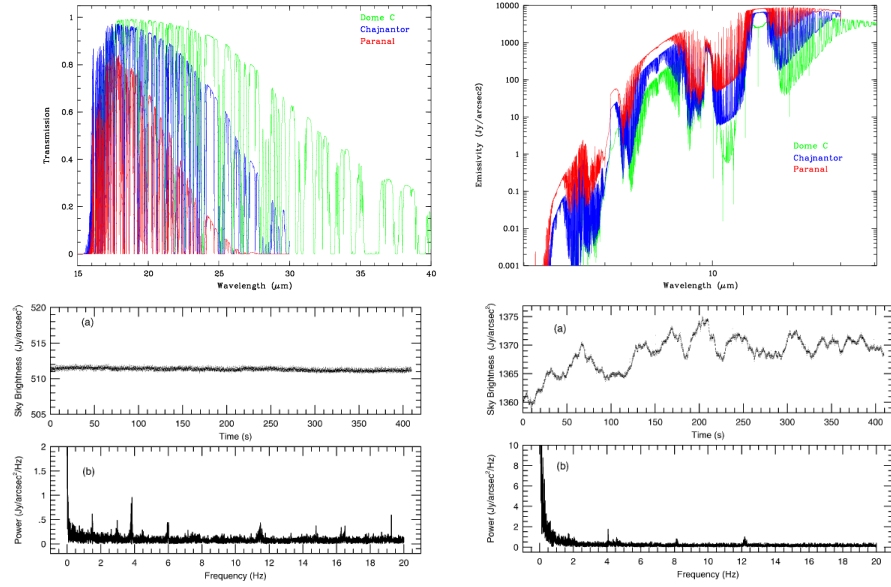
The Antarctic Plateau, with its extreme climate conditions, offers the best locations on the surface of the Earth for astronomical observations in the infrared: the ice domes, namely Dome A, C and F. Since 2005 Dome C hosts the all-year operated Franco-Italian Concordia scientific station. The extensive site testing campaigns performed at Dome C attracted the attention of the astronomical community after the report of an exceptional median seeing of  $0.27''$  at 30m above the ground [7, 15], due to the concentration of the atmospheric turbulence in a very thin boundary layer.

Appart from the seeing, Dome C is an extremely cold (summer/winter average temperature of  $-30/-60$  °C) and dry place. The median precipitable water vapour can be as low as  $250 \mu\text{m}$  during the winter [16]. These conditions have a dramatic impact on the atmospheric transmission: the standard astronomical windows are much cleaner and others do open, in particular the  $25\text{-}40 \mu\text{m}$  extended part of the  $Q$  window. The atmospheric background can also be reduced up to two orders of magnitude [6, 9]. It has been estimated that from  $2 \mu\text{m}$  ( $K$  band) onwards a 2m-class telescope at Dome C is equivalent of an 8m at Mauna Kea in terms of limiting magnitude [1]. Finally, the atmosphere is extremely stable above the Antarctic Plateau [13], which permits image survey observations in the  $Q$  band and exceptional quality photometric measurements.

## 2 Scientific case

Dome C offers several advantages compared to temperate site observatories, but the operation of large astronomical facilities in Antarctica needs to be driven by outstanding scientific cases. For this contribution, we have selected three of them, in the field of formation of stars and planetary systems.

- Embedded protostars. The characterization of very young class 0/I objects can be done via the construction of the complete spectral energy distribution and its subsequent fit by template models [10]. The obtention of points in the  $25\text{-}40 \mu\text{m}$  is essential, because these objects are cool ( $\sim 30\text{-}70$  K) and have the emission peak at  $\sim 40\text{-}100 \mu\text{m}$ .
- Crystalline silicates. Dust grains in high temperature environments (e.g. protoplanetary disks) undergo thermal processes which can be traced by the fraction of crystalline silicates. Mg rich silicates can be best studied in the extended portion of the  $Q$  window (bands at  $\sim 28$  and  $\sim 34 \mu\text{m}$ ) where they can not be confused with the amorphous population or the PAHs [5].
- Exoplanet secondary transits. The detection of secondary transits in exoplanets of the “Hot Jupiter” type is a significant milestone in the field [2]. The thermal emission of the planet can be measured in several bands and compared to atmospheric models. So far, the only positive detections have been provided by the Spitzer satellite. Dome C, with the best atmospheric stability on the surface of



**Fig. 1** The Atmosphere above Dome C. Top left, the extreme cold and dry conditions highly improves the atmospheric transmission, specially in the  $Q$  window, which opens beyond  $40 \mu\text{m}$  [9]. Top right, the atmospheric emission can be reduced up to two orders of magnitude compared to temperate latitude observatories [9]. Bottom, the atmospheric stability above the Antarctic Plateau offers unique prospects for  $Q$  band image surveys and high precision photometry, taken from [13].

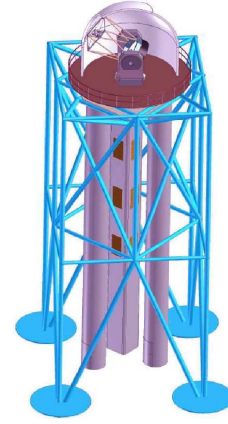
the Earth, offers the possibility to perform these observations from the ground and add essential spectral information using ad-hoc designed filters.

### 3 Infrared telescopes at Dome C

The ultimate infrared site-testing at Dome C will be performed by the 80cm infrared IRAIT telescope [14]. Equipped with the AMICA camera, sensitive in the range 1-25  $\mu\text{m}$ . It is expected that IRAIT will be put in service during the austral summer 2008-9.

[1] pointed out that a major milestone for astronomy at Dome C would be the construction and exploitation of a 2m-class telescope. Currently, the PILOT project concentrates the efforts of the community in this direction [11, 12]. After the conceptual design phase, PILOT has been defined as a 2.5m Ritchey-Chretien telescope with a tip-tilt secondary capable of observations in the range 0.4-40  $\mu\text{m}$ . It will be placed inside a temperature and humidity controlled dome atop a 30m tower. In this way, most of the turbulence power of the atmosphere will lie below the telescope.

**Fig. 2** The PILOT telescope. A 2.5m Ritchey-Chretien telescope will be placed inside an open protective dome atop a 30m tower. Most of the turbulence will lie below the telescope, and the residuals will be corrected via the tip-tilt secondary mirror. The expected seeing is  $\sim 0.25''$ . The temperature and humidity in the enclosure will be controlled to maintain the image quality and avoid frosting. Taken from [8].

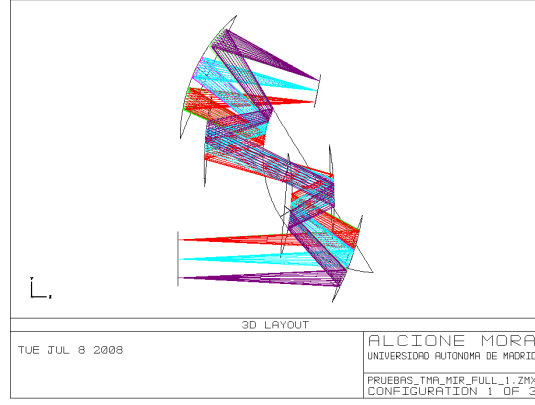


## 4 Infrared instrumentation: conceptual design

We have started a conceptual design study of two instruments for a 2m-class telescope at Dome C: a near-infrared wide-field camera and a mid-infrared camera-spectrograph. The current specifications of PILOT have been used as the input telescope. The project end date is december 2008. Requirements for the instruments and preliminar optical designs are presented in the following.

### 4.1 MIR camera-spectrograph

The MIR instrument will be an all-reflective camera-spectrograph sensitive in the wavelength range  $7\text{--}40\text{ }\mu\text{m}$ . It will be equipped with two detectors, a Raytheon Aquarius Si:As with  $1024 \times 1024\text{ }30\text{ }\mu\text{m}$  pixels sensitive in  $7\text{--}25\text{ }\mu\text{m}$  (blue arm) and a DRS Si:Sb  $256 \times 256\text{ }50\text{ }\mu\text{m}$  pixels sensitive in  $25\text{--}40\text{ }\mu\text{m}$  (red arm). If possible, both arms will share the same optics, and a dichroic or flip mirror will direct the light towards the proper detector. The pixel scale will be optimized for  $Q$  band observations (blue arm:  $0.86''/\text{pixel}$ , Nyquist sampling at  $17\text{ }\mu\text{m}$ ; red arm:  $1.43''/\text{pixel}$ , Nyquist sampling at  $28\text{ }\mu\text{m}$ ). The fields of view are  $14.6' \times 14.6'$  for the blue arm and  $6.1' \times 6.1'$  for the red arm. The strawman optical design for the collimator and the camera is a three mirror anastigmat (see Fig.3). The image quality requirement is to achieve the diffraction limit both in image and collimation. A good quality cold stop of diameter  $\sim 50\text{mm}$  is needed to reject background radiation. The collimated beam will have  $\sim 100\text{mm}$  available to introduce filters and dispersive elements. This instrument would be competitive with 8m-class camera-spectrographs located at temperate sites, and would outperform them for wavelengths greater than  $20\text{ }\mu\text{m}$ , where the improved atmospheric transmission at Dome C (Burton et al. [1, 9]) would make this instrument unique in its kind.



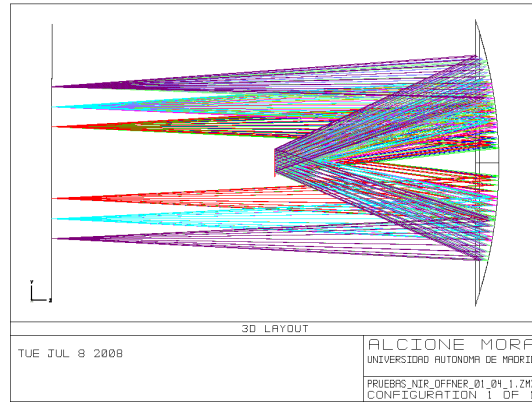
**Fig. 3** MIR optical design. The initial optical design of the MIR wide-field camera-spectrograph for PILOT is shown. Both the collimator and the camera are composed of three off-axis aspherical mirrors. The telescope focal plane is located at the bottom and the detector at the top of the figure. A dichroic or flip mirror would direct the incoming light to the blue- or red-arm detectors.

## 4.2 NIR wide-field camera

The NIR instrument would be based on a 2x2 or 1x4 mosaic of 2048x2048 pixels Teledyne Hawaii 2RG HgCdTe arrays. The plate scale is 0.15''/pixel, giving a field of view of 10.2'x10.2'. The images would be Nyquist sampled under nominal seeing conditions in the whole wavelength range. The resolution is limited by the seeing in bands *YJH* and the diffraction limit in *LM*. In case of exceptional seeing, the full spatial resolution in the *YJHK* bands would be recovered via Drizzle-like algorithms [3]. Narcissus mirrors baffled NIR wide field cameras have been proposed [4], but we have demonstrated that a good quality cold stop is essential to achieve the ultimate sensitivity provided by Dome C in the thermal infrared (*KLM* bands). The initial optical design (see Fig.4) is an Offner relay, based on [12], in which two concentric off-axis mirrors generate an image of the telescope image plane. It provides a good quality image ( $EED_{80} < 2$  pixels) over the whole field of view, along with a cold stop and a compact configuration. An Offner design is feasible because the focal length of PILOT has been tuned to give a pixel scale of 0.15'' using the Hawaii 2RG detectors. The filters would be placed in the convergent beam in front of the detectors.

## 5 Conclusions

Dome C, the third summit on the Antarctic Plateau, is currently the best astronomical site on surface of the Earth for infrared observations, because it provides the best natural seeing, lowest temperature, highest atmospheric transmission and stability



**Fig. 4** NIR optical design. The initial optical design of the NIR wide-field camera for PILOT is shown. It is an Offner relay system. The telescope focal plane is located at the bottom and the 1x4 detector mosaic at the top of the figure. The optics is composed of two concentric off-axis mirrors. The filters would be placed on the convergent beam in front of the detectors.

and lower emissivity. The PILOT project aims at building and operating a 2m-class telescope at Dome C. We have started a conceptual design study to study the feasibility of two infrared instruments for PILOT: a MIR wide-field camera-spectrograph and a NIR wide-field camera. Initial optical designs have been developed. The two alternatives will be evaluated in terms of their feasibility and scientific return. The most attractive one will be selected for a preliminar design phase-A study.

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