Mem. S.A.It. Vol. 74, 239

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The Italian participation to the NGST medium IR instrumentation

F. Bortoletto[1], C. Bonoli[1], E. Giro[1], C. Pernechele[1], A. Franceschini[2], P. Conconi[3], R. Mazzoleni[3], E. Molinari[3], F. Zerbi[3],

[1] Osservatorio Astronomico di Padova, Vicolo Osservatorio 5, 35122 Padova
[2] Dipartimento di Astronomia, Universitá di Padova, Vicolo Osservatorio 2, 35122 Padova
[3] Osservatorio Astronomico di Merate, Via Bianchi 46, 23807 Merate (LC)

Abstract. The Italian participation to the consortium for the construction of a mid infrared (MIR) instrument for the Next Generation Space Telescope (NGST) has been defined during 2001. In this paper, a brief discussion about the key points of this participation is given.

Key words. NGST – MIR instrumentation – Space telescope – Optics

1. Introduction

The Next Generation Space Telescope (NGST) is a collaborative effort between NASA, ESA and the Canadian Space Agency to develop a large, near- and mid-infrared optimized space telescope that will expand the science driven in the last years by the HST. Its main features, though still very much in development are:

- a 6m class mirror, lightweight, deployable;
- telescope passively cooled by a large sunshade;
- operating from 0.6 μm up to 28 μm;
- diffraction-limited imaging quality (Strehl = 0.8) at 2 μm;
- imaging and spectroscopic instrumentation covering this wavelength range;
- 5 year required lifetime, 10 year goal.

Scheduled to be launched in 2009, the telescope will be placed on the L2 Sun-Earth Lagrangian point. The scientific instrumentation will be integrated in a common module named ISIM (Integrated Science Instrument Module) mounted on the OTA (Optical Telescope Assembly) focal plane. In order to prevent thermal background, due to the structure and telescope enviroment emissions, both the OTA and ISIM will be protected by an extended sunshield, providing a passive temperature of 40 K. A solid hydrogen tank will allow an active cooling of the medium IR instrumentation down to 7 K. In Fig. 1 an optical sketch of the OTA and its main parameters is shown.

Send offprint requests to: F. Bortoletto
Correspondence to: vicolo Osservatorio 5, 35122 Padova, Italy

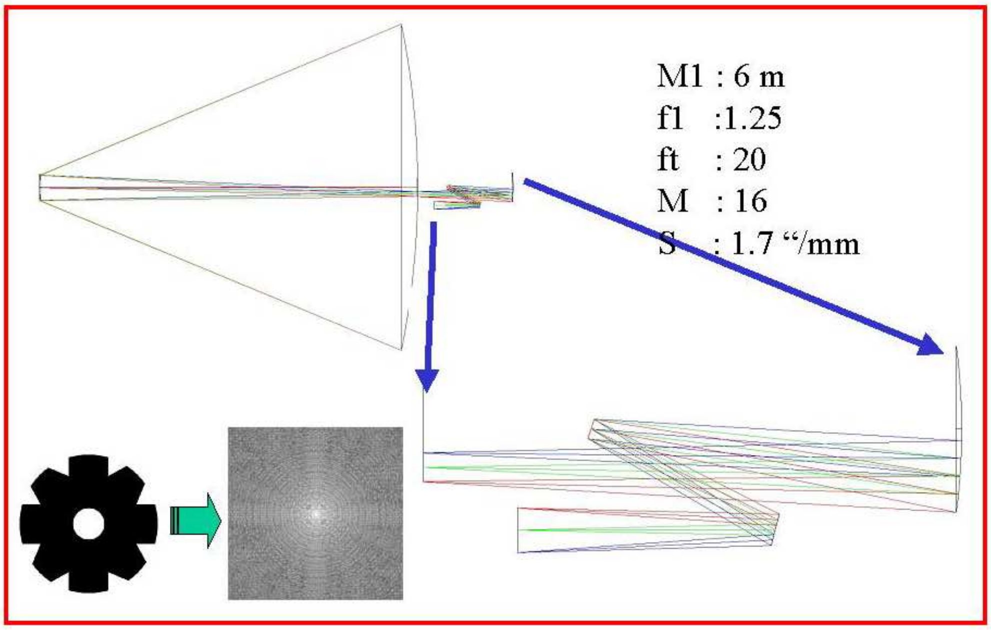

Fig. 1. The Optical Telescope Assembly (OTA) and its main parameters

The scientific instrumentation will be composed by three modules:

- a near infrared (NIR) instrument provided by NASA
- a NIR multi objects (MOS) spectrograph provided by ESA
- a MIR instrument (MIRI) provided by a consortium composed by USA (50%), Europe (50%) and with a possible small participation of the Canadian space agency.

The involvement of the European Consortium is concerned with the realization of the following parts:

- mechanics;
- optics and optical bench;
- servo electronics;
- low level software.

while the US part will cover:

- focal plane arrays (FPA) with read out electronics;
- high level software;
- final integration.

The overall science goals of NGST are described in the NASA Design Reference Mission (DRM). They will be met by a combination of instruments capable of carrying out the observational programs in a wide range of wavelengths. MIRI, in particular, is meant to cover a large part of the scientific aspects described in the DRM. In addition the mid-IR spectral band is relatively unexplored at the spatial resolution and sensitivity NGST will be capable of, and so there is great potential for serendipitous science.

2. General overview of the MIRI Consortium

Development, qualification and delivery of the European contribution to the MIRI instrument will be carried out by a Consortium of the involved european in-

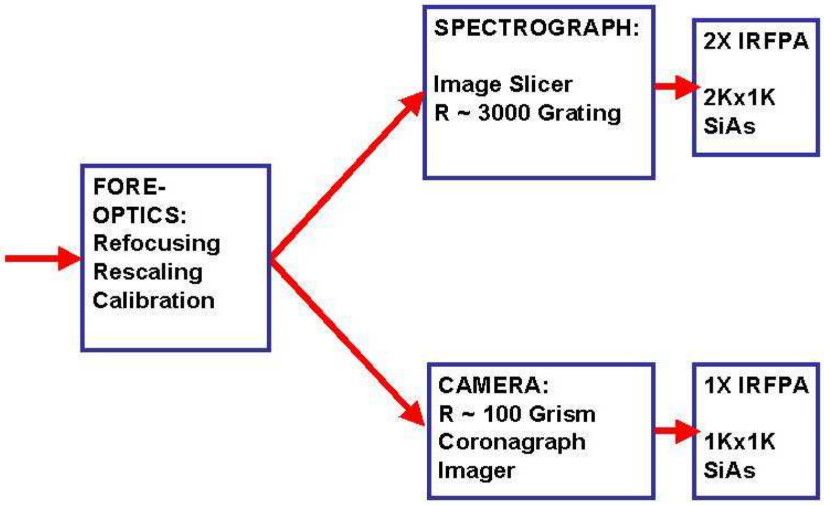

Fig. 2. MIRI instrument concepts

stitutions under the responsability of a european Principal Investigator (PI). Every country has a Coinvestigator (Co-I) and a Scientific Investigator. For the US side, Jet Propulsion Laboratory (JPL) and Goddard Space Flight Center (GSFC) will be responsible for the local implementation, the integration with the European part of the instrument, and the final delivery. The interface between the EU and US sides will be managed by the MIRI Science Team (MST) and by a Science Working Group (SWG).

3. MIRI instrumentation

Starting in 2001, an interim committee (MISC, Medium IR Steering Committee), composed by researchers from the different countries participating to the MIRI project, has been appointed with the role to fill the gap until the European Consortium and the US MIRI Team will be in charge. So far the MISC has delivered a Design Concept Document (DCD), that covers the following points:

– The scientific rationale for the MIRI instrument. MIRI in fact will provide unique capabilities to probe the deeply dust-enshrouded regions of the universe, thereby investigating the history of star formation. MIRI will be three orders of magnitude more sensitive than any ground-based telescope in the 5-30 μm window and will not suffer from atmospheric features which completely block large parts of this wavelength range for ground-based observations. The main topics addressed by the DCD are:

– Origin and evolution of the galaxies. Imaging and spectroscopy of high-redshift dust-embedded galaxies will allow determination of the level and type of distributed star formation or nuclear activity. Observations with MIRI will penetrate regions of high extinction and allow the detection of otherwise invisible AGNs. Measuring the dynamical masses of proto-galactic building blocks at high redshift is a key to understanding their subsequent assembling into present day galaxies.
– The formation of stars and planets. Deep imaging will help to find can-

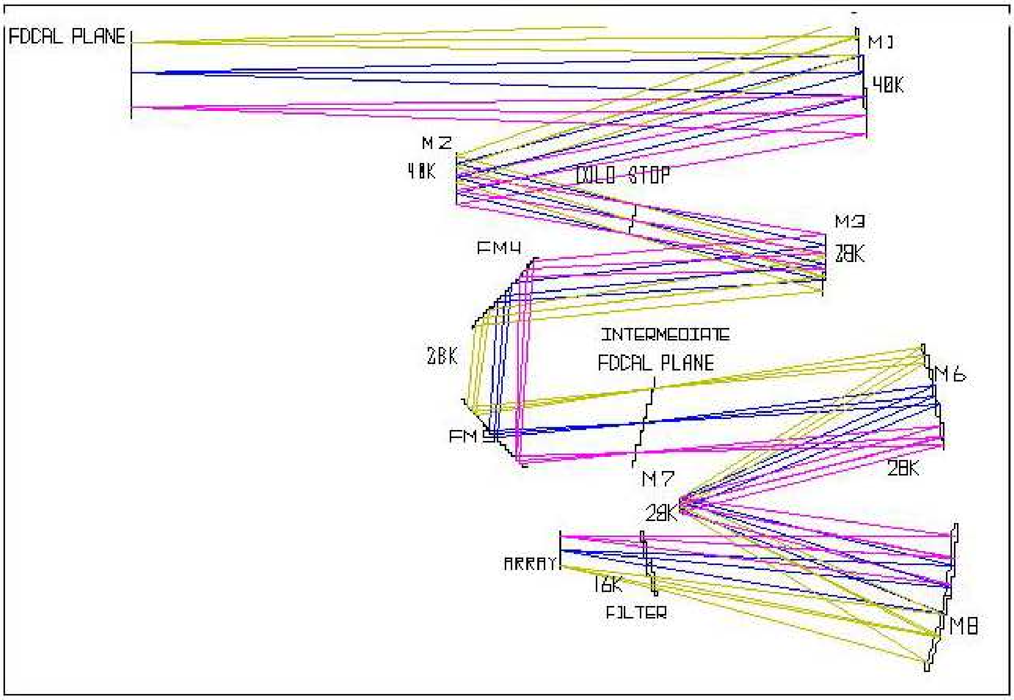

Fig. 3. MIRI fore-optics and camera

didates for young brown dwarf down to the jupiter-mass. The candidates will be confirmed both by NIR and MIR spectroscopy. The initial mass function (IMF) could be measured in young cluster from 0.001 up to 1 solar mass. Atmospheric model studies of very low mass objects and the measurement of the influence of the star formation in the interstellar medium can benefit of MIR spectroscopy.

– Planetary system evolution. Spectral imaging of debris disks, accompanying the formation and evolution of planetary systems, will lead to an understanding of how these systems evolve. Photometry and spectroscopy of the Kuiper belt objects may help to know their surface composition and to study the origin of our Solar System. Coronagraphic images will be able to identify jupiter-like planets in outer stars and to study their circumstellar disk structure to identify other planetary systems.

– The instrumental technical requirements to carry out the above described scientific programs. Among these:
  – For the imaging:
    - spectral range: 5-27 μm;
    - Nyquist sampling at 5 μm;
    - covered field of view of 1.5 x 1.5 square arcmin;
    - at least eight spectral bands, 5 for the SED definition and the other to isolate the PAH and for the color identification of brown dwarfs;
    - coronagraphy;
  – For spectroscopy:

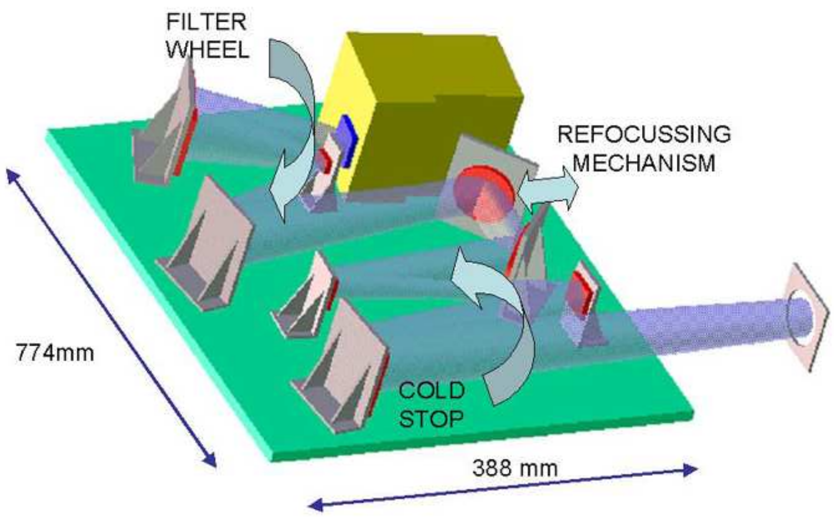

Fig. 4. 3D scheme of MIRI fore-optics and camera

  - single object spectroscopy in the range 5-27 μm, with the goal to go up to 28.3;
  - resolving power R $\approx$ 100 from 5 to 10 μm;
  - resolving power R $\approx$ 1000 - 3000 from 5 to 28 μm;
- A rough design for the instrument. The basic idea is to keep optics and mechanisms as simple as possible in order to minimize the overall instrument complexity and calibration procedures. The resulting design foresees separated modules for imaging and for spectroscopy, with a common fore-optics (see Fig. 2).

  - camera. The optics of the camera channel are shown in Fig. 3 while a solid drawing of them is shown in Fig. 4. The instrument has a fixed spatial scale through the 5-28 μm wavelength range and optimally sampled at 5μm that means a pixel scale of 0.1 arcsec/pixel and a total covered field of about 1.7x1.7 arcmin (based on a 1024$\times$1024 with 27 μm square pixel detector). The low resolution spectroscopic mode (R$\approx$100) is provided by a grism placed in the filter-wheel in front of the detector plus a set of slits placed in the intermediate focal plane. The coronagraph mode is provided by a mask (passive or interferential) placed in the intermediate focal plane plus an apodizer mask placed in the intermediate pupil (M7 mirror). A strong simplification of the instrument arises from the choice to have a single scale; this choice is based on the fact that at long wavelengths the total instrument background will overcome the readout-noise so making possible a scale rematch via pixel rebinning.
  - spectrograph. The spectrograph will be fed from the intermediate focal-plane at the end of the fore-optics through a small pick-up mirror in a way to provide a small field of 4x4 arcsec sampled by a Bowen-like image-slicer in steps of 0.2 arcsec (those numbers can be changed in design phase). The present design is evolving in four separated slicers fed by dichroics splitters and

four gratings working at the first order (for better efficiency) in four selectable angles. Each detector will see two channels. The spectrograph will cover the 5-28 μm wavelength range in 16 segments with a resolving power ranging from $\approx$1300 to $\approx$5200.

4. The italian participation

The italian participation to the project foresees the implementation of the following parts:

- study, design and construction of the fore-optics;
- calibration system;
- implementation and control software development of the MIRI instrument mechanisms;
- electrical hardware.

the following expertises are then needed:

- optical studies;
- thermal contribution analysis;
- technologies for reflective optics;
- coatings for the IR;
- software development in real time system;
- space qualified electrical design and components.

Basic functionnalities of the fore-optics will be:

- to provide a common focal plane for the MIRI devices;
- to provide a focussing mechanism;
- to provide a calibration unit;
- to reimage the telescope pupil e to provide a first cold stop.

References

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