DENIS : a Deep Near Infrared Survey of the southern sky

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Abstract

DENIS is the first attempt to carry out an all southern sky digital survey in the near-infrared range. It will be undertaken with a dedicated three channel camera in the I, J and K' photometric bands installed at the ESO 1 meter telescope in Chile. Expected limiting magnitudes are 18, 16 and 14 in the IJK' bands, respectively and the spatial resolution will be 3" in JK' and 1" in I. Several areas of astrophysics will take advantage of this survey: the exploration of hidden stellar populations of our Galaxy, the improvement of the Initial Mass Function towards low mass stars, counts and statistics of evolved Galaxies leading to a better knowledge of the local structure of the Universe. The survey is planned to start early in '94 and to last for approximately 4 years. Data will be released in stages and will be made available to the community as soon as appropriate processings and calibrations will be achieved.

1. Objective of DENIS

Large scale K band surveys are of extreme importance to probe the stellar populations content of our Galaxy and evolved galaxies, in general. The 25-year-old *Two Micron Sky Survey (TMSS)* very limited in sensitivity ($m_K = 3$) and uncomplete in the southern sky is still the only available document in this range. A situation which is no longer satisfactory, whereas a gain of more than 4 orders of magnitudes in sensitivity can be achieved with modern array detectors, and while future very expensive space and ground based instruments partly aimed at near infrared wavelengths observations will badly need deep and complete catalogs and atlasses that would provide accurate source fluxes and positions.

DENIS, is the first accepted and funded project that will attempt to perform a digitized survey of the all southern sky in the near infrared. It will produce images in 3 photometric bands (I = 0.8, J = 1.25, K' = 2.15 μm) with a spatial resolution of 3" in the JK' band and 1" in the I band at the millijansky level (*i.e.*, [I] = 18, [J] = 16, [K'] = 14). The upper limit of the spectral domain is basically dictated by the very constraining effect of the thermal background emission of an uncooled telescope on the detector performances. Inclusion of a visible red band (I) was eventually chosen to provide a closer link with optical large scale surveys (Schmidt plates), and to allow a better spatial resolution than in the JK' bands. Hence, identification in real time of detected sources with objects in optical catalogs (e.g. the *Guide Star Catalog, Tycho Catalog* etc..) and separation of stars and galaxies should be greatly facilitated. The ultimate aim of *DENIS* is to build catalogs and databases of point-like sources and small extended sources and to open the access to the results through computer networks in the shortest delay compatible with the release of highly reliable data.

2. Scientific justifications

Several domains of astrophysics such as stellar and galactic populations statistics will clearly draw out a great benefit of a better knowledge of the sky at near-IR wavelengths. The two micron band is of extreme importance to probe the stellar content of evolved galaxies and, primarily, of our Galaxy, just because most of the stars in spiral and elliptical galaxies are K and M dwarf stars that radiate the bulk of their energy in the 1-2 micron range. Another well known advantage is the good transparency of the interstellar dust in the K band that will permit probing young stellar objects embedded inside their parental molecular clouds, and stars in highly reddened regions, such as the bulge of our Galaxy. In addition, stars surrounded by thick circumstellar dust shells will be also detected. It is estimated that all the supergiant stars and most of the stars of the Asymptotic Giant Branch in our Galaxy will be recorded in the survey. The combination of *IRAS* and near infrared colours will improve the classification of AGB stars and, in particular will permit a reliable

break-up of carbon versus oxygen rich stars. Near infrared surveys such as *DENIS* will lead to significant improvements of the Initial Mass Function, and to better determinations of the scale heights of several poorly known species of stars such as *OH-IR* objects, extreme carbon stars, young planetary nebulae, etc....

DENIS will also produce the first complete digitized catalog of evolved spiral and elliptical galaxies up to a redshift limit of $z = 0.2$. Some 250 000 galaxies should be detected and recognized and notably in the obscured lane of our Galaxy. The near infrared emission is also a reliable tracer of the stellar mass contained in a galaxy and relatively independent of the evolution. This digitized catalog of galaxies will bring out new insights in the investigation of the local structure of the Universe.

3. The Instrument

The survey will be achieved with a specially designed and dedicated camera equipped with 3 array detectors working simultaneously in the 3 bands and attached at the cassegrain focus of the 1 meter telescope of the *European Southern Observatory* at La Silla (Chile). The telescope is granted to the survey during two consecutive months each trimester in the framework of an ESO keyprogram.

The infrared camera consists of a set of 3 dewars each equipped with one array. The J and K' channels houses one NICMOS 3 array (256 x 256) made by *Rockwell Int'l* and the I band one *Tektronix* CCD array (1024 x 1024). Both types of detectors are cooled to liquid nitrogen temperature. The f/15 beam that comes out of the telescope is split off into 3 separate beams thanks to 2 dichroic mirrors. The field of view of the camera is 12'. A microscanning device acting on the J and K' beams allows an improved sampling of the infrared images. The full coverage of one hemisphere requires about 1 million elementary images per colour taking into account some overlapping. The sky will be scanned in a step and stare mode at constant right ascension, near the meridian, along declination arcs of 30° amplitude, by steps of 10'. It is expected that, taking into account average meteorological conditions at La Silla, the coverage of the sky should be completed in less than 4 years of observation. Data are handled and processed in real time with three independent controllers based on *68040 Motorola* processors. The data flow will be approximately 130 kbytes/sec/channel that will yield an average of 8 Gbytes per night and a final amount of data of some 4 Tbytes, after completion. Raw data will be stored on digital audio tapes (DAT) after compression with no loss of informations. Sources brighter than approximately K = 8 will saturate the NICMOS arrays. To allow measurements of these sources, an additional filter, attenuated by 5 magnitudes, has been added on each channel. The main tasks that will be achieved in real time are flat fielding, sky subtraction, astrometric and photometric calibrations and identifications with entries of the Guide Star Catalog. A preliminary small source catalog will be produced in real time in order to

allow the immediate follow up of newly discovered interesting sources, but the final data processing will be performed in two dedicated computing centers located at Leiden Observatory and Paris Institut d'Astrophysique.

4. Data processing and Analysis

It is out of the scope of the real time computers and of the operations team on the mountain to process properly such a stream of data. Moreover, special attention will be drawn to obtain an homogeneous set of measurements and data reduction methods will undoubtedly improve with the experience and time. The two analysis centers will achieve improved standard reductions, each one being in charge of a compiementary task in the data reduction stream. The center in Paris will receive the raw image data on DAT, re-process them in an homogeneous way and to make them scientifically usable. Elementary images in three colours will be archived and made accessible in a databank. A copy will be forwarded to Leiden where the extraction of point like objects will be achieved in order to create a *small source database* that will eventually become the *small source catalog*. The Paris center will, in turn, identify and archive the extended sources and will create an extragalactic databank with the participation of Lyon Observatory. Other more specific databases will be implemented under the responsibility of the partners or users, but the normal access to the *DENIS* data, before final release will be through the 2 dedicated centers. Data will be delivered in stages in order to open an access of the community before the completion of the survey. However, the co-investigators of the project will have a priviledged access to the new data during one year.

5. Organisation, and planning

DENIS became an European project, after the initial plan of collaboration with the American *2MASS* project had failed. *DENIS* results of a collaboration between several Institutes pertaining to 7 European countries (Austria, France, Germany, Hungary, Italy, Netherlands and Spain) and a significant contribution of Brazil. The project involves about 60 scientists and engineers. The Space Department (DESPA) of Paris Observatory is leading the project and is responsible for the construction of the 3 channel camera with important technical and funding contributions of the partners. An operations team of 2 senior and 2 postdoctoral astronomers and one dedicated engineer, all resident in Chile will carry on the survey and take care of the continuity of the observations. Commissioning of the camera at the telescope is planned by the end of '93 and the survey should start early in '94. The total cost of the project, excluding salaries, but including 3 years of operations is approximately 12MFF (2.4 M$). The project is funded with the contributions of several National Institutions of the partners countries, and of the *SCIENCE* plan of the Commission of the European Community .