PANEL B2: SOLAR SYSTEM

Th. Encrenaz, E. Lellouch, D. Bockelée-Morvan, and J. Crovisier

Observatoire de Paris, F-92195 Meudon, France

Abstract

During the symposium 'The Promise of FIRST', held in Toledo on 12-15 December, 2000, the Solar-System panel has identified five high-priority programs. Two of them are large programs: 'H_2O in the solar system' and 'Far-infrared photometry of trans-neptunian objects'. The three other high-priority programs require less observing time, but should also be started early in the mission: 'Formation and evolution of the giant planets', 'Aeronomy and photochemistry of Mars', and 'Chemical composition of small bodies'.

Key words: Solar system: planets, comets – Missions: FIRST

1. Introduction

The success of ISO observations in exploring the infrared spectra of solar-system bodies has illustrated the capabilities of an Earth-orbiting satellite to investigate the chemical composition of planets and comets (Lellouch 1999; Lellouch 2001; Bockelée-Morvan 2001). In addition, ground-based heterodyne millimeter spectroscopy has also been very successful for detecting new cometary gaseous species (Bockelée-Morvan et al. 2000) and minor stratospheric constituents in planetary and satellite atmospheres (Encrenaz et al. 1995). These two data sets have significantly improved our knowledge in planetary and cometary physics. FIRST, as a follow-up of these studies, is also expected to provide unique and valuable information in this field, in complement to dedicated space missions.

2. Large programs

2.1. H_2O in the Solar System

Water is the main constituent of comets; its study provides key information on the comet production rate but also on the physical properties of the inner coma (Bockelée-Morvan 2001). Water has been detected in the stratospheres of the giant planets and Titan, and its origin remains unclear (Feuchtgruber et al. 1999). Water is also an important minor constituent of the Martian atmosphere which plays an important role in its aeronomy and photochemistry (Jakosky and Haberle 1992; Encrenaz et al. 2001). We also note that FIRST will be unique for solar-system observations of H_2O in the far infrared or submillimeter range, with a few specific exceptions (CIRS/Cassini on the Saturn system, MIRO/Rosetta on comet Wirtanen).

2.1.1. Comets

Four different types of observations are proposed:

-Study of water production and kinematics in a large number of comets (about 10/year), using the 557 GHz H_2O transition with HIFI.

-Study of the physical conditions of the inner comae, by observing several H_2O transitions on selected comets (about 4/year), using HIFI, SPIRE and PACS.

-Study of the water production rate evolution in selected comets by monitoring the 557 GHz transition with HIFI as a function of heliocentric distance.

-Determination of the D/H ratio in the brightest comets (about 2/year) using the HDO transition at 894 GHz with HIFI.

For all H_2O measurements on comets, simultaneous far-infrared photometry measurements will be performed (in a very short observing time) for the measurement of the dust production rate. In addition, a Target of Opportunity program will be proposed if a bright non-periodic comet appears during the lifetime of FIRST.

2.1.2. Asteroids

In order to search for a possible activity in asteroids below 2 AU, it is proposed to search for H_2O in a few bright Near-Earth Asteroids (NEA), using HIFI at 557 GHz, SPIRE and PACS.

2.1.3. Giant planets and Titan

In order to better constrain the origin of the external oxygen flux detected by ISO in the stratospheres of the giant planets and Titan (Lellouch 2001), it is proposed to observe a couple of H_2O transitions with HIFI, and to obtain a spectroscopic scan with SPIRE and PACS. In the case of Jupiter a low-resolution mapping will be possible at short wavelength for studying latitudinal variations.

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In the case of the brightest objects (Jupiter, Saturn and Uranus), it would be useful to repeat these observations about once a year in order to investigate a possible temporal variability.

2.1.4. Mars

FIRST will be an ideal tool for monitoring the Martian water vapor abundance as a function of the areocentric longitude. The observations will be performed with PACS and SPIRE (complete spectral scans) as well as in a few H_2O transitions with HIFI. FIRST will also allow a precise determination of the D/H ratio on Mars through the observation of the 894 GHz transition of HDO with HIFI.

Using the sensitivities announced for the PACS, SPIRE and HIFI instruments, we tentatively estimate that the full H_2O large program could require, per year, about 80 hours on comets, 20 hours on asteroids, 50 hours on the giant planets and Titan, and 10 hours on Mars, i.e. a total of about 700 hours over a 4-year lifetime.

2.2. FIR photometry of trans-neptunian objects

About 300 TNOs have been detected so far, at heliocentric distances of 30-50 AU; the expected number of existing objects with a diameter above 300 km is about 10^4 (Lellouch 2001). The visible flux provides the quantity aR^2, where a is the albedo and R the radius.

The typical temperature of the TNOs is about 40 K. The far-infrared photometry of these objects will thus provide an information on T and R, and, with the visible measurement, a determination of T, R and a.

We propose to perform a statistical study of about 100-200 targets using PACS and SPIRE photometry. Taking into account the expected flux of these objects and the instrument sensitivities, we tentatively estimate that about 400 hours will be needed for this program.

3. Other high-priority programs

3.1. Giant planets: formation and evolution

Elemental and isotopic ratios are key parameters for understanding the formation and evolution processes of the giant planets (Lellouch 2001). Both D/H and He/H were retrieved from ground-based and Voyager IRIS data; more recently, D/H was retrieved from Galileo (Jupiter) and from ISO on the 4 planets, using HD rotational lines. FIRST should be able to improve these datasets using PACS and SPIRE. The following program is proposed:

-Determination of D/H in the four giant planets from the HD transitions R(0) at 112 μm and R(1) at 56 μm, using the spectroscopic mode of PACS;

-Determination of He/H in the four giant planets by measuring the far-infrared continuum (determined by H_2-H_2 and H_2-He collisions) of the four giant planets, using both PACS and SPIRE in the spectroscopic mode;

In addition, these spectroscopic surveys, which should be also acquired on Titan, will allow an exploratory search for minor stratospheric species.

There is a clear link between this program and the first large program 'H_2O in the Solar System', as both programs have as a common objective the measurement of D/H in the solar system.

The preliminary estimate of observing time for this program is about 50 hours.

3.2. Mars: aeronomy and photochemistry

The capability of spectroscopic survey offered by FIRST provides a unique opportunity for studying the Martian atmospheric species, which will not be obtained by in-orbit instruments. Two programs are proposed below:

-Extended search for oxygen-bearing molecules (in particular H_2O_2) with PACS and SPIRE in spectroscopic modes and HIFI in a few transitions;

-Exploratory search for minor constituents, using a complete spectroscopic survey with HIFI.

As a preliminary estimate, this program could be performed in about 50 hours.

3.3. Chemical composition of small bodies

As a follow-up of the ISO spectroscopic study of comets and asteroids which, in particular, provided the chemical identification of cometary dust, we propose to record full spectroscopic scans of PACS and SPIRE on bright comets (about 10 samples). The same study should be performed on bright asteroids (also about 10 samples) to study their surface composition. The expected observing time for this program is in the range of 50 hours.

In summary, our preliminary estimate for the observing time required for the high-priority solar-system programs mentioned above is in the range of 1000-1500 hours, i.e. 3-5 per cent of the total available observing time assuming for FIRST a 4-year lifetime.

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