The JIRAM (Jovian InfraRed Auroral Mapper) Experiment.

A. Coradini[1] , A. Adriani[1], G. Filacchione[2], J.Lunine[1,3], G. Magni[2] , M. Cosi[4] and L. Tommasi[4], [1] INAF-IFSI, Via Fosso del Cavaliere, 100, Rome, Italy, angioletta.coradini@ifsi.rm.cnr.it, [2]INAF-IASF, Via Fosso del Cavaliere, 100, 00133, Rome, Italy, [3]Lunar and Planetary Lab, University of Arizona, Tucson, AZ, USA, [4] Selex-Galileo Avionica, Via Albert Einstein 35, 50013 Campi Bisenzio (FI), Italy.

Introduction: The atmosphere of Jupiter requires multiple techniques at a variety of wavelengths. The present Juno payload is well-suited to a study of the magnetic field and interior structure of Jupiter, as well as its plasma environment, but it will be strongly improved by adding the capability to (a) image and make spectra with high contrast of the Jovian aurora and (b) explore the region between roughly 1-10 bars where water—Jupiter's principal condensable because of the relatively high interior abundance of oxygen and appropriate conditions in the 1-10 bar region—forms clouds and aids energy transport by moist convection. Hence we describe a camera (to monitor the temporal evolution and to study the morphology of the atmospheric phenomena) and a spectrometer (to measure spectral radiance) in the crucial wavelength realm of the near-infrared which could be included in the Juno payload.

Auroral region. Jupiter's aurora is by far the most powerful among the planets in the Solar System. It is generated largely by energy extracted from planetary rotation, although there seems also to be a contribution from the solar wind. Studying the aurora and its genesis not only informs us about similar but less energetic phenomena on our own planet; it also provides a model system for potentially observable phenomena associated with Jupiter-mass and super-Jupiter-mass bodies around nearby stars. Auroral emissions are practically spread over the full electromagnetic spectrum (from X-ray to far IR wavelengths): the spectral analysis allows us to recognize the molecules responsible for the emission (ammonia, methane, H_3^+, ethane and acetylene) and the energy released in the process. In the main auroral structure, centered over the magnetic poles (the magnetic axis is tilted about 10° with respect to the rotational axis), are distributed the footprints of the emissions generated by the flux tubes of the satellites. These spots have fast dynamics, related to the orbital periods of the satellites. By using magnetospheric models it is possible to correlate the aurora's emission observed into concentric ovals centered over the magnetic poles to the magnetic field lines strengths from 8 to about 30 RJ. The electrons trapped and accelerated in the Jupiter magnetic field also come from Io's plasma torus, composed of sodium and sulfur generated by the volcanic emissions of Io. Among the various molecules that undergo emission in Jupiter's aurora, the H_3^+ is optimal for study. This molecule is formed at the base of the exosphere through the reaction $H_2^+ + H_2 \rightarrow H_3^+ + H$. The main roto-vibrational band is around 4 µm and it is composed of more than 200 possible transitions in the range 3.0 to 4.5 µm [1]. The H_3^+ auroral spectrum was observed by Cassini VIMS from a large distance in 2000, at much lower spatial resolution and signal-to-noise than that potentially available from JIRAM. Figure 1 shows the capability of imaging spectrometers to obtain excellent data on emission features from which time-variability and correlation with magnetic field strength can be obtained.

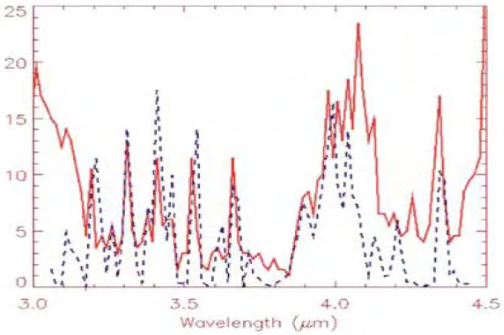

Figure 1: VIMS auroral spectrum in the H_3^+ emission range (3.3–4.5 µm). A synthetic spectrum of pure H_3^+ emission [2] is shown for comparison (dashed line); the solar reflected component of Jupiter accounts for the difference with the observed spectrum below 3.2 µm and above 4.0 µm.

Jupiter hot spots. Hot spots are a way to penetrate into the deep atmosphere because of their relative lack of ammonia and water gaseous and cloud opacity. They allow probing of the properties of the atmosphere down at least to 8 bars in the 4-5 µm low opacity spectral region [3]. Understanding the morphology of the hot spots in a three dimensional sense, which requires their observation as a function of wavelength, and particularly the morphology at deeper pressure levels where hot spot dry air may be remixing with ambient moister air, will permit a much better understanding of why hot spots form and their implications for how energy and condensables are transported within the Jovian atmosphere. The NIMS instrument on the Galileo orbiter took spectra of spatially-resolved regions on the Jovian disk at wavelengths between 0.7 and 5.2 µm. JIRAM will increase the spatial and spectral resolution more than a factor 2, in respect to NIMS, and the spatial resolution up 2 orders of magnitude – depending on the orbital position.

Sounding of the troposphere. The optical surface of Jupiter is dominated by the ammonia clouds (along with trace species which give these clouds their color). At tropospheric levels between ~1-10 bars, water dominates as the principal condensate and hence the nature of convective transport is different from that above and below. Understanding the nature of moist convection [4], of lightning, of cloud formation [5] and transport of disequilibrium species [6] all require observations that reach below the layer of ammonia clouds into this barely explored deeper troposphere, where water moist convection may be the dominant factor in converting internal heat flow into atmospheric kinetic energy. An imager accompanied by a point spectrometer working in the range 2-5 µm can address this important science objective. For the JIRAM baseline, a 4000-km scale moist convective mid-latitude storm system, such as that observed by Galileo, can be mapped with an image of 104-105 pixels at maximum spatial resolution of 10 km, and spectroscopically probed over hundreds of wavelength channels from 2 to 5 µm, providing the possibility of profiling the moist convective columns and the dry intervening regions of subsidence with excellent horizontal and vertical resolution.

Instrumental Concept and design: JIRAM is designed to obtain high spatial resolution images of the Jupiter atmosphere and to retrieve its spectral properties in the 2.0-5.0 µm range. Thanks to an innovative optical design concept, JIRAM will share a single telescope for the infrared camera and spectrometer: this configuration allows to obtain the image of the polar regions of the planet and the spectral radiance over the central zone of the image at the same time. Instrument design, modes and observation strategy will be optimized for operations aboard a spinning satellite in polar orbit around Jupiter. The instrument will fulfill the following scientific objectives:

1. Explore the dynamics and chemistry of Jovian auroral regions by high contrast imaging and spectroscopy;
2. Study Jovian hot spots through the troposphere so as to determine vertical structure and hence test formation mechanisms;
3. Sound the Jupiter atmosphere to map water moist convection and determine the abundance of water and other constituents at depths corresponding to the water clouds.

The optical design is based on a solid architecture, making use of a reflecting telescope and a grating spectrometer in Littrow configuration. Two dioptric doublets are used to correct aberrations both in the telescope and spectrograph optical path. Two distinct IR focal plane detectors are used for imaging and spectroscopy. Even if in principle hyperspectral imaging could be obtained by a single 2D array detector, making use of satellite motion with respect to ground, the spinning platform makes it very difficult to realize. For this reason, the adoption of a dedicated detector for imaging is preferable. Moreover, since the signal on a large band (such as that envisaged for imaging) is much higher than on a single spectroscopy spectral band, the imaging detector requires a shorter integration time, that can be better matched with the short dwell time imposed by the fast S/C motion with respect to the target (due to the combination of spin, orbit and planet rotation). On the other hand, integration time on the spectrometer's detector can be much larger allowing some spatial smearing. Finally, the resulting baseline optical design is based on single telescope, feeding both focal planes through a beam splitter. The magnification of the spectrograph is unitary, so the same spatial scale on both focal planes can be reached. The JIRAM Optical Head is shown in figure 2.

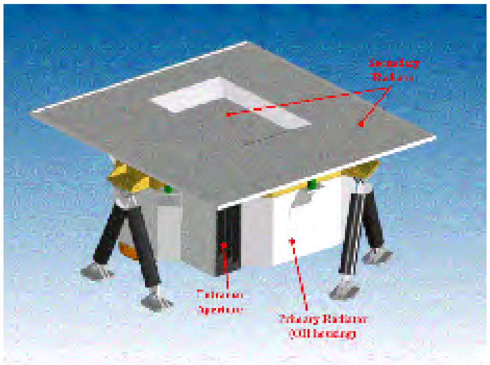

Figure 2: Top view of JIRAM Optical Head, in which the entrance aperture and the Primary & Secondary radiators are shown.

References: [1] Lindsay, C.M., B. J., McCall (2001), *J. Mol. Spectrosc., 210,* 60–83. [2] Kao, L., Oka, T., Miller, S., Tennyson, J. (1991), *Astrophys. J. Suppl. Ser., 77,* 317–329. [3] Roos-Serote, M., Atreya, S.K., Wong, M.L., and Drossart, P. (2004), *Planet. Sp. Sci. 52,* 397-414. [4] Ingersoll, A. P., Gierasch, P. J., Banfield, D., Vasavada, A. R. (2000), *Nature, 403,* 630-632. [5] Stoker. C., *Icarus, 67,* 106-125, 1986. [6] Visscher, C., Fegley, B. (2005), *Astrophys. J, 623,* 1221-1227.