Jovian Quakes

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1. Introduction

Two coordinated programmes have been carried out jointly with the TIMMI camera at the ESO 3.6-metre telescope during and after the impact of comet SL-9 on Jupiter. They were concerned on the one side with the chemical and meteorological consequences of the impact (see the article in this *Messenger* issue), and on the other side with the search for possible seismic consequences[1].

Less than two months after the observations, it is still impossible to say whether this first attempt to observe seismic effects with an IR camera has been successful. However, we may expect that the energy release by some of the biggest impacts (impact H in our case) has been strong enough to excite seismic waves.

The TIMMI camera (Käufl *et al.* 1992, 1994), developed by the Service d'Astrophysique (CEA), allowed us to monitor the atmospheric temperature over the full planetary disk, with 64×64 pixels and a resolution of 0.6"/pixel. According to the expected temperature resolution (10 mK with 100 sec exposure time), the adiabatic thermal waves created by a single impact and crossing the entire planet in about 2 hours (similar to the waves obtained when throwing a stone into a pond) can be detected under the condition that the energy of the impact exceeds 10^{20} J. Detectable pressure modes, corresponding to resonant low frequency waves, require an energy impact of about $2 \cdot 10^{21}$ J (Lognonné *et al.* 1994). For a review on Jovian seismology, see Mosser (1994).

During the Impacts

The optimal time partition suitable for both programmes during the impact period was decided as follows. The first two hours following each impact were dedicated to the search for the waves excited by the impact; this requires a rapid acquisition rate, without any change of filters, contrary to what is needed during the following hours which were dedicated to the atmospheric programme.

Four impacts (A, B, F and H) have been observed. Only accurate data processing will eventually reveal if TIMMI actually detected impact B. For each impact we have recorded a quasi-continuous series of images, at the rate of about 1 image every 3 seconds. About 10,000 images of the full disk of Jupiter were recorded for the seismic programme. These images were not nodded, in order to obtain the high acquisition frequency required for the observation of the high frequency primary waves excited by the impact. This acquisition procedure has allowed us to obtain a first spectacular result: the light curve of impact H, showing either the entry of the bolide into the very high atmosphere a few minutes before the emergence of the impacted region, or its explosion.

Even if seismological considerations would have favoured the use of a 7.8 μm filter (i.e., by isolating the stratospheric methane emission lines), the use of a broad band filter (from 9 to 10.4 μm), which isolates the Jovian tropospheric regions, was preferred. First, the absorption due to telluric water and methane is important in the methane band, and secondly, the thermal emission of Jupiter and the sensitivity of the array are more favourable at 10 μm.

The data reduction consists of the following steps. First, each image will be corrected using the flat fields and the point-spread function, and the position of the planet will be re-centred. Then, new geographical coordinates, with the impact point as origin, will be calculated, in order to obtain seismograms (seismic signal versus time at a given epicentric distance). The signal-to-noise ratio will be increased by stacking all regions at the same angular distance with respect to the impact. Finally, the hodograms (arrival time versus epicentric distance) will be calculated, from which the interior sound speed profile can be inferred.

After the Impacts

Half of the six "nights" following the impacts period have been devoted to the search of pressure modes (resonant waves with periods in excess of 5.5 minutes) trapped in the Jovian cavity. The same broad-band filter was used as during the period of the impacts, but rapid acquisition was now not necessary; this permitted to record nodded images (about 1 per minute). IR thermal observations, starting not later than 2 PM local time, have permitted us to obtain during the 6 half-"nights" a total of more than 22 hours of observations.

In order to perform a Fourier analysis of these data, they will be mixed with the ones obtained in similar conditions at the 2.5-m Nordic Optical Telescope (NOT) at La Palma with the CAMIRAS camera developed by the Service d'Astrophysique (Saclay), as well as with those from the CFHT with the C10μm camera developed at the Observatoire de Lyon. Data during no less than 40 hours of observations were collected at these three sites. The good weather, a favourable southern latitude and early opening of the dome explain why half of the data were obtained at La Silla.

The combination of the three different data sets is possible because they have been collected under very similar conditions, and is in fact necessary in order to decrease the "window effect" (i.e., the fact that false periods may be found because the observations at each observatory only cover a fraction of 24 hours and are done at daily intervals). Overlaps between the data collected at the NOT and at ESO will make this operation easier. The data reduction will be similar to the one commonly used in helioseismology: decomposition of the signal in spherical harmonics, each harmonics contributing to a given Fourier spectrum.

References

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Käufl H.U. *et al.*, 1992, *The Messenger* **70**, p. 67.

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[1] The following colleagues have also contributed to this programme: Tim Livengood (GSFC), Hans-Ulrich Käufl (ESO), Marc Sauvage, Pierre-Olivier Lagage (SAp, CEA), Philippe Lognonné (IPGP), Daniel Gautier, Pierre Drossart (DESPA, Observatoire de Meudon), Françoise Billebaud (ESTEC), Mark Marley (NMSU,) Juan-Antonio Belmonte, T. Roca-Cortes (IAC) and François Sibille (Observatoire de Lyon).