Proposed high-speed optical spectrophotometry of the mutual events of the Galilean satellites of Jupiter

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1. Introduction

An interesting event, the passing of the Earth and the Sun through the orbital plane of the Galilean satellites of Jupiter can be observed in 1997. This event occuring every six years provides the chance to monitor mutual eclipses and occultations of the moons of Jupiter (Arlot 1997). The interest in observing these phenomena is twofold: Careful measurements of the eclipse timings yield high precision astrometric data. On the other hand colour lightcurves from the mutual events provide spectrally resolved scans across the surfaces of the satellites which may reveal their physical and chemical conditions. Furthermore, by simultaneously obtaining eclipse-lightcurves in different colours the correlation between the mass center and photo center can be discussed.

2. Observing program and instrumental requirements

In order to fit both aims, a high-speed multi-colour photometry of the mutual phenomena shall be performed. The individual events typically last a few minutes thus a time resolution of 0.1 s seems sufficient. High precision measurements from ground based sites require the simultaneous monitoring of the object, of at least one nearby comparison star and of the sky background. These requirements favour the application of CCDs. Their high quantum efficiency yields maximum photometric accuracy for a given telescope aperture. The required high time resolution may be achieved by applying the window read out mode (see also Beisker et al. 1997). The enhanced read out noise need not to be taken into account due to the brightness of the objects (approx. 5th mag)

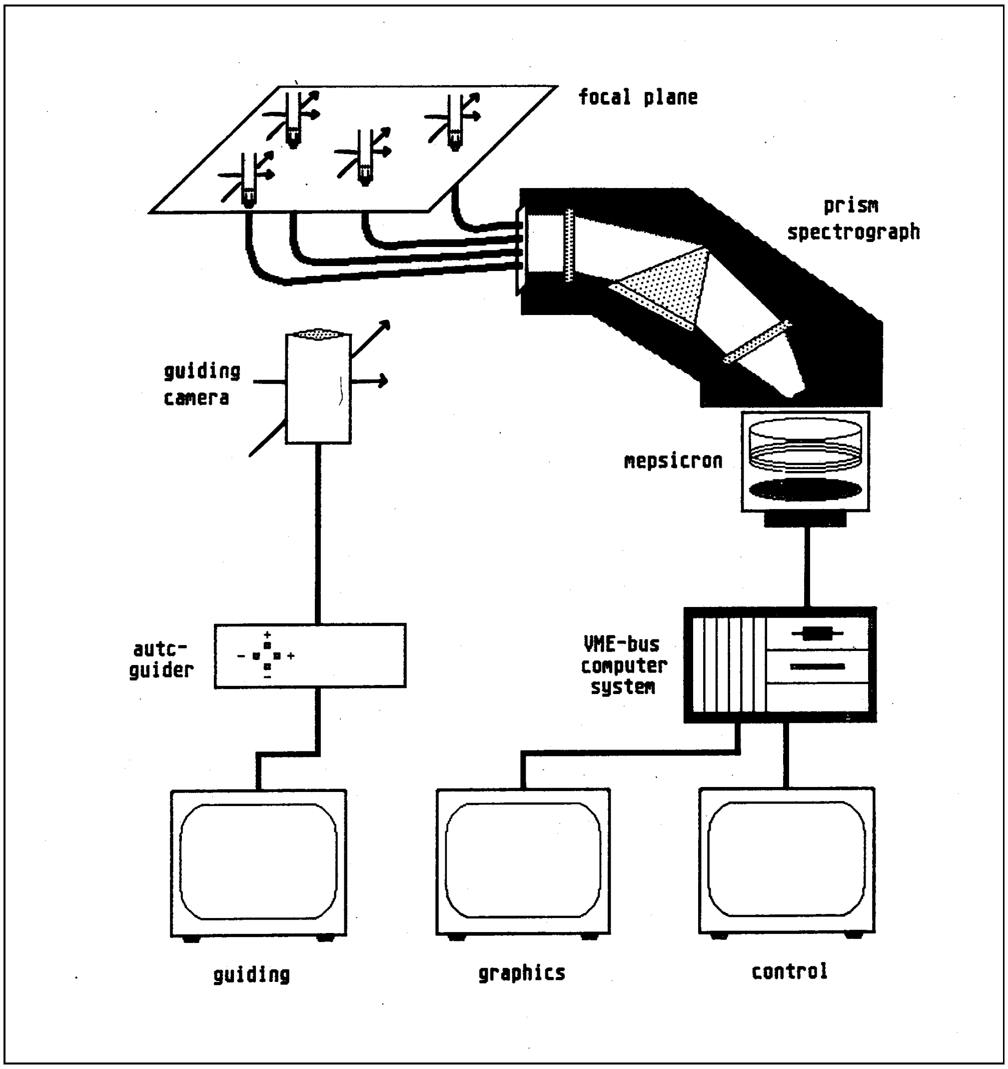

Figure 1: Block diagram of the multi-channel spectrophotometer MEKASPEK.

when using telescopes with apertures lager than 50 cm.

However, the most serious problem arises from the required simultaneity of spectrally resolved exposures which cannot be simulated e.g. by serial measurements with different filters due to the short duration of the eclipse events and the expected spatial frequencies of possible surface structures. The use of a multi-slit spectrometer in front of the CCD was proposed instead. However, this instrumentation does not entirely cope with the problem since the photometric accuracy depends on the separation of the satellites as well as on the seeing conditions and the corresponding vignetting at the slit-jaws. On the other hand, using wide slit-widths in order to increase the photometric precision may result in an unreliable spectral calibration.

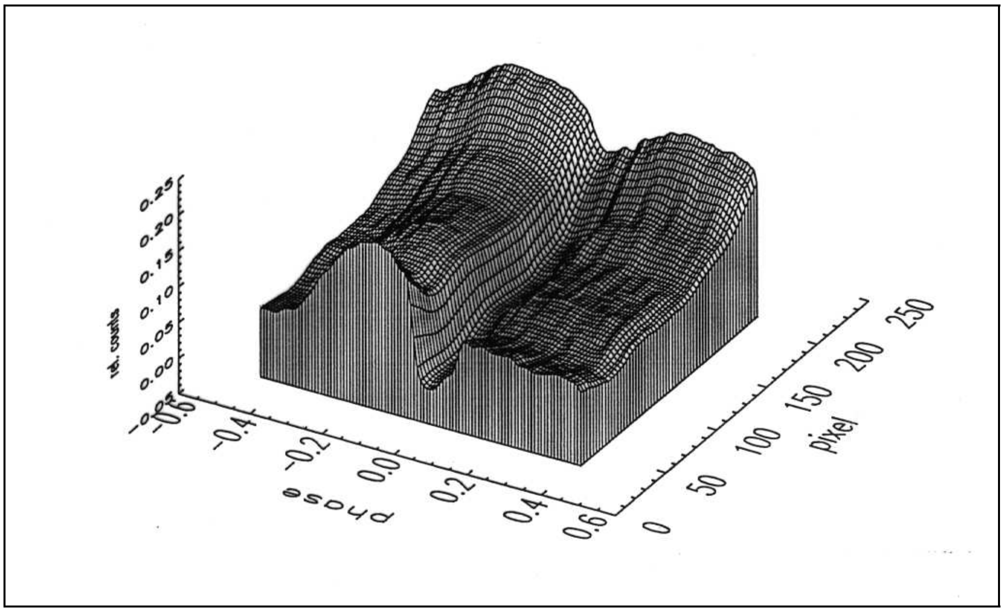

Figure 2: High-speed spectrophotometry of the cataclysmic variable Ip Peg. The displayed pixel range correspond to 3700 Å to 8500 Å. The eclipse of the accretion disk and the white dwarf is centered at phase 0. Around phase -0.2 the orbital hump is visible, which is mostly pronounced in the UV.

3. Application of a multi-channel spectrophotometer

For high precision photometry of rapid variable phenomena which are characteristic for e.g. cataclysmic variables, pulsars, burst sources as well as for star occultations by planets, a multi-channel spectrophotometer (MEKASPEK) with high time resolution has been developed at the Universitäts-Sternwarte München (USM) and is described by Mantel et al. (1988, 1993). Four input channels allow simultaneous observations of object, two comparison stars and sky background in order to compensate for atmospheric extinction effects and changing sky contribution. As shown in figure 1 the input channels are realized by optical fiber bundles which can be positioned by computer control in the focal plane of the telescope. The fiber ends form the slit of a double prism spectrograph which produces four spectra covering the wavelength region $\lambda\lambda 3600 - 9000 \mathring{A}$ with a spectral resolution of $\lambda/\Delta\lambda \approx 50$. The spectra are projected onto a 2-dimensional photon-counting detector (MEPSICRON) which allows exposure times as short as 10 ms. After online reduction and binning of the data into overlapping filter curves the reduced photometric measurements can be transformed to any broadband photometric system (e.g. Johnson, Kron-Cousins, Stroemgren). This spectrophotometric device had been used for many observing programs even at the largest telescopes at ESO in Chile and Calar Alto in Spain. As an example for the application of MEKASPEK the high-speed monitoring of the spectrally resolved orbital light variations of the cataclysmic variable IP Peg is displayed in figure 2. Another example for spec-

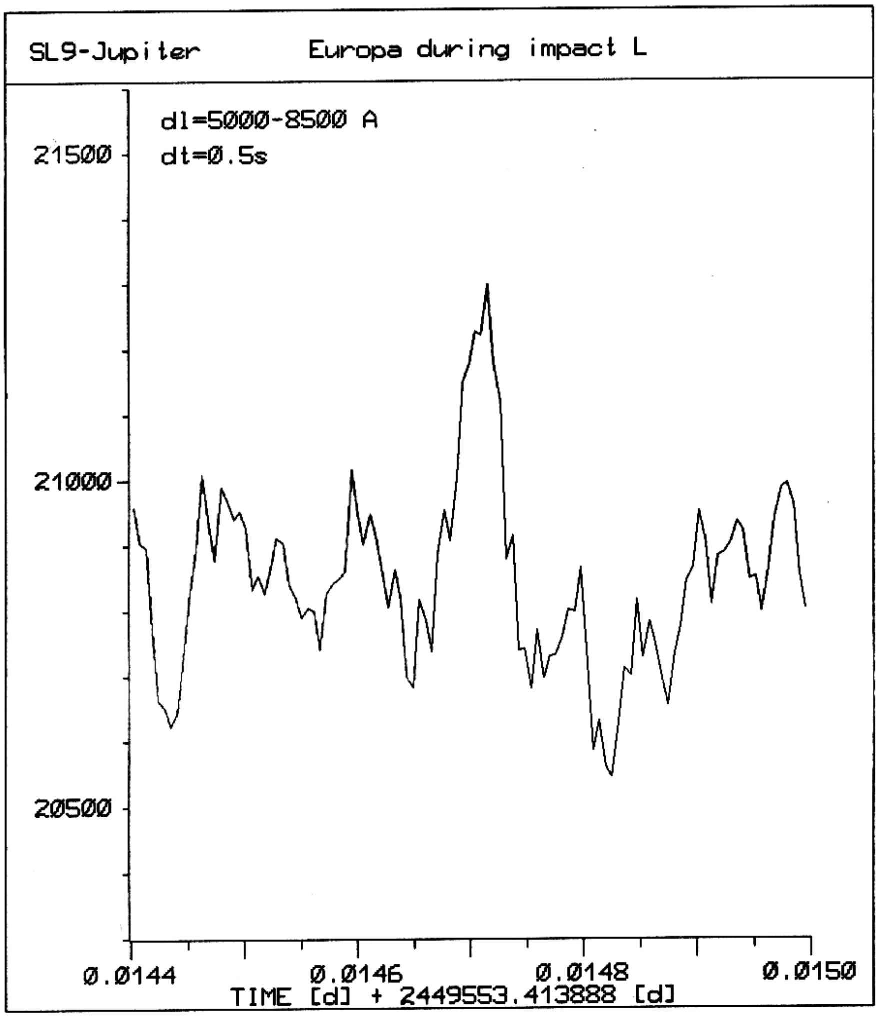

Figure 3: High-speed photometry with a time resolution of 0.5s of the Galilean satellite Europe during impact L of comet shoemaker-Levy-9. The flash-like event can be interpreted as an echo of impact L on the backside of Jupiter.

trophotometric measurements of high-speed phenomena using MEKASPEK is given in figure 3: during the impacts of SL-9 on the backside of Jupiter one of the fibers was used to track the Galilean satellite Europa in order to search for light echoes from impact L. One single flash-like event could be detected which fits quite well the arrival time of the impact flash observed with the Galileo space telescope.

4. Observational procedure

For the proposed campaign to monitor the mutual events of the Jovian satellites our observations shall be performed at the Wendelstein Observatory situated in the Bavarian Alpes at an altitude of 1845m. MEKASPEK will be mounted at the 80 cm RC-telescope of the USM. One of the fiber-channels will be positioned in a way that both satellites are within the measuring diaphragm just prior to the occurrence of the mutual event. If necessary, the fiber can follow the motion of the center of the two satellites. The second fiber will be centered on Jupiter for comparison whereas the two remaining fibers may serve as sky background and straylight indicators. The times which are stored with each single photon impact on the detector are taken from a DCF77 receiver. Though the received clock signal is accurate to less than 1 ms, the arrival times of the individual photons are of similar accuracy only if a real-time computing system is used.

5. Concluding remarks

MEPSICRON will be a powerful tool for observing the spectrophotometric behaviour of the mutual events of Jovian satellites. In particular, the eclipse ingress and egress times can now be compared for different colours. Any time difference that may be observed would clearly indicate the difficulties of deriving reliable astrometric results from observations performed e.g. in integral light only. Furthermore, from the spectrally resolved data we hope to extract the reflectivity of the scanned area of an eclipsed satellite thus obtaining further knowledge on the surfaces of the individual moons.

One of the difficulties which may be encountered by applying the MEKASPEK instrument for this observing program should be mentioned in advance: Due to the relatively low overall dynamics of the MEPSICRON detector (5x10e4 cts/s) this spectrophotometer is appropriate mainly for analysing faint objects. In the case of monitoring the bright Galilean satellites neutral density filters will have to be applied thus decreasing considerably the S/N which could be achieved otherwise. The option to replace the photoncounting detector by a CCD for this purpose will be provided in the near future. As an alternative device the multi-channel UBVRI photometer MCCP, the first generation instrument (Barwig et al. 1987), may be used. It is charcterized by three fiber channels each feeding a single prism spectrograph. The spectra are projected onto fiber bundles which select the UBVRI colour ranges and connect the light signals to 15 photon counting photomultipliers. It needs to be carefully examined whether the MCCP with its higher dynamic (5x10e5 cts/s) but lower spectral resolution will fit the proposed observing program better than MEKASPEK.

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