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Oscillations in the Regions of Evershed Flows

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Abstract. Authors have investigated the line-of-sight velocity difference in the radial direction of sunspot penumbrae simultaneously at two height levels, NiI 4857 and H_β by the differential method. Power spectra of time series exhibit in the range under consideration three groups of periods: 30–40, 12–15, and 8–10 minutes. Particular emphasis has been placed on the low-frequency portion of the spectrum (0.5–2 mHz). In addition to the 12-minute oscillations as detected by Rimmele the line-of-sight velocity component that is caused by Evershed motion is responsible for oscillations with periods of 15–35 minutes, which occur concurrently at the two height levels.

1. Observations and Results

For local sunspot helioseismology it is necessary to have a detailed knowledge of oscillation characteristics in sunspot, especially in its penumbra (Lites 1997). The line-of-sight velocity distribution in it extremely variegated (Balthasar et al. 1997). In authors opinion, such observations should be carried out with moderate spatial resolution but with high sensitivity (10–30 $m{\cdot}s^{-1}$) for an understanding of the general regularities of the velocity field in penumbra. In our observations (1998–2000 years) we have investigated the line-of-sight velocity difference in the radial direction of penumbra simultaneously at two height levels, NiI 4857 (photosphere) and H_β (chromosphere) by the differential method (Kobanov 1983) which permits filtering of the wave motions with a given size and direction. Large sunspots with well-developed umbra and penumbra, as a rule, were selected for the observation. The length of the time series varied from 40 to 80 min.

Figure 1. a, b show samples of temporal periodical changes of the line-of-sight velocity signals associated with the Evershed effect. In these figures, the values of the photospheric oscillations (NiI) are enlarged ≈4 times for ease of representation. The thin lines show the smoothed signals which are just the ones representing the components of the line-of-sight velocity caused by Evershed flows. Periodic variations of this component are clearly seen. These variations are remarkably concurrent in the photosphere and chromosphere, suggesting their causal relationship. In addition to the 12-minute oscillations as detected

by Rimmele (1995) the line-of-sight velocity component that is caused by Evershed motion is responsible for oscillations with periods of 15–35 minutes, which occur concurrently at the two height levels (Figure 1. a, b). The oscillations with periods of 5 and 8–10 min have been recorded with confidence in the photosphere of the sunspot middle penumbra (Figure 2). Usually their amplitude does not exceed 40 m·s^{-1}. Interesting that some sunspot penumbra show periodic variations in the slope of the $H_\beta \lambda$ 4861Å and NiI λ 4857Å spectral line profiles, with the predominant period of $\approx$8 min and shorter periods in the 3–5-min range (Kobanov 2000). A distinguishing characteristic of some observational series (not true for all time series) is the fact that the line-of-sight velocity signals in H_β and NiI are opposite in sign, i.e. they are displaced from the zero level in opposite directions. This is accounted for by the effect of Evershed flows. We

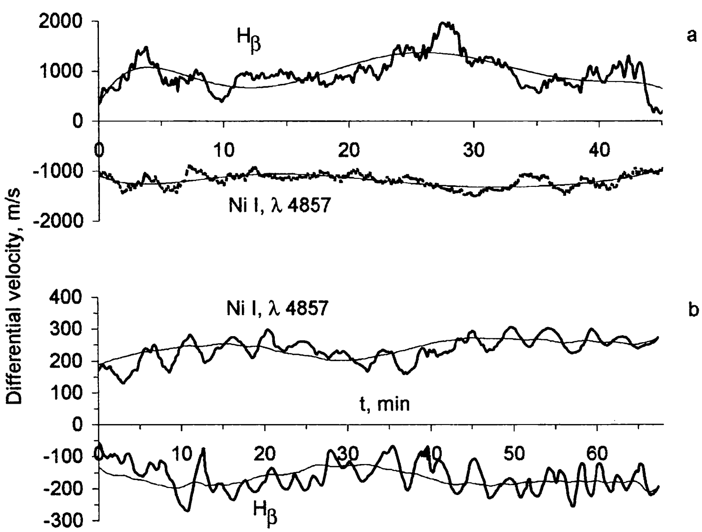

Figure 1. Examples of periodical variations of the line-of-sight velocity differences in middle penumbra sunspot: a – NOAA 8951 (13.04.2000); b – NOAA 8299 (13.08.1998).

have tried to use this to identify the oscillations associated with Evershed flows, and to separate them from oscillations of a different origin. Particular emphasis has been placed on the low-frequency portion of the spectrum (0.5–2 mHz).

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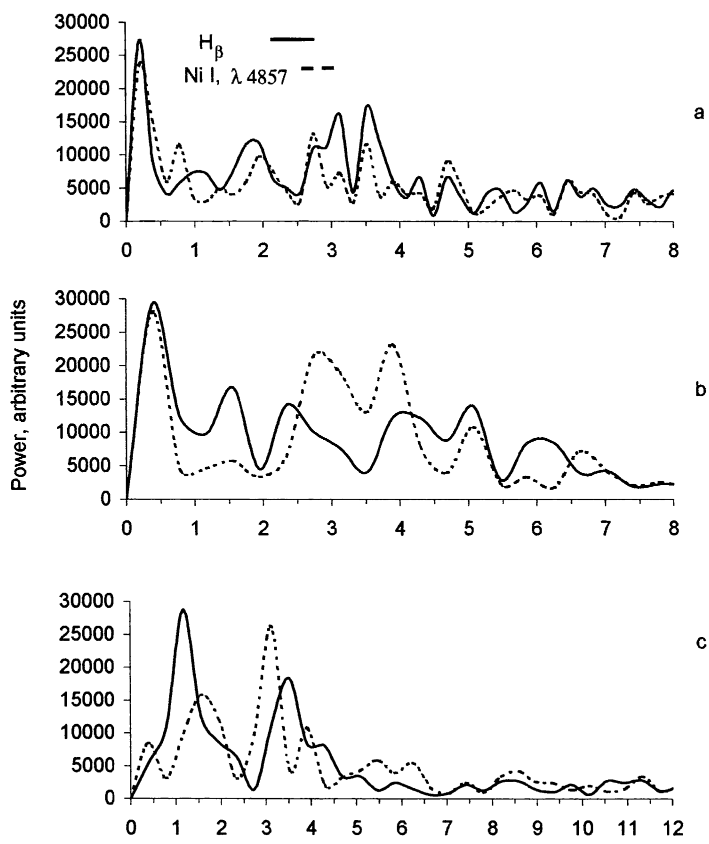

Figure 2. Power spectra of the middle penumbral velocity oscillations. a – Sunspot NOAA 8602, north part (29.06.1999); b – the same 2 hour late; c – Sunspot NOAA 8627, east part (17.07.1999).

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