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Pulsation Spectra of the Chromospheric Radiation from the Solar Flare SOL2015-10-01

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The present study is devoted to the quasi-periodic pulsations (QPPs) in the chromospheric emission of solar flares that are often observed during these phenomena. We analysed the chromospheric emission of an M4.5-class flare (SOL2015-10-01) obtained with the Horizontal-Sonnen-Forschungs-Anlage spectrograph (HSFA-2) at the Ondřejov Observatory of the Czech Academy of Sciences. We also used X-ray time profiles obtained with the Ramati High Energy Solar Spectroscope Imager (RHESSI) and observations in the microwave range obtained with the radio telescope RT3 at 3.0 GHz (Ondřejov Observatory) to test the reliability of the detected chromospheric QPP periods. The processing and analysis of the spectra in the CaII H, Hβ, Hα, and CaII IR 8542 Å lines and the time profiles of the X-ray and microwave emission revealed the presence of oscillation periods in the range of 1–2 minutes.

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1. Introduction

Quasi-periodic pulsations (QPPs) are observed in the time profiles of solar flares in a wide range of the electromagnetic spectrum - from microwaves and UV to emission in chromospheric lines and gamma radiation. Their periods varies from subseconds to tens of minutes, which indicates the different nature of these pulsations. There are two main classes of mechanisms explaining QPPs. The first one relates the observed pulsations to the direct impact of magnetohydrodynamic (MHD) waves, and the second mechanism is associated with a repetitive process of magnetic reconnection [1, 3]. Often, the mechanisms of the two classes coexist and complement each other. For example, the process of magnetic reconnection can be initiated by MHD waves. The absence or presence of QPPs in several spectral ranges, varition of properties from one spectral range to another allows us not only to find the mechanism contribution but also to diagnose the properties of flare plasma. We devote our analysis to searching for QPPs in the chromospheric emission of solar flares, which is most popular for study of such events. However, the emission in this region of the solar atmosphere forms under the influence of many parameters that vary over a wide range: temperature, density, and motion of matter.

2. Observations and processing

For analysis, we chose the M4.5-class flare SOL2015-10-01, observations of which were obtained at the Ondřejov Observatory of the Czech Academy of Sciences with the Horizontal-Sonnen-Forschungs-Anlage spectrograph (HSFA-2, 500 mm/35 m). We also used time profiles in the X-ray range obtained with the Ramaty High Energy Solar Spectroscopic Imager (RHESSI) [2] and observations in the microwave range obtained with the radio telescope RT3 [4] (3.0 GHz frequency, Ondřejov Observatory).

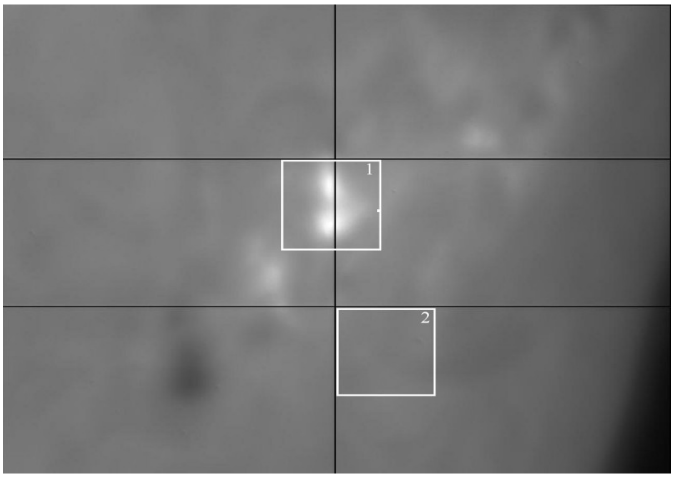

Fig. 1. An M4.5 flare in NOAA 12422, (start 13:03 UT, max 13:10 UT, end 13:14 UT).
SJ box 106 x 155 px, 1—active region, 2—quiet region.

The integrated intensities were obtained for the images of the chromosphere on the slit of the spectrograph (SJ) and the spectra (see Figs. 1–2) normalized after calibration to the region of the quiet chromosphere near the flare. The time interval is 13:07:54–13:28:50 UT, the interval between exposures is 4 s.

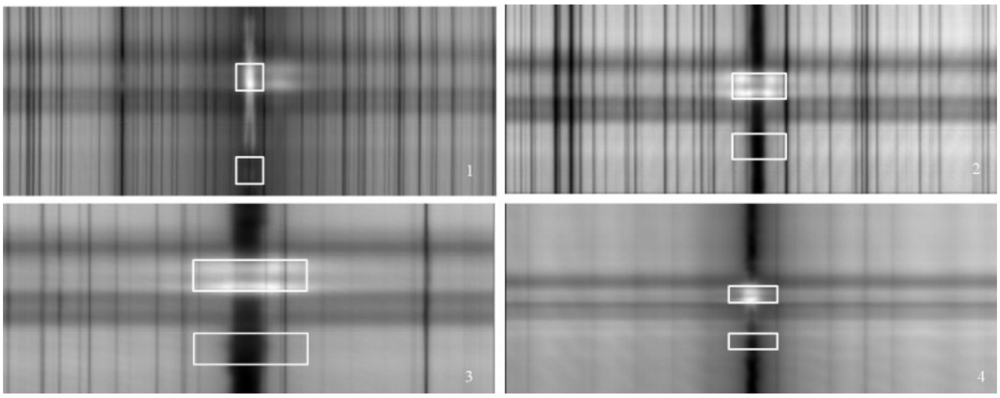

Fig. 2. Spectrum images in the CaII H (1), Hβ (2), Hα (3), and Ca IR 8542 Å lines. The regions of integral intensity measurements are shown by rectangles.

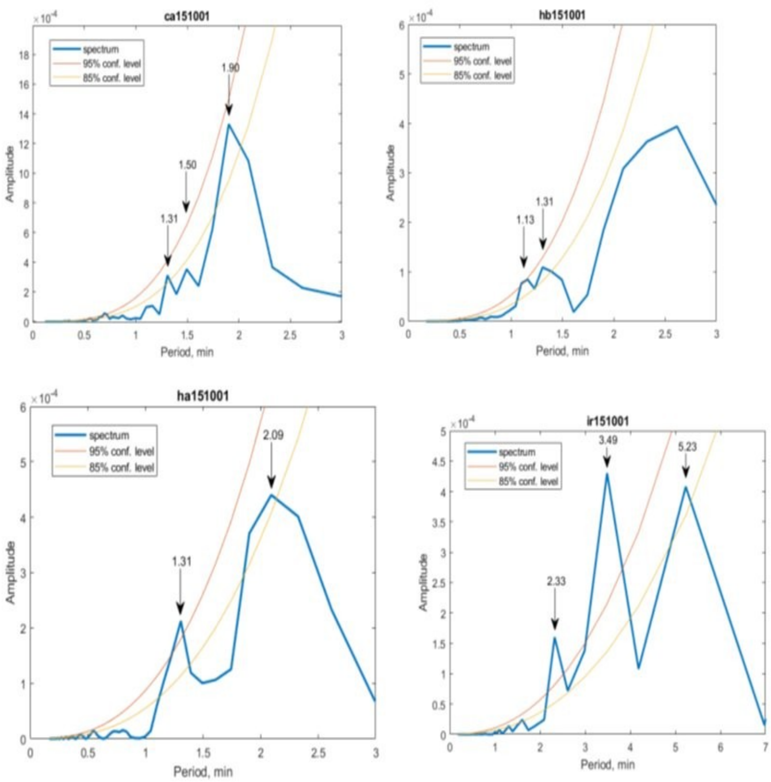

Fig. 3. Power spectra for the data in the CaII H, Hβ, Hα, and Ca IR 8542 Å lines. The 95% and 85% significance levels are marked.

As quasi-periodic pulsations in solar flares are damped oscillations of a quasi-harmonic or triangular shape against the background red noise [1, 5], the red noise could result in false periods, and we should exclude them. That is why for selection of flare QPPs we used the technique proposed in the paper of [6]. Figures 3–5 demonstrate the results of data processing with the significance levels.

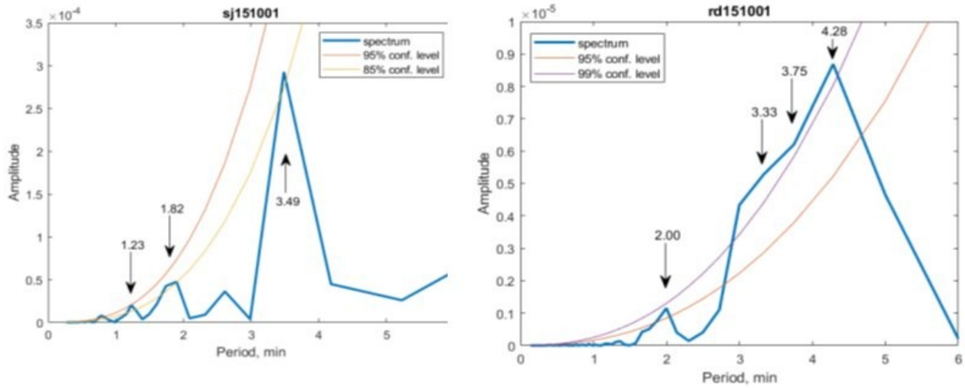

Fig. 4. Power spectra for the Hα (SJ) spectroheliograms (left) and for the radio telescope RT3 data (3.0 GHz frequency) (right).

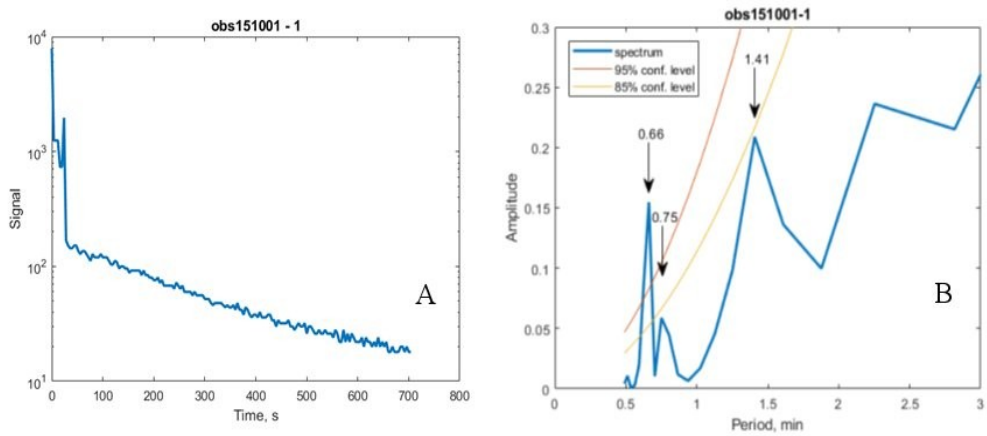

Fig. 5. RHESSI data at 6–12 keV: A—temporal profile, B—power spectrum.

The X-ray temporal profile obtained with RHESSI was represented in logarithmic scale to approximate the trend by a quadratic function. Then the trend was subtracted from the data, and the time profile corrected for the trend was analysed using the power spectrum. As time resolution of the data is 4 s, the found periods of 0.5–1.5 m are trustable.

3. Conclusions

Quasi-periodic pulsations of flare emission are an effective tool for diagnosing both the flare processes themselves and the parameters of thermal plasma and accelerated particles. After processing the spectra in the CaII H, Hβ, Hα, CaII IR 8542 Å lines and the spectroheliograms (SJ) as well as the RHESSI and RT3 data, and taking into account the significance level, we found oscillation periods in the range of 1–2 minutes. Probably, the found 5-minute oscillations according to the RT3 3 GHz data are of the same nature as in the study of [7], the flare was a modulator of oscillations already existing in the chromosphere.

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References

[1] E.G. Kupriyanova, L.K. Kashapova, T.V. Doorsselaere, et. al. *Quasi-periodic pulsations in a solar flare with an unusual phase shift, MNRAS* **483** (2019) 5499–5507 [10.1093/mnras/sty3480].

[2] R.P. Lin, B.R. Dennis, G.J. Hurford, et al. *The Reuven Ramaty High-Energy Solar Spectroscopic Imager (RHESSI)*, *Sol. Phys.* **210** (2002) 3–32 [10.1023/A:1022428818870].

[3] E. Kupriyanova, D. Kolotkov, V. Nakariakov and A. Kaufman *Quasi-periodic pulsations in solar and stellarflares. Review*, *Solar-Terrestrial Physics* **6** (2020), 3–23 [10.12737/stp-61202001].

[4] M. Karlický, K. Jiřička *Regular variations of 3 GHz radio flux and current-loop coalescence model of solar flares*, in proceedings of *JSCS 2003 Symposium, 'Solar Variability as an Input to the Earth's Environment ', Tatranska Lomnica, Slovakia, 2003*.

[5] C.E. Pugh, A.-M. Broomhall and V.M. Nakariakov, *Significance testing for quasi-periodic pulsations in solar and stellar flares, A&A* **602** (2017) A47 [10.1051/0004-6361/201730595].

[6] S.A. Vaughan, *A simple test for periodic signals in red noise, A&A* **431** (2005) 391–403 [10.1051/0004-6361:20041453].

[7] A.A. Chelpanov., N.I. Kobanov., *Модулированные вспышкой 3- и 5-минутные колебания как средство зондирования солнечной атмосферы, Astron. zhurn.* **97** (2020) 341–347 [10.31857/S0004629920030020].