Astronomický ústav AV ČR

Opinion of the supervisor

PhD Thesis **"Chromospheric waves and their contribution to heating of the atmosphere"**
by **Mgr. Vahid Abbasvand Azar**

Heating of the upper layers of the solar atmosphere is currently a "hot" topic crucial for the understanding of basic processes taking place on the Sun and other stars. This topic is widely debated using different viewpoints and approaches. The dissertation aims to estimate the ability of acoustic and magnetoacoustic waves to heat the solar chromosphere. In brief, the energy deposited by waves in the chromosphere has to be compared quantitatively with the energy released by radiation (radiative losses) in quiet-Sun and active regions.

The doctorand dealt successfully with a number of difficult tasks that are necessary to solve the problem. First, suitable spectroscopic observations with high time resolution of chromospheric lines had to be collected, namely four extended data sets acquired at large ground-based solar telescopes, 23 sets retrieved from the IRIS satellite archive, and complementary magnetic-field data provided by HMI at the SDO satellite. The doctorand participated successfully in two observing runs at the Vacuum Tower Telescope on Tenerife. He managed the complex procedures of data calibration and processing, particularly Doppler velocity measurement, fitting of line profiles, and co-alignment of complementary data. Another task was the non-LTE inversion of chromospheric lines to obtain semiempirical models of solar atmosphere necessary for the calculation of energies deposited by (magneto)acoustic waves and released by radiative losses. For this purpose, he used the non-LTE radiative-transfer code developed by Petr Heinzel. A public online database of model atmospheres, profiles of chromospheric lines, contribution functions, and radiative losses was created as a by-product of these calculations. The deposited energy of (magneto)acoustic waves was computed from power spectra of Doppler velocities, model atmospheres, and magnetic field inclination using a code developed by Michal Švanda.

The results presented in the thesis are based purely on observations. Use of different spectral lines present in different data sets makes it possible to distinguish between the middle and upper chromosphere and to estimate the contribution of deposited energy of (magneto)acoustic waves to the heating of these layers. It is shown that the deposited acoustic-wave energy can fully balance the energy released by radiation in the quiet-Sun middle chromosphere while in the

upper chromosphere its contribution is negligible. In active regions (plages), the energy deposited by magnetoacoustic waves is insufficient to balance the radiative losses in the middle as well as in the upper chromosphere. These novel results provide useful constraints to more sophisticated observational studies and theoretical simulations in the future.

The doctorand elaborated his thesis with a dedicated effort and acquired a solid background and skills in the field of astrophysics thanks to his hard work. He published three papers on chromospheric heating, which currently have 17 citations, in leading international referred journals. In my opinion, the goals of the thesis were fully accomplished and I recommend to grant Vahid Abbasvand Azar the doctoral degree.

Ondřejov, March 7, 2022

RNDr. Michal Sobotka, DSc.
supervisor