REVIEW OF DOCTORAL THESIS

Author: Vahid Azar Abbasvand
Title: "Chromospheric waves and their contribution to heating of the atmosphere"
Reviewer: Dr. Marco Stangalini PhD

General aspects

The PhD thesis focuses on the assessment of the contribution of acoustic and magneto-acoustic waves to the heating of the solar chromospheric plasma and, in particular, to the deposited acoustic flux in relation to the radiative losses. This is still an open and long debated science question and it is of paramount importance to study how much the acoustic flux contributes to plasma heating in the chromosphere to constraints different heating mechanisms.
However, this is a complicated task given the fact that one has to deal with complex radiative transfer effects and detailed atmospheric modelling at the same time and put together information about wave propagation in complex magnetic structures at different layers in the atmosphere.
I have to say that I was impressed by the maturity of the PhD candidate and in particular by his ability to work and combine different methodologies as well as data sets obtained from ground and space. With regard to the large number of data sets exploited, I would like to stress that, since they are acquired by direct types of instruments (i.e. from imaging spectropolarimeters to slit spectrographs), they present different peculiar aspects that need to be carefully taken into account when analysing them. In addition, chromospheric lines are formed in non-LTE conditions requiring an in-depth knowledge of all the radiative transfer aspects related to this. It appears to me that the PhD candidate has acquired a solid background and maturity to correctly manage all these tasks, obtaining at the end interesting and novel results.
The thesis work has also brought to 3 peer-review papers published on major astrophysics journals.

Methods

The investigation of the heating of the solar chromosphere due to acoustic and magneto-acoustic waves is done by measuring the deposited acoustic flux derived from observations of chromospheric lines from different instruments on ground and space (i.e. IRIS). The deposited flux is obtained by considering the power spectrum of Doppler velocity oscillations at different heights in the solar atmosphere. The Doppler velocity at different heights is obtained by measuring the shift of the line at different distances from the line core or considering different spectral components, as in the case for example of the Mg II data. This requires a detailed knowledge of the height of formation of the signals, which is obtained by carefully investigating the contributions functions of the spectral lines through the MALI radiative transfer code.

Radiative losses and their spatial distributions are computed through a large grid of 1D non-LTE hydrostatic semi-empirical models, which are assigned to each pixel of each data set according to the observed spectral profiles. The models were selected from a large grid obtained by scaling the temperature and column-mass stratifications of initial VAL models. The grid of models constructed in this work largely extends that used in a previous work by Sobotka et al. (2016), and enables a much better match of the synthetic to the observed time-averaged profiles. Further, this extended grid of atmospheric modes is now applied to a large number of datasets to explore different solar atmospheric conditions, from quiet Sun to active regions.

Scientific results and their significance

The thesis work has led to very good scientific outcome. The work itself can be seen in continuation with previous work in the literature (i.e. Sobotka et al. 2016), where a smaller grid of semi-empirical models was employed to study and compare radiative losses and the deposited acoustic flux of waves. However, this work largely extend the previous works on the subject by largely improving the grid of models itself and applying this approach to a number of data sets representative of different solar atmospheric conditions.

The main finding of the work is that the acoustic flux compensate for a substantial fraction of the chromospheric losses in quiet Sun regions, while this flux is not sufficient to explain the radiative losses in active regions, meaning that other mechanisms come into play. This is an important addition to the current knowledge of the chromospheric heating problem.

One point that was only briefly touched in the thesis is the impact of the spatial resolution on the rms of the Doppler oscillations used to identify the waves. This is certainly true. However, I believe it is worthwhile underlining that this fact makes this study and, in particular, the approach adopted suitable for more future investigations with the new 4-meter class solar telescopes like DKIST, which is just entering its nominal science phase, or the European Solar Telescope.

Finally, there are three first author peer-review papers by the PhD candidate. The scientific outcome is not dispersed but gives a clear impression of highly focused and systematic work.

Presentation

The thesis consists of 8 chapters, starting with a comprehensive introduction to the main aspects linked to the solar chromospheric heating problem and the primary aims of the work. It follows an accurate overview of the magneto-acoustic wave propagation in the solar atmosphere, a detailed analysis of the atmospheric modelling, of chromospheric lines formation and finally and exhaustive description of the datasets and the analysis methods used and the results obtained.

The structure of the thesis conforms to principles of scientific correctness and provides all the details to replicate the results. Appropriate number of references and detailed explanations of all the methods and data used are also provided.

Conclusions

In my opinion the thesis work by Vahid Azar Abbasvand presents novel and interesting original results, and I recommend that the candidate is awarded the doctoral degree.

Sincerely,

Dr. Marco Stangalini PhD
ASI, Italian Space Agency
Via del Politecnico snc, 00133
Rome, Italy