PROJECT FOR FAPESP POST-DOCTORAL FELLOWSHIP

Project Title

Precision Spectroscopy of Solar Type Stars

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Summary

This postdoctoral project aims to explore the differential analysis technique in order to determine stellar parameters and chemical abundances in solar-type stars. Using precise abundances (0.01 dex) we will investigate the connection between chemical anomalies and planet formation and we will study various stellar nucleosynthesis processes at unprecedented detail.

Description of goals

In the last few years it has been demonstrated that it is possible to achieve an accuracy of 0.01 dex in solar twins (e.g. Meléndez et al. 2012; Nissen 2015; Spina et al. 2016, Yana Galarza et al. 2019) and in other type of stars such us cool giants (Yong et al. 2013), open cluster stars (e.g. Liu et al. 2016, Spina et al. 2018A) and binary stars with planets (e.g. Ramírez et al. 2015, Tucci Maia et al. 2019), as far as the stars are similar between them. The differential technique has also been successfully applied to metal-deficient stars, albeit at lower precision. Nissen & Schuster (2010) studied metal-poor stars of the thick disk and the Galactic halo, showing the existence of two halo populations in our galaxy; Reggiani et al. (2017) analyzed very metal-poor stars for constraints on cosmic scatter; and Reggiani et al. (2016) applied the line-by-line differential technique to extremely metal-poor stars ([Fe/H] < -3). Thus, the differential technique has important implications for different areas of astrophysics, from exoplanets to Galactic archaeology.

The project's goal is to use the differential analysis technique to study solar-type stars with atmospheric parameters very similar to each other, in order to explore chemical tagging at high precision.

Work plan

The data has been acquired with high-resolution spectrographs at large telescopes. We have available spectra taken with the HIRES spectrograph at the 10m Keck telescope, and with the HARPS spectrograph at the 3.6m ESO telescope; also we can explore the large amount of data available at different archives. The first part of the work will be to complete the reduction of the spectra, mainly the continuum normalization and Doppler correction. We could also acquire more data, and our group has been very successful in obtaining observing time with different 4-10 m telescopes.

The second part of the project consists in the measurement of equivalent widths. We will use semi-automatic and fully manual measurements, using exactly the same criteria to measure a given spectral line. This is a time-consuming process because the measurements have to be done very carefully and exactly in the same way for the star of interest and the standard star, in order to achieve high accuracy.

The third part of the project consists in the determination of an initial set of atmospheric parameters using the photometric calibrations of Casagrande et al. (2010) for the determination of effective temperature, GAIA parallaxes for determining the surface gravity, the calibration of Ramirez et al. (2013) for the microturbulence velocity, and literature values for the metallicity.

In the fourth part of the project we will obtain precise stellar parameters, determining iteratively the values of temperature, log *g,* and microturbulence velocity (e.g., Meléndez et al. 2012). Then we will obtain differential abundances with errors of the order of 0.01 dex. We will also use isochrones to determine ages and masses based on our stellar parameters, using probability distribution functions (e.g., Meléndez et al. 2012; Chanamé & Ramírez 2012; Spina et al. 2018B).

In the fifth and final part of the project, we will study the connection between photospheric chemical abundance anomalies and planet formation, as well as various processes of stellar nucleosynthesis (AGB stars, supernovae, stellar depletion), and finally we will write articles related to the research developed.

Schedule

Months 1 - 4: Data Reduction.

Months 5 – 8, 15 – 18 and 25 - 28: Measurement of equivalent widths in different samples

Months 9 – 10, 19 – 20 and 29 - 30: Determination of initial values for atmospheric parameters.

Months 11 – 12, 21 – 22 and 31 - 32: Differential analysis for final determination of atmospheric parameters and chemical abundances, in order to obtain high accuracy. Discuss the implications of the high precision abundances in the context of anomalies due to planets and various nucleosynthethic processes.

Months 13 – 14, 23 – 24 and 33 - 35: write papers

Month 36: Write final FAPESP report.

How the postdoc fellowship fulfill the goals of the FAPESP postdoctoral fellowships

We intend to attract a promising young scientist, who has obtained its doctorate degree no earlier than seven years ago, thus fulfilling the goals and rules of FAPESP. We will conduct an internationally selection process, as was already done for our previous FAPESP postdocs (Dr. Talawanda Monroe, Indiana University; Lorenzo Spina, *Università di Firenze*) and the current FAPESP postdoc Diego Lorenzo de Oliveira (UFRJ).

Our request fits perfectly within our proposed FAPESP *Temático* project because the research plan deals with the study of stellar parameters and high precision differential abundances, hence it is important to have the postdoctoral grant approved along with the *Temático* project.

Following the recommendations of FAPESP, we will select preferably a scientist who has not done its PhD at the host Institution (either IAG/USP or Mackenzie), unless no suitable candidates from other institutions are found. Nevertheless, the proposed FAPESP *Temático* certainly has the potential to attract young talents from different institutions.

Bibliography

- Casagrande, L.; Ramírez, I.; Meléndez, J.; Bessell, M.; Asplund, M. 2010, A&A, 512, A54
- Chanamé, Julio; Ramírez, Iván 2012, ApJ, 746, 102
- Liu, F. et al. 2016, MNRAS, 457, 3934
- Meléndez, J.; Bergemann, M.; Cohen, J. G.; et al. 2012, A&A, 543, A29
- Nissen, P. E.; Schuster, W. J. 2010, A&A, 511, L10
- Nissen, P. E. 2015, A&A, 579, A52
- Ramírez, I. et al. 2013, ApJ, 764, 78
- Ramírez, I. et al. 2015, ApJ, 808, 13
- Reggiani H., Meléndez, J., Kobayashi, C. et al. 2017, A&A, 608, 46
- Reggiani, H., Meléndez, J., Yong, D. et al. 2016, A&A, 586, A67
- Spina, L., Meléndez, J., Karakas, A. I. et al. 2016, A&A, 593, A125
- Spina, L., Meléndez, J., Casey, A. et al. 2018A, ApJ, 863, 179
- Spina, L., Meléndez, J., Karakas, A. I. et al. 2018B, MNRAS, 474, 2580
- Tucci Maia, M., Meléndez, J., Lorenzo-Oliveira, D. et al. 2019, A&A, 628, A126
- Yana Galarza, J., Meléndez, J., Lorenzo-Oliveira, D. et al. 2019, MNRAS Letters, 490, L86
- Yong, D., Meléndez, J., Grundahl, F. et al. 2013, MNRAS 434, 3542