Boletim da Sociedade Astronômica Brasileira, **32**, no. 1, 119-120

Revisiting the spectroscopic chromospheric activity of solar-like stars

R. R. Ferreira, M. Castro, & J.-D. do Nascimento Jr.

[1] Departamento de Física Teórica e Experimental, Universidade Federal do Rio Grande do Norte, Natal, RN, CEP: 59072-970, Brazil
e-mail: rafaelferreira@fisica.ufrn.br

Abstract. The evolution of solar and stellar magnetic activity has been subject to intense investigations along the last decades. Searching to characterize the magnetic activity behavior of solar-type stars in time, several surveys have been performed over the last 60 years. We are revisiting and enhancing the chromospheric activity determination of approximately 4500 solar-like stars originally inferred by the Mount Wilson project. In addition, we are computing the activity indexes (Ca II H&K, Ca IRT and Hα index) from HARPS, NARVAL, ESPADONS, ELODIE and SOPHIE high-resolution spectra archive available. It allows us to cover a larger time interval over 60 years. We are determining the activity-cycle periods using the Lomb-Scargle periodogram to analyze the active and inactive branches in the rotation-activity-cycle diagram. We are also looking for stars with flat activity in this sample, as the way to find Maunder minimum stars.

Resumo. A evolução da atividade magnética solar/estelar tem sido tema de intensa investigação ao longo das últimas décadas. Buscando caracterizar o comportamento da atividade magnética das estrelas do tipo solar no tempo, vários levantamentos vem sendo realizados ao longo dos últimos 60 anos. Nós estamos revisitando e aumentando a determinação da atividade cromosférica de aproximadamente 4500 estrelas do tipo solar, que são observadas desde o projeto do Monte Wilson. Além disso, nós estamos calculando os índices de atividade (Ca II H&K, Ca IRT and Hα index) dos espectros de alta resolução disponíveis em arquivo dos instrumentos: HARPS, NARVAL, ESPADONS, ELODIE e SOPHIE. Isto, nos permite cobrir um grande intervalo de tempo de 60 anos. Nós estamos determinando os períodos do ciclo de atividade usando o periodograma Lomb-Scargle para analisar os ramos ativo e inativo do diagrama rotação-ciclo de atividade. Nós também estamos olhando para estrelas com perfil fixo de atividade nesta amostra, como caminho em busca de estrelas no mínimo de Maunder.

Keywords. Stars: activity – Stars: evolution – Stars: chromospheres

1. Introduction

The study of solar magnetic activity has been the subject of intense discussion in astrophysics. Continuous observations of sunspot numbers exist since the first observation of Galileo at the beginning of the 17th century. Currently, several surveys have been achieved to investigate the solar/stellar magnetic activity behavior in time. The study of magnetic activity of solar analog stars is an excellent opportunity to study the Sun's activity history Wright (2004).

Considerations about the determination and length of the activity cycle period of solar-like stars, are matter of debate over the last decades. Indeed, evidences about the singularity of the solar activity behavior history and possible implications for solar-like stars evolution are intensively investigated.

One of the most intriguing phenomena is a long period, called Maunder Minimum (MM hereafter), which defines a phase of the solar activity during 70 yrs between the 16th and the 17th centuries when almost no sunspot has been observed (Eddy 1976). Currently, there is no explication for the lowest activity period of the Sun, however, it is historically known that it coincided with a short glacial era in the Earth.

Therefore, the problem of the extremely low activity in main sequence stars is still a real puzzle for the modern stellar astrophysics. It is known that these stars have a strong activity when young, the extremely low activity in young stars along many decades could be the first evidence for possibles MM candidates.

Continuous spectroscopic observations have been performed since 1960, firstly through the Mt. Wilson (MW) program and after mainly by California and Carnegie Planet Search program. From 1990 until today many others surveys have been made and activity index measurements have been analyzed from these spectra.

This work is organized as follows: in section 2 we present our database of stars, in section 3 we show a draw of our computational project and discussion about some selected stars of our sample, finally the last session presents the conclusion and perspectives.

2. Data

Initially, we used the data available as proposed by Saikia et al. (2018). Our sample is composed by Sun-like stars Arriagada (2011); Wright (2004); Isaacson & Fischer (2010); Henry et al. (1996); Gray et al. (2006); Hall et al. (2009); Lovis et al. (2011); Bonfils et al. (2013); Duncan et al. (1991); Baliunas et al. (1995). In addition, we are computing the activity indexes (Ca II H&K, Ca IRT and Hα index) from HARPS, NARVAL, ESPADONS, ELODIE and SOPHIE high-resolution spectra archive available.

The S-index of MW (S_{MW}), is one of the main indexes of activity measurements. For the other instruments, its necessary to apply a calibration transforming the instrument S-index to the MW one. Briefly, our database is detailed below:

- The Magellan survey Arriagada (2011) provided 643 stars.
- The California and Carnegie planet search provided 1101 stars Wright (2004). Additionally, 1798 stars were also observed as part of the California planet survey Isaacson & Fischer (2010).
- A survey of southern solar-type stars carried out by Henry et al. (1996) and Gray et al. (2006). The southern sample of stars in Henry et al. (1996) consists of 758 stars. 1288 southern stars were also taken from Gray et al. (2006). 28 stars were taken from the solar and stellar activity program

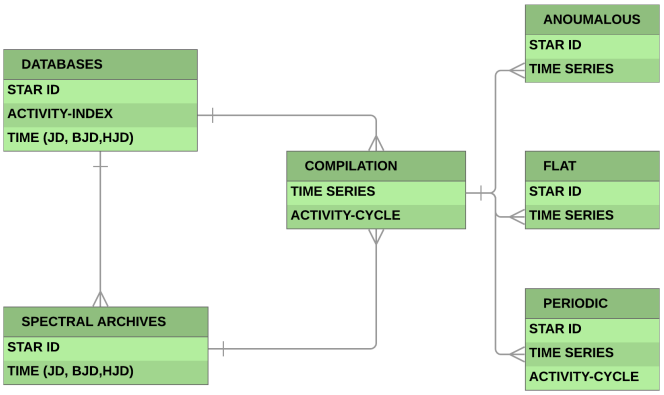

Figure 1. UML diagram represents a draw of computational code in python to collect, compute and compile the activity time series. In addition, we propose classification in periodic-activity, flat-activity, anomalous-activity.

of the Lowell observatory Hall et al. (2009). High-resolution archival spectra were obtained for 304 F, G, K from Lovis et al. (2011); Bonfils et al. (2013).

– Data from the Mount Wilson survey Duncan et al. (1991); Baliunas et al. (1995) have recently been re-released by the NSO and are included in the catalog. We included 827 cool stars from the National Solar Observatory (MW survey).

3. Project

We propose to revisit and enhance the chromospheric activity time series of approximately 4500 solar-like stars originally inferred from surveys described above. We propose a compilation of other databases such as HARPS, NARVAL, ESPADONS, ELODIE and SOPHIE archives, initially using an instrumental S-index calibrated from S_{MW}.

This idea consists in collecting all available data in archives and spectral data (see Fig.1). Then, we compute the activity-index, after this, we compile an integral time series and investigate the periodicity profile.

We compute the activity-cycle periods using the well established Lomb-Scargle periodogram Horne & Baliunas (1986) to analyze the active and inactive branches in the rotation-activity-cycle diagram. We are also looking for stars with flat activity in this sample, as the way to find Maunder minimum stars. In addition, we are seeking to revisit the activity-rotation diagram (see Fig. 2) showed by Saikia et al. (2018). We are recomputing the activity-cycle period from all database and spectra archive referred before.

4. Perspectives

We propose a study to revisit the chromospheric activity-cycle period of solar-like stars observed since the MW project. We pretend to increase the number of stars in each profile of activity behavior (periodic, flat and anomalous). The difficulty to perform the necessary calibrations lies in the various instrumental erros.

We want alto to investigate many stars that have a flat activity profile and may be considered MM candidates according to Lubin et al. (2010). According to Baliunas et al. (1995) 65% of their star sample present a periodic-activity, 15% a flat-activity and 20% have a anomalous profile. These proportion

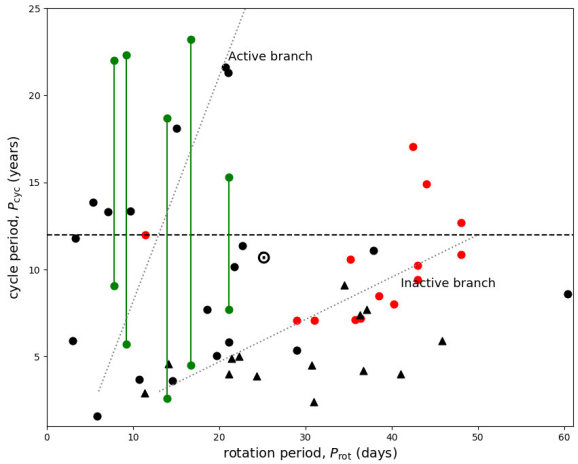

Figure 2. Activity-cycle period in years as a function of rotation period in days for stars showed by Saikia et al. 2018. The red symbols are activity cycles well determined, green symbols are stars with multiples activity cycles periods, and black symbols are activity cycles without activity-cycle determined. The circles denote Mount Wilson stars, and triangles represent HARPS stars.

could change from our time series and would be a significant result after 20 years of the seminal work of Baliunas et al. (1995).

The authors thanks to financial support from CAPES/CNPQ and DFTE/UFRN.

References

Wright, J. T. 2004, AJ, 128, 1273
Eddy, J. A. 1976, Science, 192, 1189
Boro Saikia, S., Marvin, C. J., Jeffers, S. V., et al. 2018, A&A, 616, A108
Arriagada, P. 2011, ApJ, 734, 70
Isaacson, H., & Fischer, D. 2010, ApJ, 725, 875
Gray, R. O., Corbally, C. J., Garrison, R. F., et al. 2006, AJ, 132, 161
Henry, T. J., Soderblom, D. R., Donahue, R. A., & Baliunas, S. L. 1996, AJ, 111
Hall, J. C., Henry, G. W., Lockwood, G. W., Skiff, B. A., & Saar, S. H. 2009, AJ, 138, 312
Lovis, C., Dumusque, X., Santos, N. C., et al. 2011, arXiv:1107.5325
Bonfils, X., Delfosse, X., Udry, S., et al. 2013, A&A, 549, A109
Duncan, D. K., Vaughan, A. H., Wilson, O. C., et al. 1991, ApJS, 76, 383
Baliunas, S. L., Donahue, R. A., Soon, W. H., et al. 1995, ApJ, 438, 269
Horne, J. H., & Baliunas, S. L. 1986, ApJ, 302, 757
Lubin, D., Tytler, D., & Kirkman, D. 2010, ApJ, 716, 766
Soubiran, C., Le Campion, J.-F., Brouillet, N., et al. 2016, A&A, 591, A118