I. Semester Report

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Title of the thesis: Near-infrared spectroscopy of eruptive young stars: new discoveries and long term follow-up observations

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1. Introducton:

The young stellar objects (YSO) harbor circumstellar disks. The accretion that takes place in the disc in charge of moving the material inward from the edges of the disc onto the star. The mechanism which drives the accretion is not clear, but angular momentum transport by magnetic fields, and/or internal friction, or viscosity, within the disk may play important roles. Eruptive young stars are a sub-set of YSOs which show brightenings >0.5 mag in optical and/or near-infrared photometry. These brightenings indicate an increase of the mass accretion rate. There are two main classifications of eruptive YSOs: FUors and EXors. FUors show bolometric luminosities of up to 300 $L_\odot$ during the outbursts around a hundred years. The EXors bolometric luminosities can reach up to a few tens of $L_\odot$ are recurrent with separations of a few years or decades. Among the newly discovered eruptive young stars, there are some that often show a combination of features form both classifications, e.g. a powerful but short lasting outbursts.

My project is to identify new eruptive young stars. To do this, I use measurements from the Gaia space telescope or the Zwicky Transient Facility, which have alerts programs that reports if there are sudden changes in the photometry of a star. Afterwards I will compile their spectral energy distribution to verify that an alerted star is a young stellar object. Following these steps, I will prepare follow-up optical and near-infrared observational proposals to obtain their spectra with the Very Large Telescope and the Nordic Optical Telescope. I will identify the spectral lines which are typical indicators of mass accretion rate (e.g. Hα, Paβ, Brγ), and estimate the mass accretion rate from the accretion luminosity. I will analyse the CO band heads (>2.29 µm), and of other lines (e.g. FeI, NaI and CaI) to estimate the geometry of the circumstellar disk, and I will search for indications of a P-Cygni line profile, an indicator of powerful winds, which is common in eruptive young stars. Finally, I will search for jets via [FeII] or H_2 emission lines. These high-velocity mass ejections can be related to the outbursts due to their relationship with accretion. Based on what we know today they are generated in connection with the star's magnetic field, and they could have an important role in the star formation on account of allowing accretion to proceed by removing angular momentum from the surrounding disk.

2. Description of research work carried out in current semester:

My semester's work is divided into two parts. My primary goal during this semester was to gain as much in-depth knowledge of the subject as possible and to master the basics by reading a number of papers on the topic of young eruptive stars and by discussing issues with my supervisor. The articles read include, Hartmann & Kenyon 1996[1], which is the basis for research on the FU Orionis stars, or summary articles such as Williams & Cieza 2011[2] and Hartmann et. al. 2016[3]. In addition, I have reviewed other sources on the formation and interpretation of spectral lines (e.g. Hartmann & Robert 1994[4]; John & William 2011[5]) emerging from the accretion of young eruptive stars and on the jets are by-product of accretion (e.g. Ray & Ferreia 2021[6]). I worked in an IDL software environment, but this semester I have also been tasked with learning the Python programming language and how to use it as easily as possible.

For the second part of my work this semester, the Gaia alert program reported a significant brightness change in the source Gaia20dsk on 2020.08.11. The average magnitude of the source in Gaia's G band, typically 19 mag. increased to 17.85 mag. During the semester I started a spectroscopic study of this source. The UV, optical, and IR data were obtained by the X-SHOOTER instrument of the ESO VLT telescope on 2022.06.12. The telluric corrected spectra were provided to me by my supervisor. The spectrum contains several accretion tracer lines in emission from the the Balmer (e.g. Hα), Paschen (e.g. Paβ), and Bracket (e.g. Brγ) series, as well as other Helium atomic lines and the the Calcium II triplets are also observed as tracer of the accretion. In addition, possible forbidden iron [FeII] emission lines may be present, which are tracers of bipolar jets. In the next step, the spectrum was corrected for extinction and the continuum was subtracted. Then, after determining the flux of the observed lines, I proceeded to the determination of the mass accretion rate using the method described in the paper by Alcalá et. al. 2017[7]. In the Figure 1 you can see an example for one of the line in the case of Hydrogen α. Firstly I used the 'line_flux' python function to determine the flux of the line within a wavelength range where are the edge of the line wings (red lines on Fig. 1.). This value was converted to luminosity knowing the distance of the star from Gaia data. After I calculated the accretion luminosity I used this value to determinate the mass accretion rate. I made a python code that computed all of these data for each one of the line, that I found in the spectrum, and are represented in the Alcalá et. al. 2017[7] paper. In the Figure 2, you can see the calculated mass accretion rate for all the identified emission lines. The aim is to publish an article from this source after the data have been fully processed, preferably by the summer.

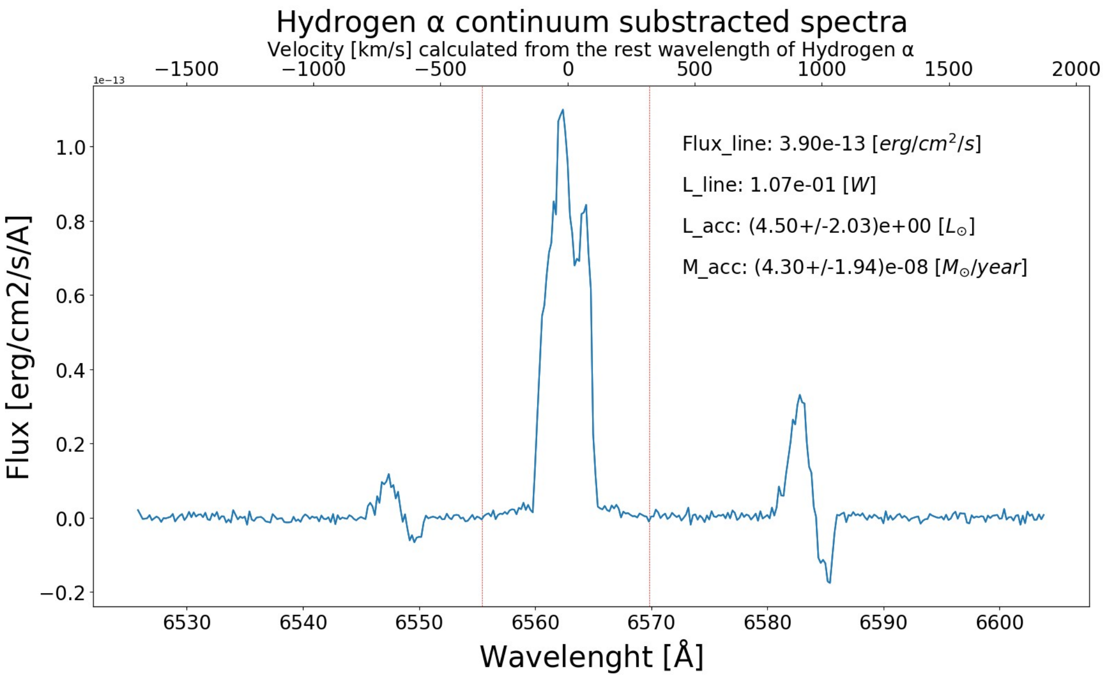

Fig. 1.: Hydrogen α continuum substracted spectra. As you can see in Section 2, I used the continuum substracted spectrum of each one line to determinate the mass accretion rate. The red lines are the range within I calculated the flux of the line. The calculated values in the upper right corner the follows from top to bottom: Flux_line: Flux of the line; L_line: Luminosity of the line; L_acc: Accretion luminosity from the line; M_acc: Mass accretion rate from the line.

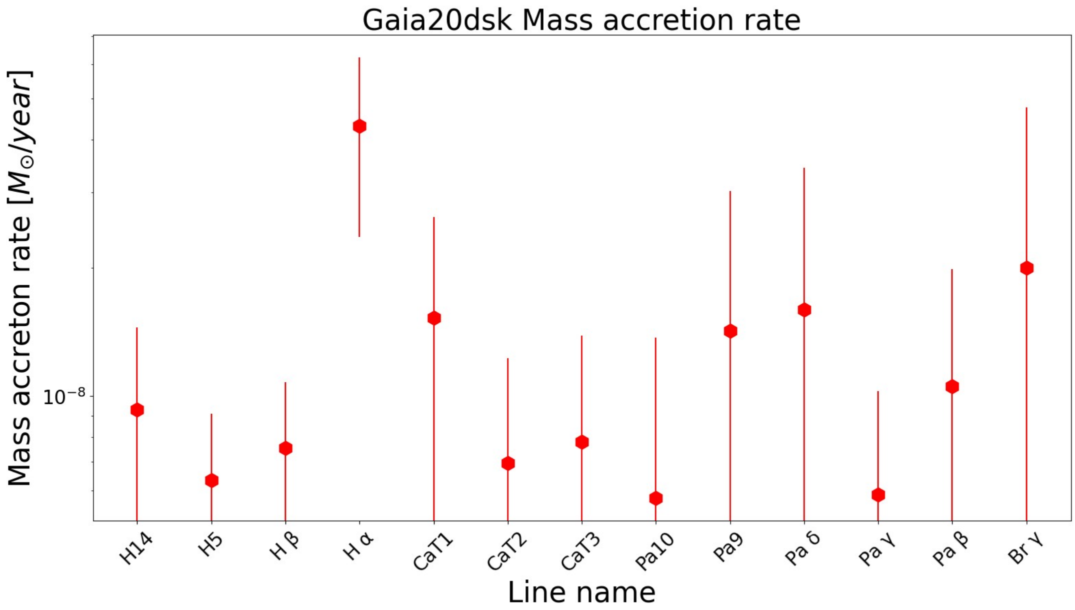

Fig. 2.: Gaia20dsk mass accretion rate. The mass accretion rates for some of the identified emission lines. These are calculated from the lines flux as I mentioned in the Section 2.. The lines are in order of wavelength. Hx lines are part of the Balmer series (where x = 14, 5, β, α), Pay lines are part of the Paschen series (where y = 10, 9, δ, γ, β), and the Brγ is part of the Bracket series. The numbers after the letters associated to the upper energy level of the transmission in the series. CaT1, CaT2, CaT3 are the CalciumII triplets.

3. Studies in current semester:

Exoplanetary research (FIZ/5/040)

Chapters from the theory and observations of multiple stellar and planetary systems I. (FIZ/5/041)

References:

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[7] Alcalá, J. M.; Manara, C. F.; Natta, A. et. al.; 2017, X-shooter spectroscopy of young stellar objects in Lupus. Accretion properties of class II and transitional objects; Astronomy & Astrophysics, Volume 600, id.A20, pp.