Observational and Theoretical study of the inner region of HH 30

Phd thesis

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Abstract

The theory of low mass young stellar formation establish that they form because of the gravitational contraction of the molecular cloud. The cocoons, where stars will form, rotate. This rotation causes the formation of a keplerian disk around the star. The disk is composed of gas and dust. Observationally, in the optical and near infrared wavelengths, is very easy to see sources with edge-on disks, because they are optically thick and veil the light from the star. The images of edge-on disks consist of the scattered starlight by the dust in the disk in the infrared. On the other hand, in the optical wavelengths, is more complicated to observe sources with a disk that is parallel to the plane of the sky because we are looking directly at the star.

HH 30 is a classical T Tauri star that has been extensively studied during the last two decades. Hubble Space Telescope (HST) observations reveal the existence of a variability in the external disk illumination, this is the result of the starlight scattered by the dust in the disk. In this study our goal is to determine the period or periods of the variability or better constrain the time scale of a period. For example, photometric studies of the outer disk variability in HH 30 indicate that this periods must be less than 6 months, some other suggest that they must be less than 300 days. It is important to note that depending on the period scale, the variability should related with the star or with the disk. The mechanisms related with short periods are connected with the photosphere or regions close to the star, however, mechanisms linked with long periods are related to asymmetries in the inner parts of the accretion disk. Previous photometric studies of the outer disk variability in HH 30 indicate that this periods must be less than 6 months. It is important to note that the period may indicate whether the variability should related with the star or with the disk. The mechanisms related with short periods are connected with the photosphere or regions close to the star. However, mechanisms linked with long periods are likely to be asymmetries in the inner parts of the accretion disk. To fulfill our goal, we made an observational and theoretical analysis of HH 30. At first we obtained direct photopolarimetric images with a the 84 cm of National Observatory of Mexico located at San Pedro Martir (OAN-SPM). We obtained images of the object in four different positions of the analyzing prism. This different positions allow us to determine the normalized Stokes parameters q and u, which reveal variability. We tried to measure the photomeric variability, howeverthis was not periodic.

A method used to determine periods is called the Lomb-Scargle normalized periodogram, which calculates a power spectral density, that depends on the observable quantities like the magnitude and the observation time. We applied this method to three

sets of photometric data, but we do not find a variability period of the source. It drives us to look for a different way to mitigate short time correlations effects, which consist of binning the sets of data in a 1/8 of the period that we want to test. We calculated the Lomb-Scargle periodogram of the polarimetric data and we found a variability period of 7.5 days. The level of significance of this polarimetric period was high whereas the significance of the same period in the photometry was lower. However, we found that both periods are consistent, and have a particular characteristic, that the sin fit of photometric variability is displaced by a quarter of the sin fit of polarimetric variability. That means that the photometric component shows a minimum or a maximum when the polarimetric component is null.

Different mechanisms have been suggested to explain the variable asymmetry, including mechanisms that are directly linked to the star and mechanisms that are not. In the first place, in the photosphere there are hot spots that are produced by the shock of material from the disk. In the other hand, they are mechanisms that are related with asymmetries in the inner disk or a close companion like a brown dwarf or a big planet. Our result that sin fits of photometric and polarimetric variability are displaced by a quarter in between are in agreement to the mechanisms related directly to the star, like the hot spots. A model proposed to explain the variability is the lighthouse model. This model consists of a beam or a shadow from the central source that has an azimuthal movement that sweep the full disk. The mechanism proposed for the lighthouse model are, the none symmetric accretion produced by hot spots, and clumps or gaps in the disk. Unfortunately, however we determine a variability period we were not able to distinguish between the mechanisms but our observations provide quantitative constrains of the period and in the photometric and polarimetric modulation amplitude.

We show that one of the mechanisms proposed to explain the variability for HH 30 can reproduce our polarimetric observations. One model include a low mass (2 solar masses) star with hot spots in its photosphere and a flared optically thick disk round the source. We obtained the intensity of HH 30 with the radiative transfer code of Watson y Henney (2001) that includes polarization. We used the parameters of Wood y Whitney (1998) to calculate the polarimetric variability. The important parameters of that model for the source are mass, radius and temperature, mass, size, inclination, flaring, the exponent of the density power-law, size, altitude and brightness of the hot spots, the phase function for scattering of Henyey-Greenstein, albedo and opacity for the dust. We discussed these parameters and suggest a model that can reproduce our polarimetric observations.