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THE PROPERTIES OF ACCRETION DISKS OF HERBIG AE/BE STARS AND THEIR INFLUENCE ON THE SURFACE AND THE INSIDE

P.S. THÉ
Astronomical Institute "Anton Pannekoek", University of Amsterdam, Kruislaan 403, 1098 SJ Amsterdam, The Netherlands

ABSTRACT In this paper we review the observations which lead to the believe that intermediate mass pre-main sequence Herbig Ae/Be stars are surrounded by accretion disks. A discussion is given of their properties and their contributions to surface and inside phenomena of the central stars.

INTRODUCTION

It is now well accepted that Herbig Ae/Be stars (HAEBESs) are very young intermediate mass pre-main sequence objects; age between 10^5 and 10^6 years. Their masses range from 2 to 10 $M_\odot$. Their luminosities are as high as $10^3 L_\odot$, placing them high above the main sequence. It is also well-known that HAEBESs are surrounded by an extended gaseous atmosphere, with dust at the outer regions. Recent observations have shown definitely that this circumstellar atmosphere is confined to an extended disk with a dust ring at the outside. We will give a short review of these observations and will summarize the properties of the accretion disks.

THE ACCRETION DISK

It has been shown by different authors that in the disks of HAEBESs matter is accreting towards the central star. Therefore, it makes sense to name them accretion disks.

Polarization surveys

The results of polarization surveys of matter in the surrounding of HAEBESs by several authors (e.g. Ward-Thompson et al. 1985; Aspin et al. 1985) have been theoretically explained successfully as the effect of multiple scatterting by small dust particles in flattened accretion disks surrounding the objects (Bastien and Ménard 1988).

The blueing effect

The so-called blueing effect, or colour reversal, found for several HAEBESs (Bibo and Thé 1991, and references therein) can be explained by the assumption that it is caused by the dominating blue radiation of the circumstellar disk, when the radiation of the central star is severely dimmed by a dust cloud orbiting in the outer parts of the disk. Such a phenomenon will take place only when we view the disk edge-on or nearly edge-on.

Anti-correlation between brightness variation and polarization changes

The perfect anti-correlation between a deep photometric brightness change and the large increase in linear polarization, can only be explained theoretically by assuming that it is caused by multiple scattering by small dust particles located in the outer regions of the accretion disk, when the stellar light is blocked by a cloud of dust (Grinin. et al. 1991).

Infrared excess

The observed spectral energy distributions of HAEBESs exhibit strong excess emission in the infrared of which the spectral shapes are similar to those found for strong emission-line T Tauri stars. The presene of disks around these T Tauri stars is well established from the success of detailed disk models in reproducing the excess emission (Beckwith et al. 1990), and from the observed forbidden line profiles (Strom et al. 1990). Therefore, the assumption that for HAEBESs the IR-excess is also due to a circumstellar disk is reasonable.

Millimeter continuum observations

Recent mm-continuum observations of several HAEBESs also strengthen the believe that these stars are surrounded by a disk-like extended atmosphere (Strom et al. 1990). From the observed excess mm-continuum fluxes one can derive that the circumstellar envelope should contain masses ranging from about 0.01 to 2 solar masses. If this is distributed spherically symmetric around the central star, it should not be visible at the visual wavelength region. The reason is that then the optical depth will be very large. However, by assuming that the material is confined to a disk, one can obtain the same mm-continuum fluxes, and preserve an optically thin line of sight to the star for almost all viewing angles.

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THE INFLUENCE ON THE SURFACE

From the above observational facts it is clear that HAEBESs are most probably surrounded by an accretion disk. Such a disk surrounding very young still contracting stars, which have not yet ignite thermo-nuclear reactions in their interior, must have much influence on the processes taking place on the surface and in the inside of the central star.

Some properties of accretion disks

From observations by different authors the following data of accretion disks have been collected. Dimension: $10^3 - 10^4$ AU; Mass: 0.5 - 4.0 $M_\odot$; $\dot{M}_{acc}$: 0.2 - 30 $10^{-6} M_\odot/yr$. From these data it is clear that the dimension and the mass of HAEBESs are at least an order of magnitude higher than those of T Tauri stars.

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Ly-alpha emission

In a recent paper Blondel et al. (1992) describe their discovery of Ly-alpha emission in the three Herbig Ae stars: HR 5999 (A5,7 IIIe), HD 163296 (A2,3 Ve) and HD 104237 (A4,5 Ve). After making a study of the possible mechanisms which can supply the radiative energy for the emission regions, where these lines are formed, they come to the conclusion that accretion energy from a disk is large enough for this purpose. They conclude that the Ly-alpha emission in the spectra of the Herbig Ae and later type PMS stars is best explained by recombination of infalling and accreting matter.

Photometric "pulse shaped" variability

The variable Herbig Ae star HR 5999 has been observed photometrically during about 8 years under the ESO Long Term Photometry of Variables in the Strömgren photometric system. Recently the large amount of data of this star has been analysed together with those found in the litterature. This analysis reveals the fact that the large photometric variability of this star can be well-represented by a series of bursts or pulses. The mean energy (10^{41} erg) of these bursts are generally too high to be explained by passive circumstellar disturbances. Although, changes in extinction, due to dust clouds, are certainly responsible for many of the irregular variations, there must certainly be energetic phenomena closer to the star, which are really the cause of the pulse-shaped variations in brightness. Such phenomena can be caused by a sudden discrete large accretion from the disk surrounding the star. For such a phenomenon to be possible a large amount of angular momentum should be carried from the internal regions of the disk outwards. The mechanism for such a transport of angular momentum is unknown.

Reversed P Cygni profiles of Hα and MgII resonance lines

Recently a closer study have been made of the UV spectral variability of emission lines in the Herbig Ae star HR 5999, based on recemt IUE high- and low-dispersion observations taken with the long wavelength camera (LWP) and the short wavelength camera (SWP). A dramatic change in the structure of the MgII h and k lines along with some continuum flux excesses, especially at the short end of the SWP camera, have been found. Previous LWP high-dispersion observations of HR 5999 obtained since 1979 and prior to 1990 showed some variability within the same profile structure (a type III P Cygni profile for the MgII lines), however, the last four LWP images taken in September 7, 1990, September 18, 1991 and March 16-18, 1992, present reverse P Cygni profiles in the MgII lines, indicative of some active episodic accretion which can also be detected in the additional red wings of the various FeII and MnII absorption lines.

INFLUENCE ON THE INSIDE; DEUTERIUM SHELL BURNING

Recently Palla and Stahler (1992) finished their study of the influence of the accretion flow of matter in the evolution of intermediate-mass PMS objects. They have computed three evolutionary sequences with accretion rates: 10^{-5}, 3×10^{-5} and 10^{-4} $M_{\odot}/yr$. They also consider the effect of accretion onto the

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star through a circumstellar disk, by employing photospheric boundary conditions. In all cases, the protostar exhibits the same evolutionary phases: full convection, appearance of a radiative barrier, shell ignition of deuterium, rapid swelling , gravitational contraction, and central hydrogen ignition. It is obvious that accretion of matter through a disk is of the same importance as the accretion directly onto the star. The stellar birthline they can construct from the mass-radius relations shows good agreement with the observed distribution of PMS stars in the H-R diagram.

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