Investigating Inner Gaseous Disks Around Herbig Be Stars By Modeling Emission Lines

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Background

Herbig Ae/Be (HAeBe) stars are pre-main sequence A or B type stars that are surrounded by a disk producing strong optical emission lines, particularly lines of Balmer series, as well as an infrared excess, attributed to the hot or cool circumstellar dust. Likely remnants of the star formation phase, these disks are thought to be centrifugally supported, and Keplerian rotation is expected and observed (e.g. Mannings et al, 1997).

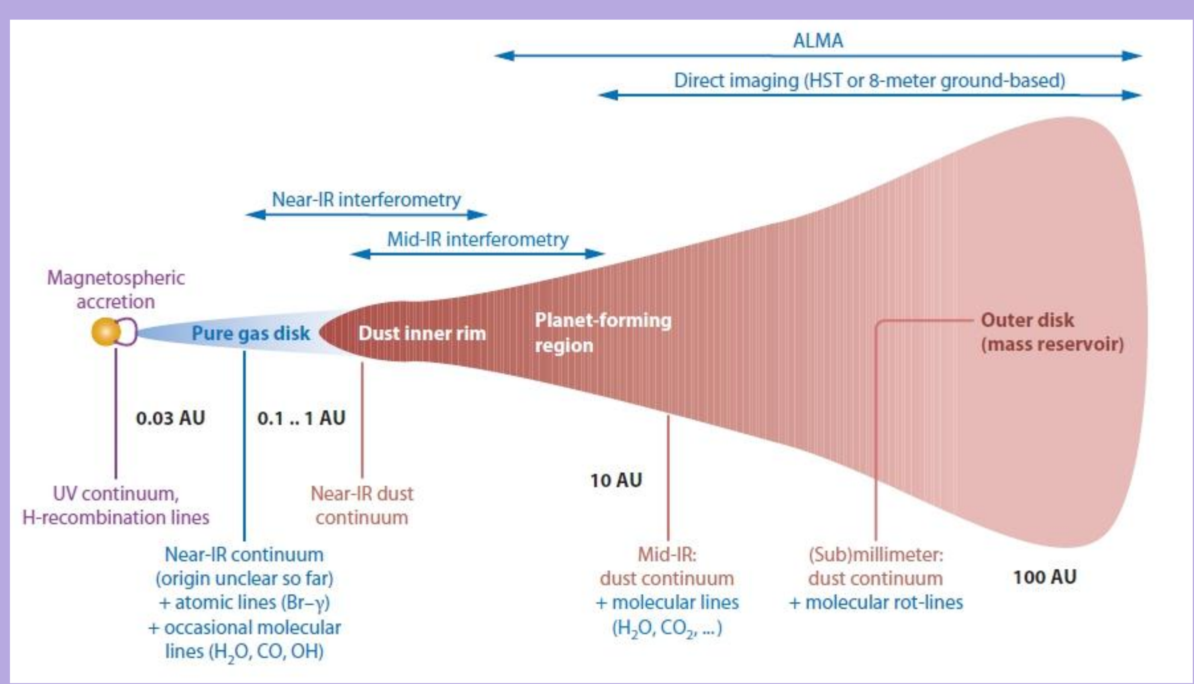

Figure 1: The disk structure around YSOs with the distance scale from Dullemond & Monnier (2010). The gaseous disk close to the star can be studied using Optical and NIR spectral lines.

Motivation

The region close to the stellar surface experiences intense radiation from the central star and very high temperatures are expected. As dust evaporates at temperatures of ~1800K, regions closer to the stellar surface will be surrounded by hot gas, which produce optical emission lines that can be observed in the spectra (Figure 2). In addition, as the disk flares further away from the star, the top and bottom layers of the disk experience the direct stellar radiation, and thus have gaseous layers. The temperature and density structure, as well as the mass of this gaseous regions, are currently unknown. Classical Be stars are known to have gaseous disks which are well studied. Using the models that have been successfully tested for Classical Be stars, we are trying to see if these models can be adapted to study gaseous disks around Herbig Be (HBe) stars.

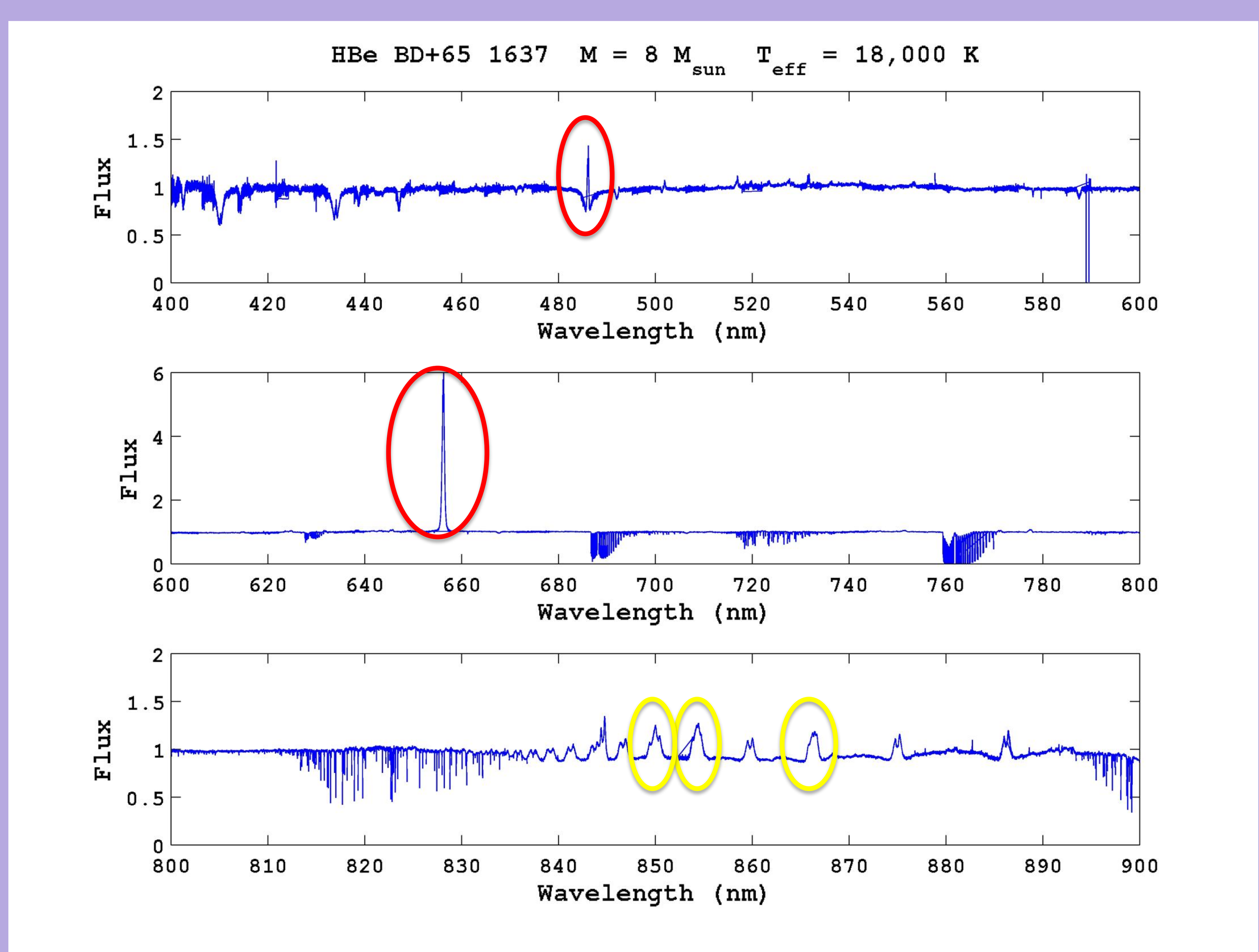

Figure 2: The observed spectra for BD+65 1637 (Alecian et al 2013), a B2e type star. The spectrum shows many emission lines, for example Balmer lines such as Hα and Hβ (circled in red) and Calcium Triplet lines (circled in yellow).

Star	Spectral Type	Effective Temperature (K)	Radius ($R_\odot$)	Mass ($M_\odot$)	Distance (pc)
MWC 1080	B0e	30000	7.3	17.4	2300
HD 216629	B2ne	19000	-	-	720
HD 76534	B2ne	18000	7.7	9.0	870
BD+65 1637	B2e	18000	6.7	8.11	1250

Table 1: The stellar parameters of the objects for which we are modeling observational data (Alecian et al., 2013).

Modeling & Observations

The non-LTE radiative transfer codes, BEDISK (Sigut & Jones 2007) and BERAY (Sigut 2011), are used to compute the thermal structure of the disk, and the line profiles and SEDs. The disk is assumed to be in radiative equilibrium with a user-specified density structure, following Keplerian rotation. The vertical structure of the disk is assumed to follow hydrostatic equilibrium. The circumstellar disk is photoionized by the central star's radiation, and the thermal structure of the disk is found by balancing the heating and cooling processes for the nine most abundant elements over many ionization stages. The temperature structure and level populations computed by BEDISK are input to BERAY, which then solves the equation of radiative transfer. We currently have observational data for four stars (Table 1) which were obtained using the ESPaDOnS high-resolution spectropolarimeter at CFHT. The spectral data ranges from 3700 Å to 10,500 Å with spectral resolution of 65000. Alecian et al (2013) provides for more details on the observations.

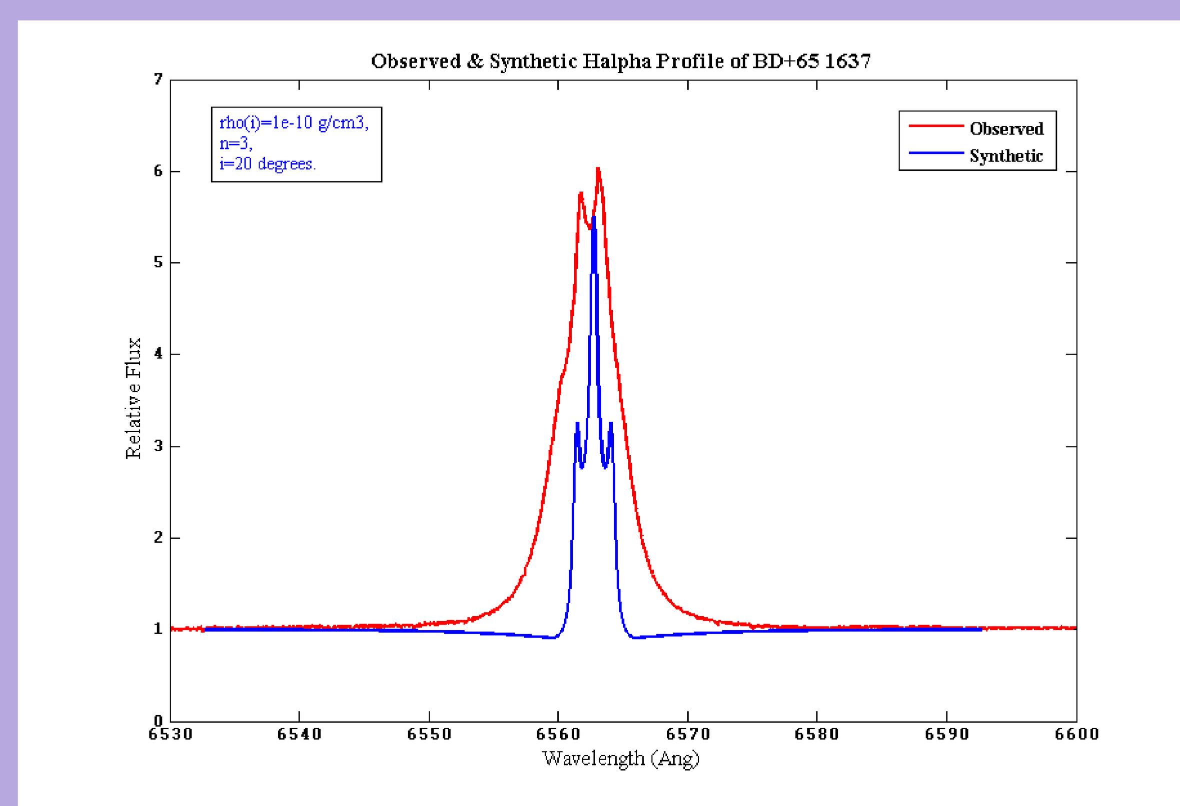

Figure 3: Hα profile for BD+651637 modeled using BERAY. The red is the observed spectrum while blue is the synthetic spectrum. This synthetic line profile is for a 40 stellar radii circumstellar disk, an inner edge density of 10^{-10} g/cm^3 when viewed at an inclination of 20 degrees. This is at a very preliminary stage of modeling where we are exploring the parameter space for approximate parameter values.

Preliminary Work

BEDISK/BERAY have successfully been able to reproduce the spectra for gaseous disks around Classical Be stars (e.g. Sigut & Jones, 2007; Halonen et al., 2008) and can be adapted to study the disks of HBe stars. We are currently modeling two HBe stars (MWC 1080 & BD+65 1637) by exploring the disk density parameter space which has been tested for Classical Be stars to see if HAeBe stars lie in or close to the parameter space. For the current models, we have experimented with the inner rim densities of 10^{-9} to 10^{-12} g/cm^3 and power law density index from 2 to 3.5. The star+disk system is seen at two inclination angles, 20 and 60 degrees. The outer radius of the circumstellar disk was kept constant at 40 stellar radii through all the models. An example of a spectrum one such model for BD+65 1637, is illustrated above (Figure 3). The density and temperature structure for the same model for BD+65 1637 can be seen in Figures 4. Further experimenting with different parameter values is required to match the large intensities seen in the emission lines.

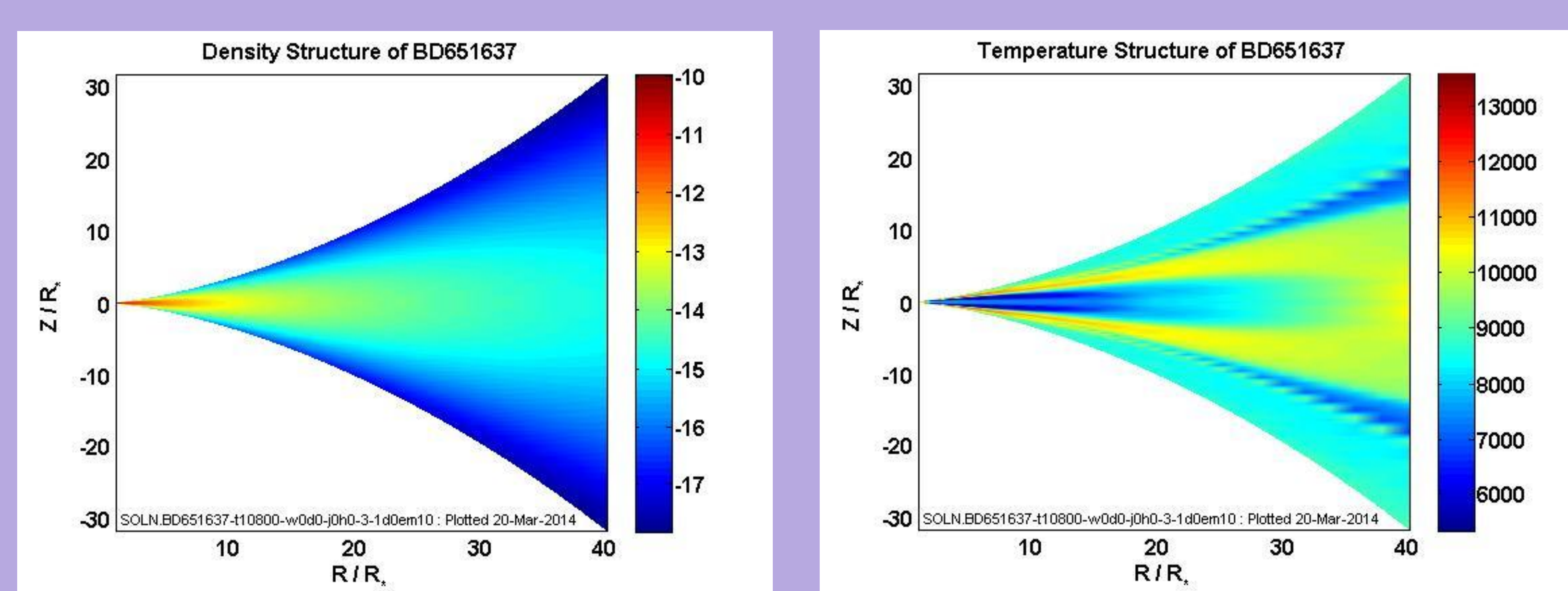

Figure 4: The density and thermal structure of the disk for BD+65 1637 modeled using BEDISK for a 40 stellar radii circumstellar disk, an inner edge density of 10^{-10} g/cm^3 and power law density structure index of 3 (same values as used to synthesize line profile in Figure 3).

References

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