PROFILES OF EMISSION LINES FROM ROTATING DISKS

D.A. Brown
Dearborn Observatory
Northwestern University
Evanston, Illinois 60201, U.S.A.

Profiles of emission lines contain key information on the dynamics, the physical condition, and the geometry of the cool envelopes of Be stars. Despite much observational evidence, doubts persist about the rotating, equatorial ring model first proposed by Struve (1931) to explain the gross features of the profiles and later developed by Huang (1972) in the two-dimensional, transparent limit. The basic rotating model is now reconsidered and profile formation studied from a physical point of view.

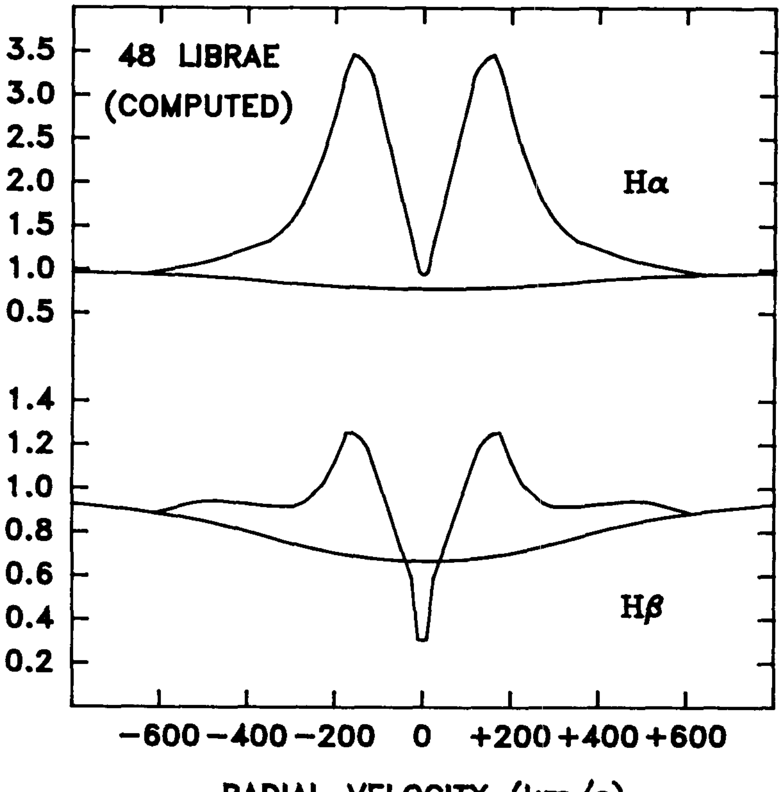
The excitation structure of a disk rotating around a B star in circular, Keplerian orbits is computed by means of a new, iterative approach. The approach takes full account of both stellar and diffuse radiation at line and continuum frequencies and makes no assumptions about the optical properties of the disk. It is applied to an isothermal model with parameters based on observations of the shell star 48 Librae. The resulting disk is highly ionized. The hydrogen levels are populated by a modified Rosseland cycle; photoionization from the second principal level of hydrogen precedes recombination to higher levels and subsequent cascades. The $H\alpha$ and $H\beta$ source functions are relatively constant with position in the disk.

Balmer emission line profiles are presented in Figure 1. In shape, they reflect the velocity field, the optical condition, and the geometry of the disk. The double-peaked structure is a consequence of disk rotation, with the separation of peaks dependent on the size of the disk. An extensive disk ranging from the stellar surface to 15 stellar radii is needed to match observed profiles (Underhill, 1954). The linear rise from line center to peak results from large optical depths in the lines; at small optical depths the profile at line center tends to be rounded. The slope of the emission wing is sensitive to disk geometry. A highly flattened geometry is needed to reproduce the shape of the observed $H\alpha$ wing. In the opaque limit, when the line source function is constant and rotation is the line-broadening mechanism, the emergent

https://doi.org/10.1017/S0252921100116525 Published online by Cambridge University Press

intensity at a given frequency in the line is proportional to the projected area of the corresponding equi-velocity surface. If the disk flares out with distance from the star, the slope from peak to wing will be steep and the profile narrow. If the disk is flat, the slope will be gradual and the profile broad. Specifically, the wing from a circular, cylindrical disk of inclination $i = 90^o$ goes as $1/v^2$ with a cutoff term that is proportional to v. This function seems to agree well with the average Hα wing observed in 48 Librae. Details will be submitted to the Astrophysical Journal.

Figure 1. Computed Balmer emission profiles for 48 Librae assuming $i=90^o$.



REFERENCES

Huang, S.-S. (1972). Profiles of emission lines in Be stars. Ap.J., 171, 549-64.

Struve, O. (1931). On the origin of bright lines in spectra of stars of class B. Ap.J., 73, 94-103.

Underhill, A. (1954). The spectrum of the shell star 48 Librae. Publ. D.A.O., 9, no. 12, 363-97.

https://doi.org/10.1017/S0252921100116525 Published online by Cambridge University Press

DISCUSSION FOLLOWING BROWN

Hoflich:

Is the fact that your source function is constant on Hα a result of the fact that these lines are optically thick and you assume constant temperature? I think, yes.

Brown:

I agree that the source function is influenced by the temperature, but would like to make two points. First, my Hα and Hα source functions are not strictly constant but actually vary by about 50% through the middle portion of the disk. Second, while one could include an equation of radiative equilibrium and obtain a self-consistent solution for the temperature and the hydrogen level populations, it might not have any relation to reality due to neglect of heating and cooling processes involving heavier elements and neglect of non-radiative energy input.

Buscombe:

The calculated profile you show agrees very well with my high-resolution observation of Hα in the spectrum of o Aquarii (Buscombe 1969).

Brown:

It would be interesting to analyze the shape of the wing from o Agr.

Collins:

What was the optical depth in electron scattering for your model, and what was the Balmer line optical depth (typically)?

Brown:

From inner to outer radial boundary, the optical depth in electron scattering was about 10^{-1} and the optical depth in the Balmer lines was of order 10^3.

Gies:

How would radial outflow affect the appearance of the line profiles?

Brown:

I would expect an asymmetry in the peak strengths, with $V/R < 1$.

Snow:

Some concern has been expressed at this conference over the disk model for Be stars. As far as I can tell, the primary objection is that the disk model does not explain time variability. It would be very interesting to apply your modeling technique to a star whose Hα profile varies, to see what changes in the disk geometry would be required in order to cause the observed line profile variations. Perhaps knowing what geometrical changes are required would help theorists in trying to understand why the changes occur.

Brown:

The precessing, elliptical disk scenario discussed by Struve, McLaughlin, and Huang would probably produce the long period V/R variations.