Numerical simulation of plasma outflow from a fast rotating star

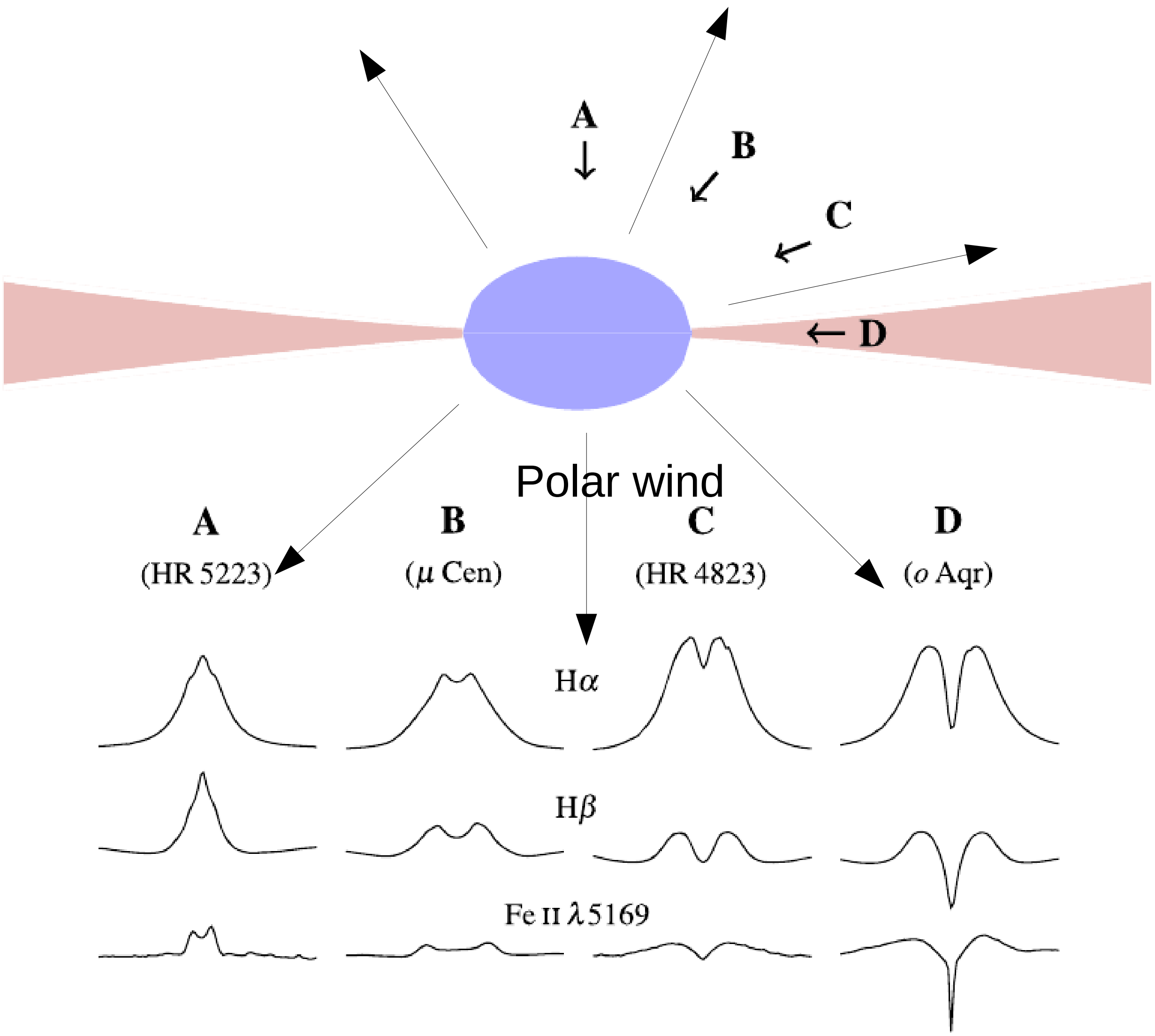
S.V.Bogovalov, V.A. Timofeev

National Research Nuclear University, MEPHI, Moscow, Russia

Motivation of the work.

- Interaction of the pulsar wind with the stellar wind from Be star defines the light curve in all the electromagnetic spectrum.
- The most impressive are GeV flares from PSR1259-63/LS 2883
- We have very unrelaible information about physics of the stellar wind from Be star, its parameters and structure of the flow.

Our understanding of observations of Be stars



Models for explanation of the disk-like outflow

- Wind compressed disk
- Decretion disk

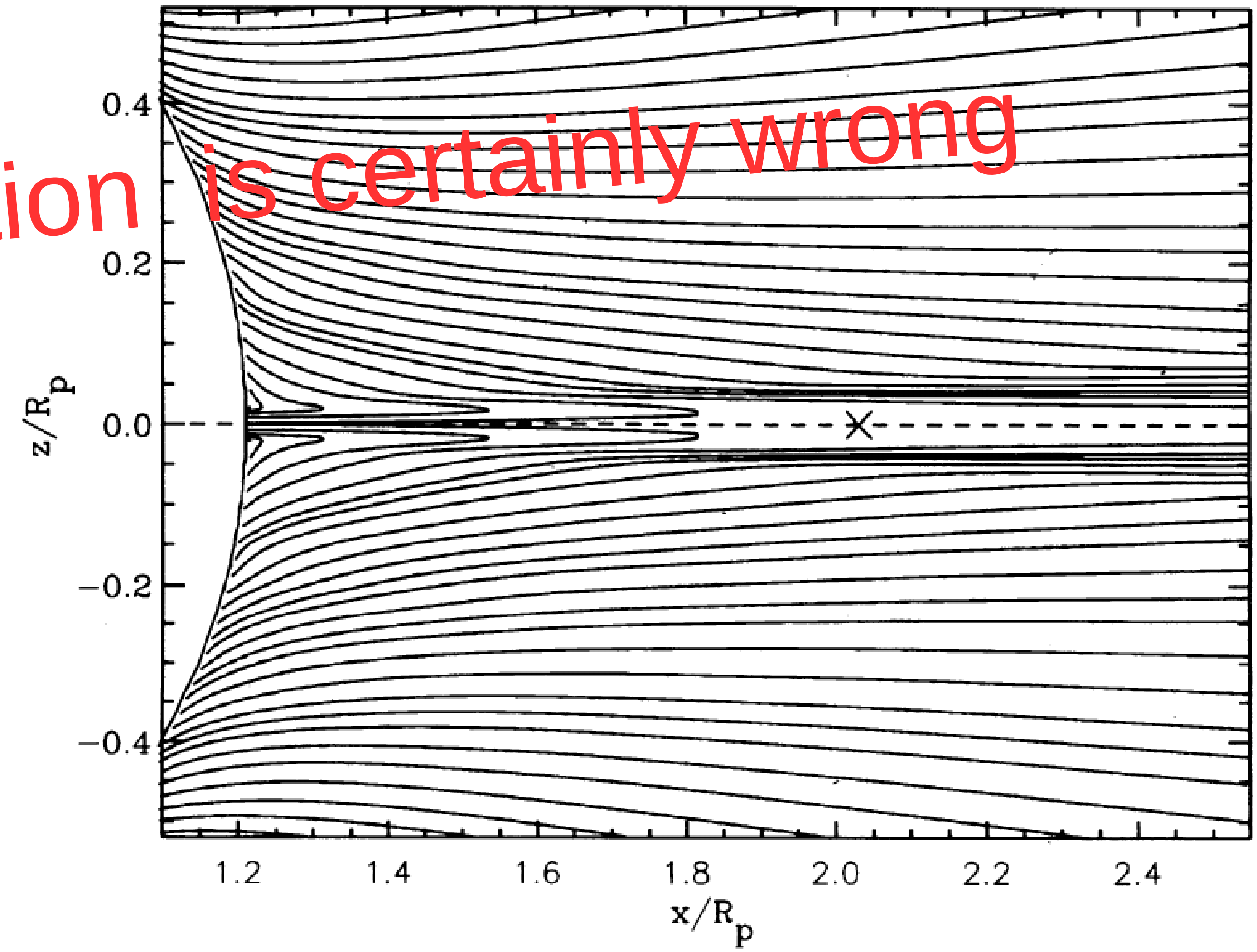
Wind compressed disk model

THE ASTROPHYSICAL JOURNAL, 424:887–904, 1994 April 1

TWO-DIMENSIONAL HYDRODYNAMICAL SIMULATIONS OF WIND-COMPRESSED DISKS AROUND RAPIDLY ROTATING B STARS

STANLEY P. OWOCKI AND STEVEN R. CRANMER
Bartol Research Institute, University of Delaware, Newark, DE 19716
AND
JOHN M. BLONDIN

This solution is certainly wrong



Idea of decretion disk

The same like accretion α-disk but with outflow instead of accretion

This is geometrically thin but optically thick Keplerian disk.

The models were discriminated observationally

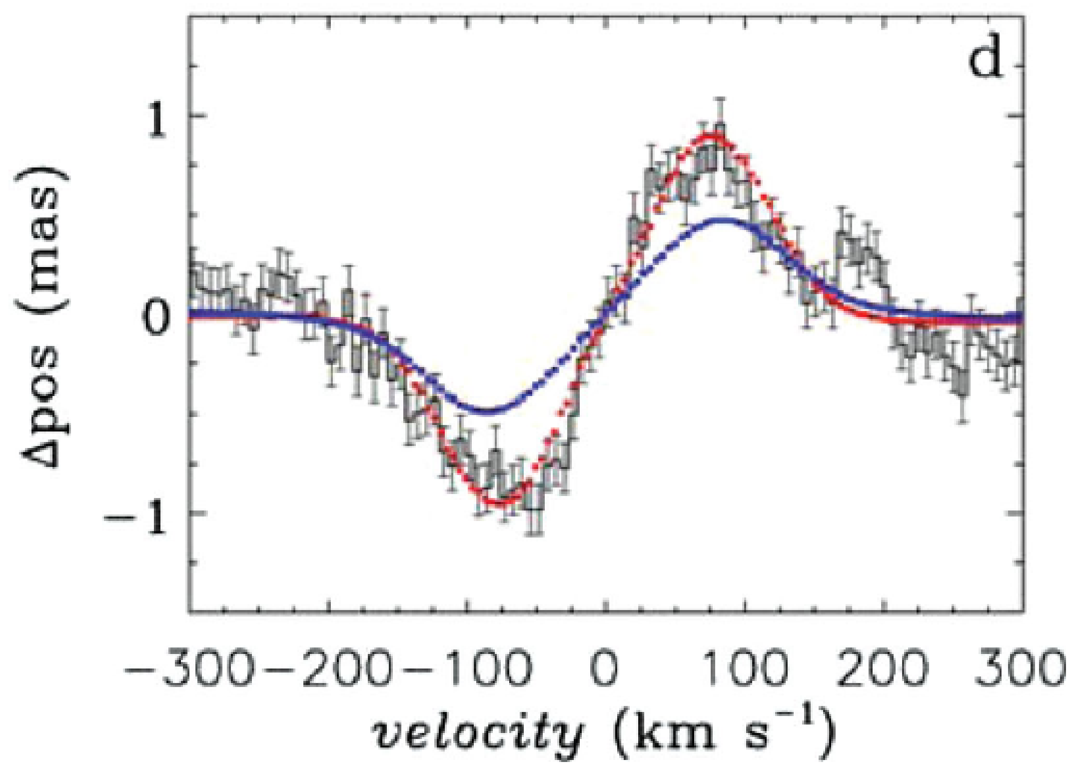
Mon. Not. R. Astron. Soc. **423,** L11–L15 (2012)

doi:10.1111/j.1745-3933.2012.01241.x

Probing the properties of Be star discs with spectroastrometry and NLTE radiative transfer modelling: β CMi★

H. E. Wheelwright,[1,2]† J. E. Bjorkman,[3] R. D. Oudmaijer,[2] A. C. Carciofi,[4]
K. S. Bjorkman[3] and J. M. Porter[5]‡

The decretion model win!
But questions remain.



The basic unsolved problems

1. Angular momentum transfer from the slowly rotating star to the faster rotating inner edge of the accretion disk (only speculations: waves, magnetic field).

2. The mass rate outflow and its longitudinal distribution remains uncertain

3. More other questions.

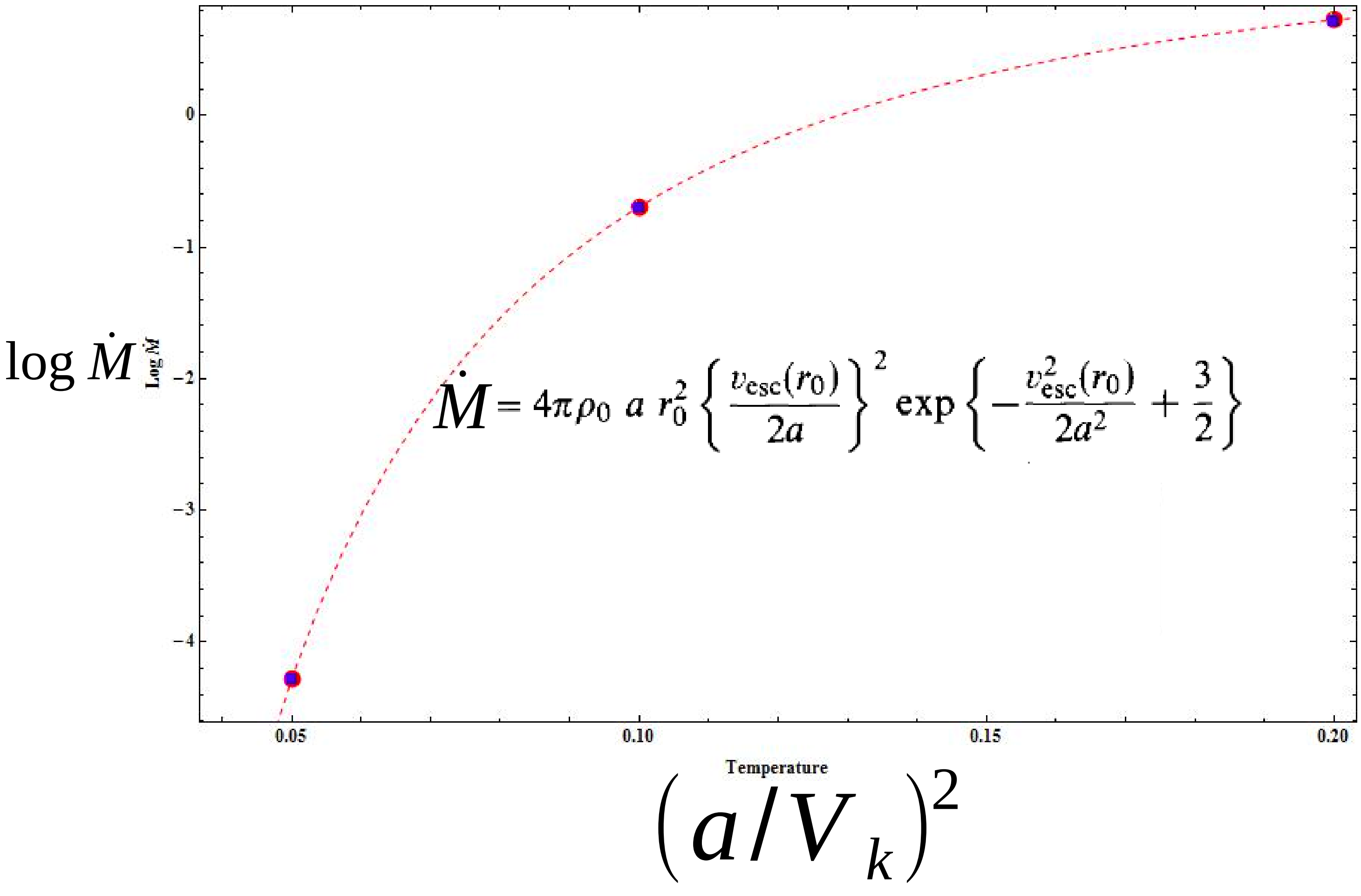
The objectives of the work

- Calculate accurately the structure of the wind from fast rotating luminous star. Isothermal wind from nonmagnetized star.
- To obtain dependence of the outflow rate from Be stars on the mass, temperature, and velocity of rotation;
- To obtain structure of the disk like outflow and its characteristics;
- To calculate observable characteristics of the outflow for comparison with observations;

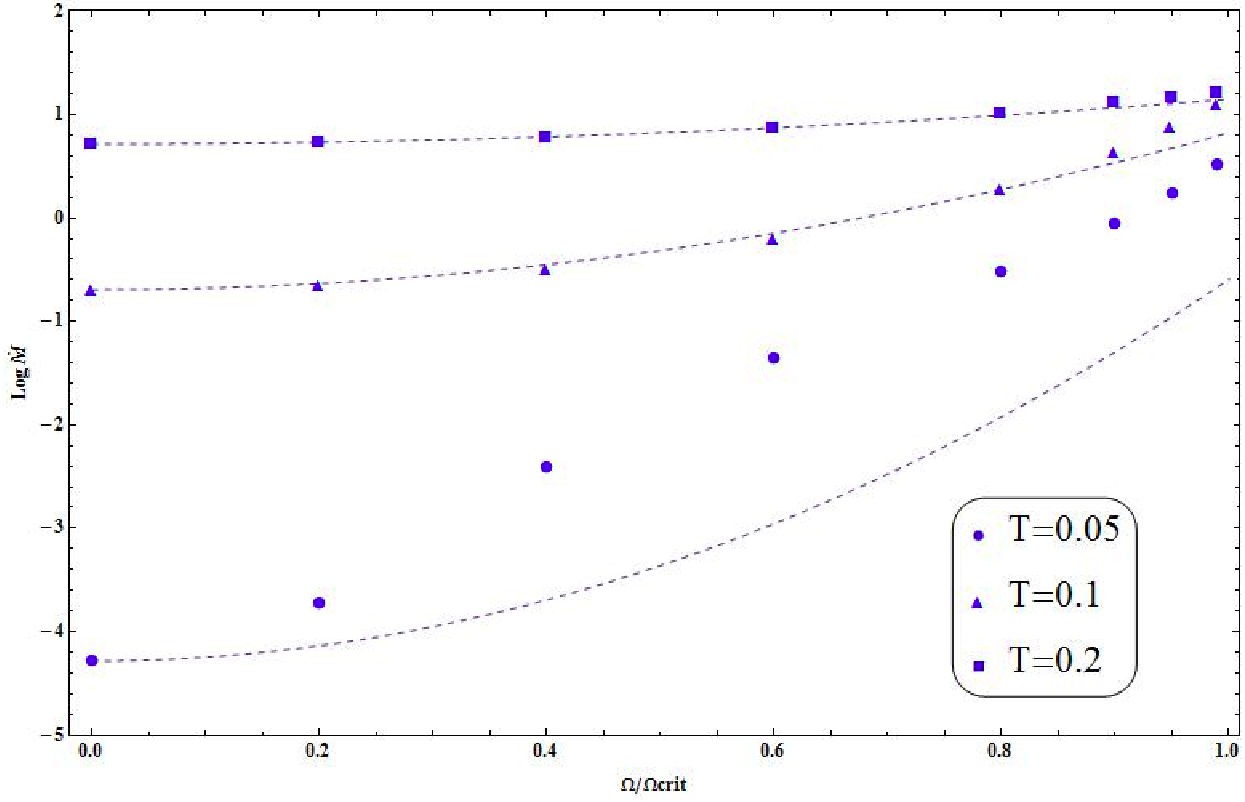
What is new in our model?

- Nonortogonal mesh. The nonspherical surface of the constant pressure at the star surface is reproduced with high accuracy;
- Turbulence (k-e model);
- The radiation force depends on the direction of motion of the wind;
- The conventional numerical code is modified to provide correct results at the high pressure gradients;

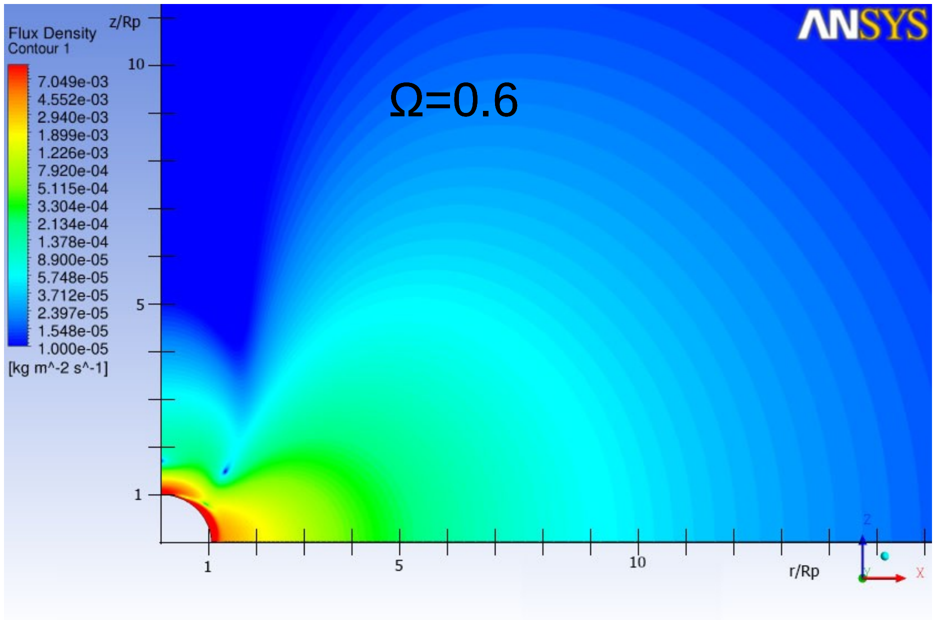
At first step we neglect radiation force
Rate of outflow vs temperature(Ω=0)

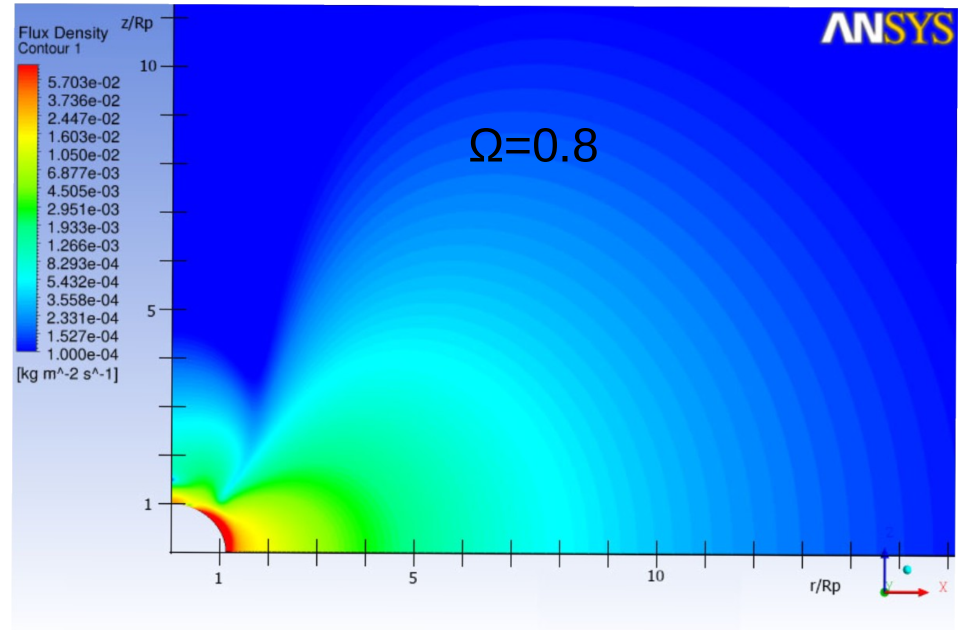


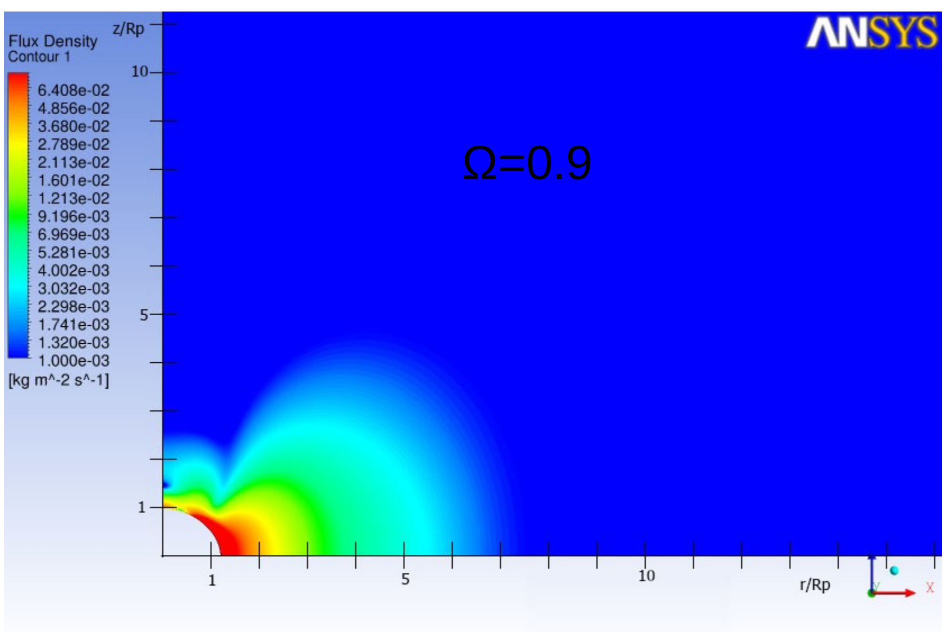
Dependence of the outflow rate on the angular velocity

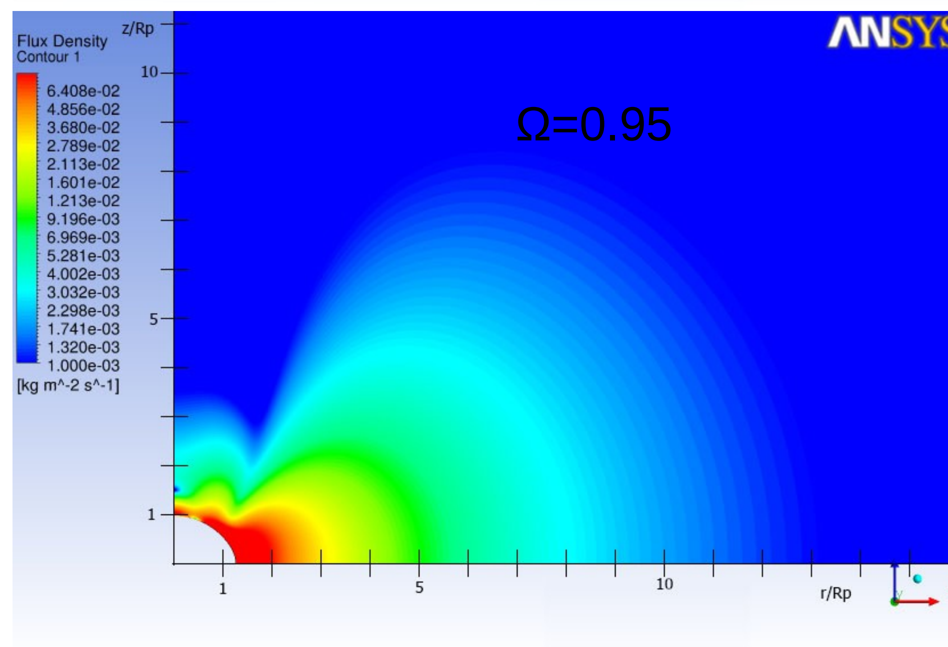


Distribution of the mass flux density

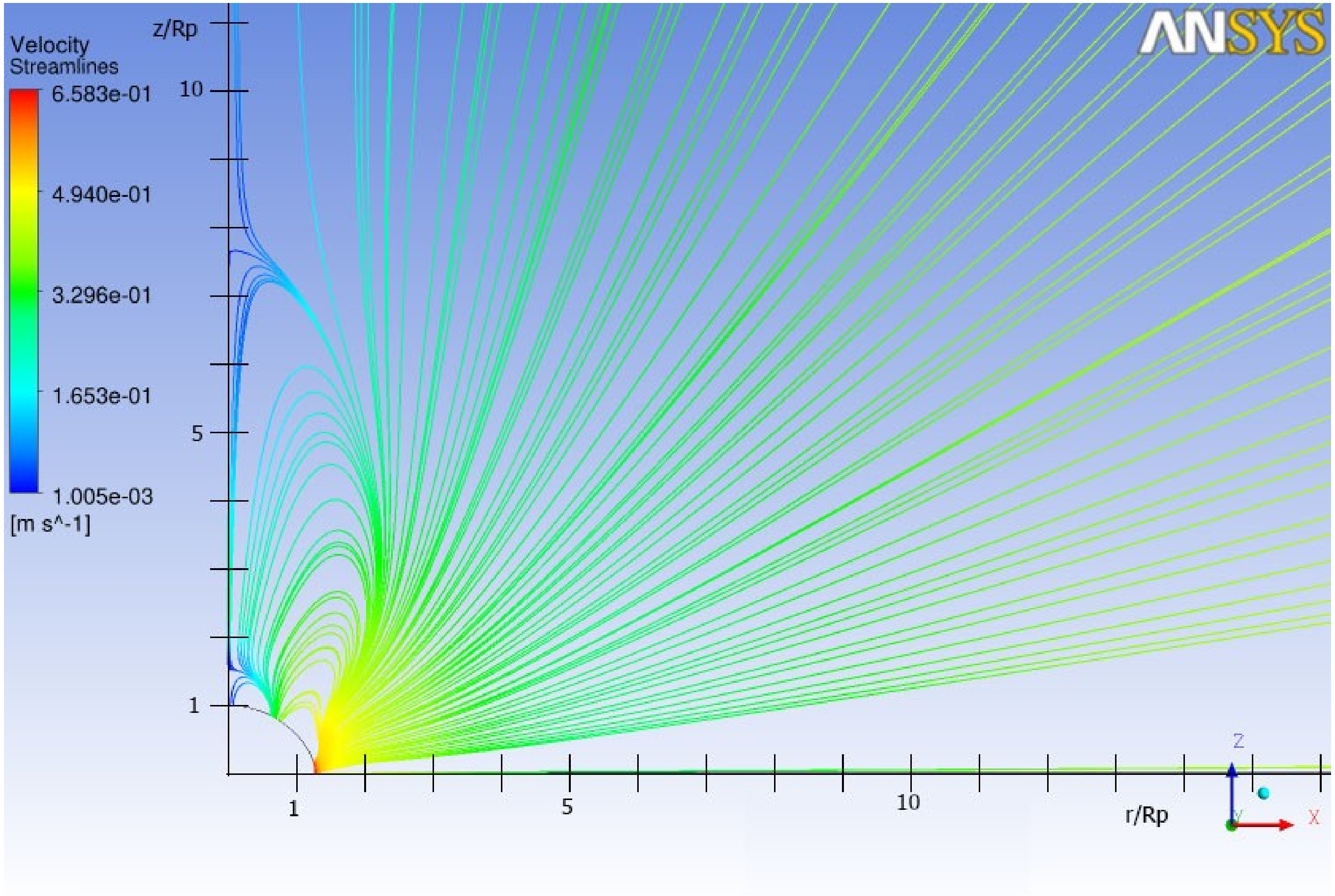




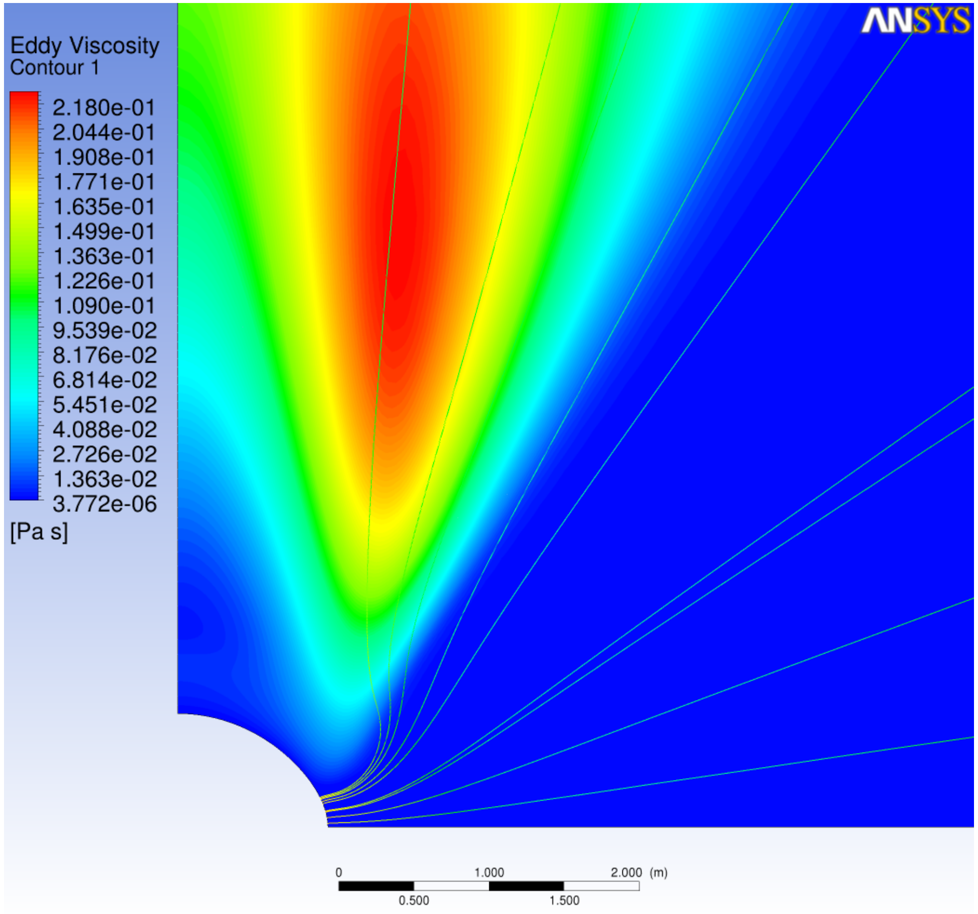




Streamlines at Ω=0.95



Eddy viscosity



Conclusion

1. In contrast to results of WCD model the outflow basically occurs at the equatorial region.

2. The radiation force will not change this result

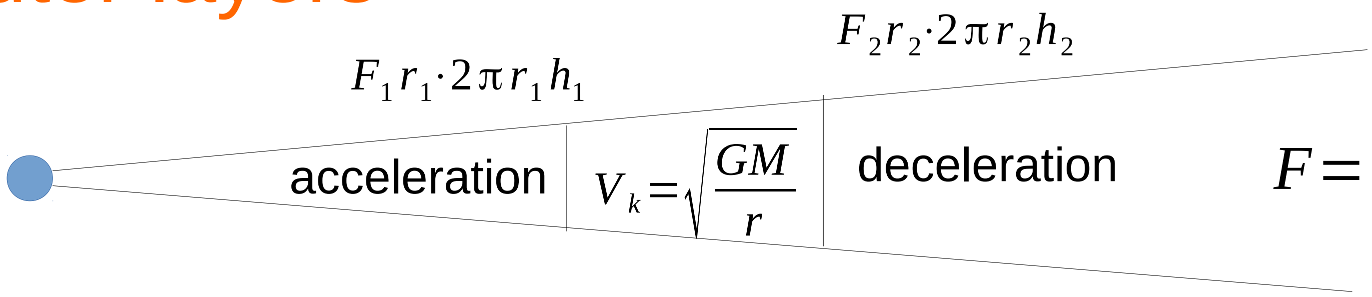
3. A part of the wind fall down back to the stellar surface at the polar region.

4. Thermal pressure destroys the formation of the disk. Apparently reduction of the temperature of the stellar surface and radiation pressure will result into formation of the disk-like outflow.

5. We will obtain in any way realistic rate of the mass outflow from Be stars.

Physics of α-disks

The accretion occurs due to the angular momentum transfer from inner layers to the outer layers



$$F = \mu r \frac{d\Omega}{dr}$$

$$\frac{d \Delta m r V_k}{dt} = -F_2 r_2 \cdot 2\pi r_2 h_2 + F_1 r_1 \cdot 2\pi r_1 h_1$$

The only important assumption about viscosity

$$\mu = \rho * v_t * l \qquad v_t = \alpha * v_s$$