The helium line at 5876 angstrem in the spectrum of the Herbig Ae/Be star HD37806 as an indicator of magnetospheric accretion

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We present some results of the spectroscopic investigation of HD 37806 connected with a search for signatures of a magnetosphere of this object

Introduction

Models of magnetically driven accretion reproduce many observational properties of young (PMS) low-mass T Tauri stars with strong magnetic fields (~ 10^3 G). Applicability of these models to more massive PMS Herbig Ae/Be stars is not so obvious because their magnetic fields are an order of magnitude less (~10^2 G).

Nevertheless, several Herbig Ae/Be stars show observational signatures, indicating that accretion flows in these stars are guided from the circumstellar disk to the stellar surface by a magnetic field of the star.

The scenario of magnetospheric accreion predicts appearance of inhomogeneous accretion streams inside the magnetosphere and high-temperature zones on the stellar surface in the regions of its contact with accretion flows. These inhomogeneities rotate rigidly with the star and can modulate the spectroscopic and photometric parameters of the object with a period equal to one or half the rotation period Prot of the star depending on the number of rotating infomogeneities.

In reality, a diagnostics of magnetospheres is based on a search for periodicity of different observational parameters on a time scale comparable with expected Prot. As a rule, it is from several to few tens of days.

Examples of such investigations are published in:

HD 101412: Schöller et al., 2016, A&A, 592, 50
HD 259431: Pogodin, et al., ASP Conf.Ser., 518, 138
HD 104237: Järvinen, et al., MNRAS, 486, 5499

In this report we propose a method allowing to discover signatures of magnetosphere during much shorter time intervals (~ one night). It is based on a study of short-term variability of the spectral line HeI 5876, which can be an informative indicator of the accretion process onto the star.

The object of our study is an isolated Herbig star

HD37806 (MWC 120, B8e-A2e)

It was included in the list of Herbig Ae/Be stars after detection of the far-IR excess (Oudmaijer et al., 1992, A&AS, 96, 625)

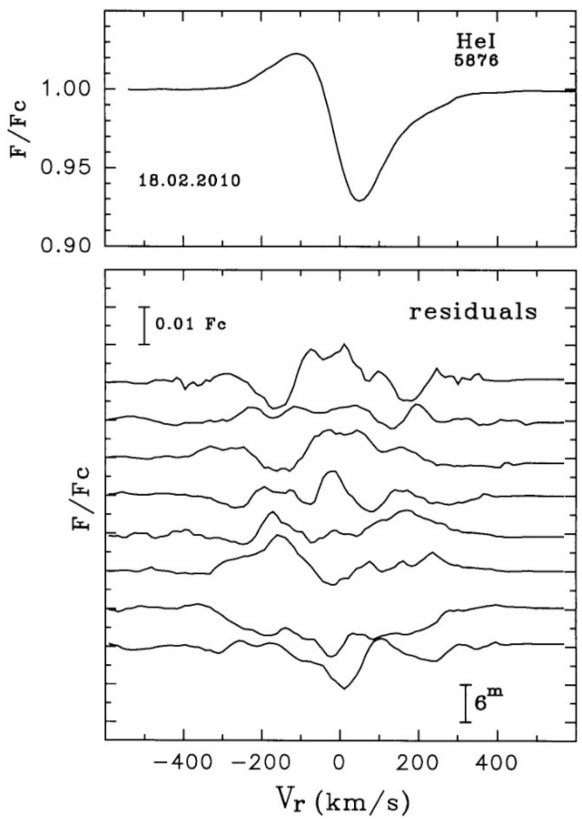
- V sin i = 120 ± 30 km/s (Böhm & Catala, 1995, A&A, 301, 155)
- Vsystem = +47 ± 21 km/s (Alecian et al., 2013, MNRAS, 429, 1001)

Observations

Crimean AO
2.6-m Shajn telescope
coude spectrograph ASP-14
R = 20000
near HeI 5876
19 spectra in Nov. 8-11, 2012

OAH SPM (Ensenada, Mexico)
2.1-m telescope
echelle spectrograph REOSC
R = 17000
near HeI 5876
8 spectra on Feb.18, 2010

The spectral line HeI 5876 is forming in the high-temperature zone near the stellar surface in the region of interaction of the star with the accretion disk. Its profile looks as an inverse-Pcyg with absorption component originating in the accretion flow near the line of sight. The velocity of the red edge of the absorption indicates the maximum velocity of the flow just before its contact with the stellar surface.

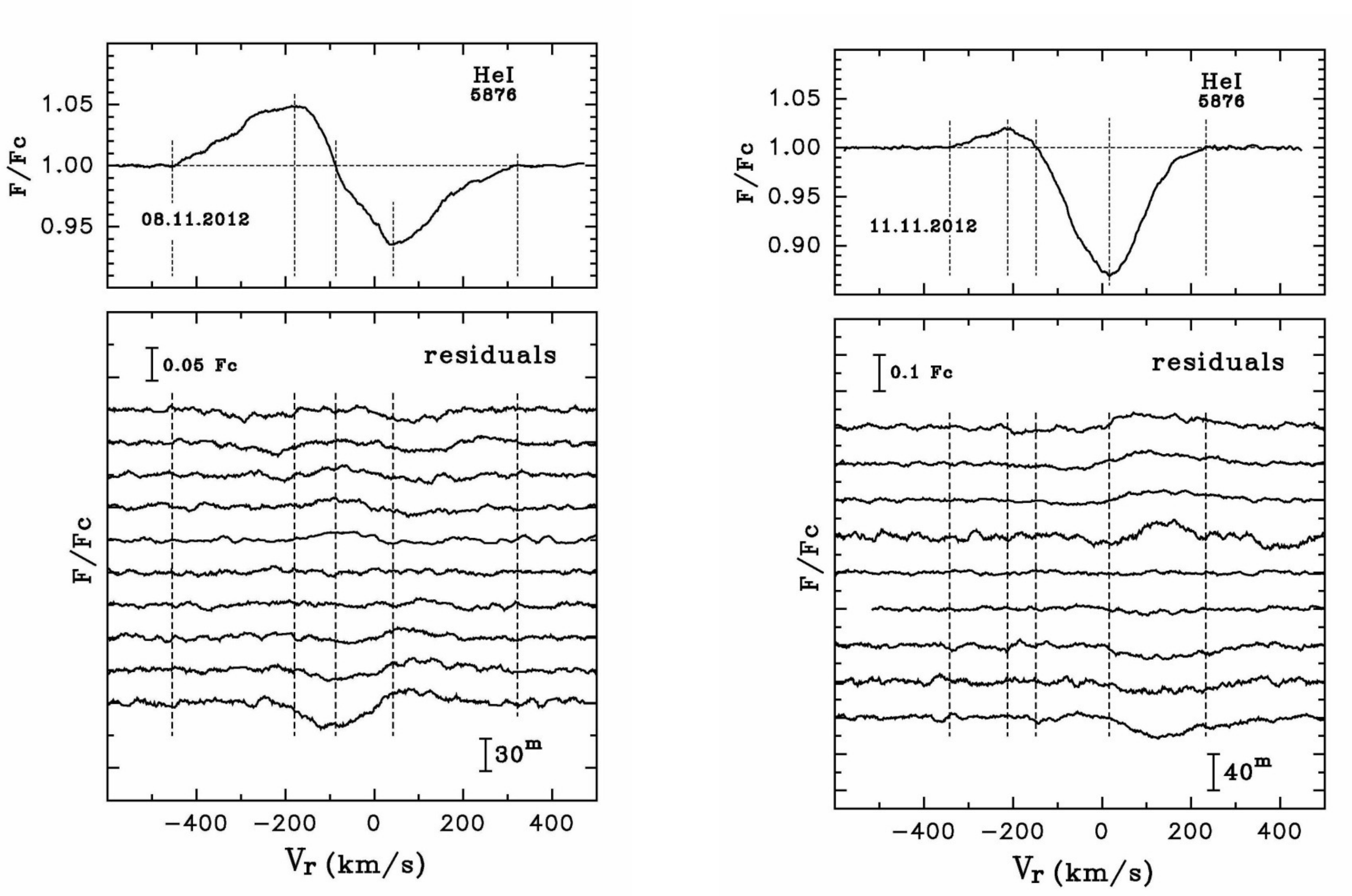


The figure illustrates the mean profile of the line obtained on Feb.18, 2010 in OAN SPM and the series of individual residual profiles constructed relative to the mean profile.

The residuals demonstrate no significant variability. It is an expected result because the duration of observational series is too short (~ 40^m).

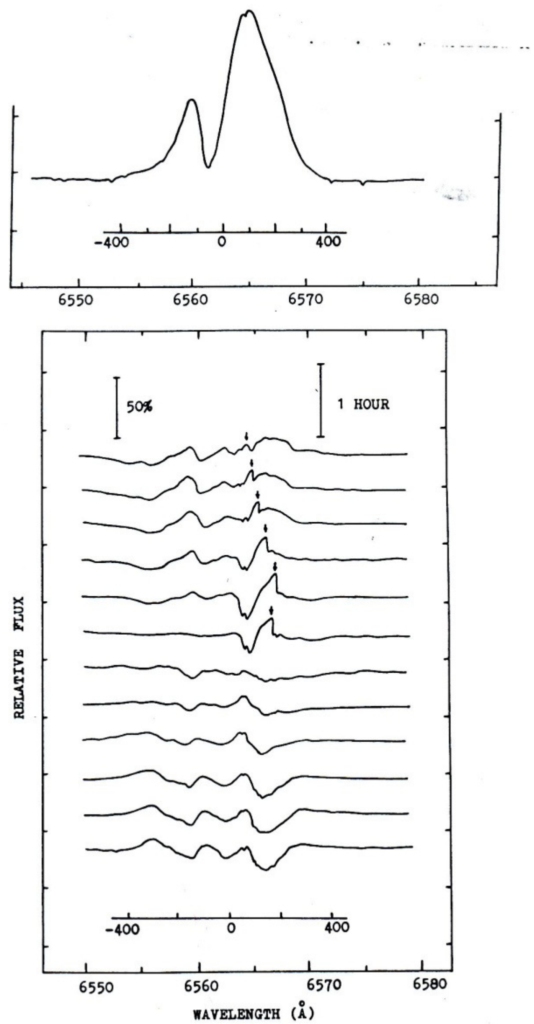
But the absorption component of the mean profile is very extended. Its red edge achieves +400 km/s. So large velocity of the accretion flow can be reached only if the accretion takes place in the free fall regime inside the magnetosphere.

So, this result can evidence in favour of the presence of magnetosphere in HD 37806.



These figures illustrate spectra obtained in Crimean AO during 2 nights. The observational series are longer and the short-term variability is observed in a form of standing waves on the residuals in the region of the red absorption component.

To interpret this phenomenon we used the analogous phenomenon observed in the line profiles with the signs of stellar wind.



Jul.27, 1992, CAT, ESO

This figure is taken from Pogodin, 1994, A&A, 282, 141 and relates to the Herbig Ae star HD 163296 and its Hα line.

The short-term variability is seen in the residuals in the form of a) a standing wave in the region of the blue PCyg-absorption b) a running wave in the central part of the profile.

Similar character of variability is often observed in some other Herbig Ae/Be stars:

AB Aur (Beskrovnaya et al , 1995, A&A, 298, 585)

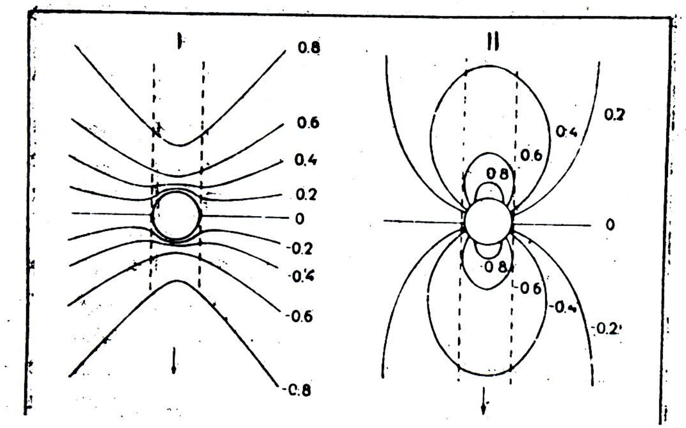
HD 31648 (Beskrovnaya & Pogodin, 2004, 414, 955)

Model interpretation of the appearance of standing intensity waves of on residual spectra in the region of the blueshifted PCyg-absorption using the methods described **by Pogodin, 1986, Astrophysics, 24, 279** has shown that these features form if the **surfaces of equal radial velocity (SERVs)** are orthogonal to the line of sight when it intersects rotating outflowing streams.

Such SERVs orientation is typical for winds with different kinematics.

Below we present fragments of figures from several old papers:

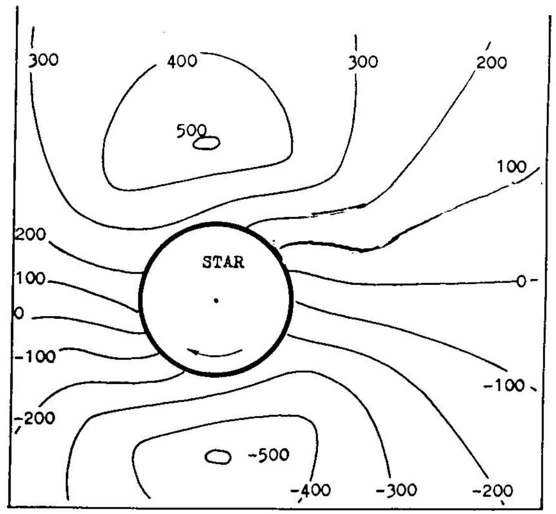
Grinin, 1984, Astrophysics, 20, 190



a **b**

The observer is at the bottom

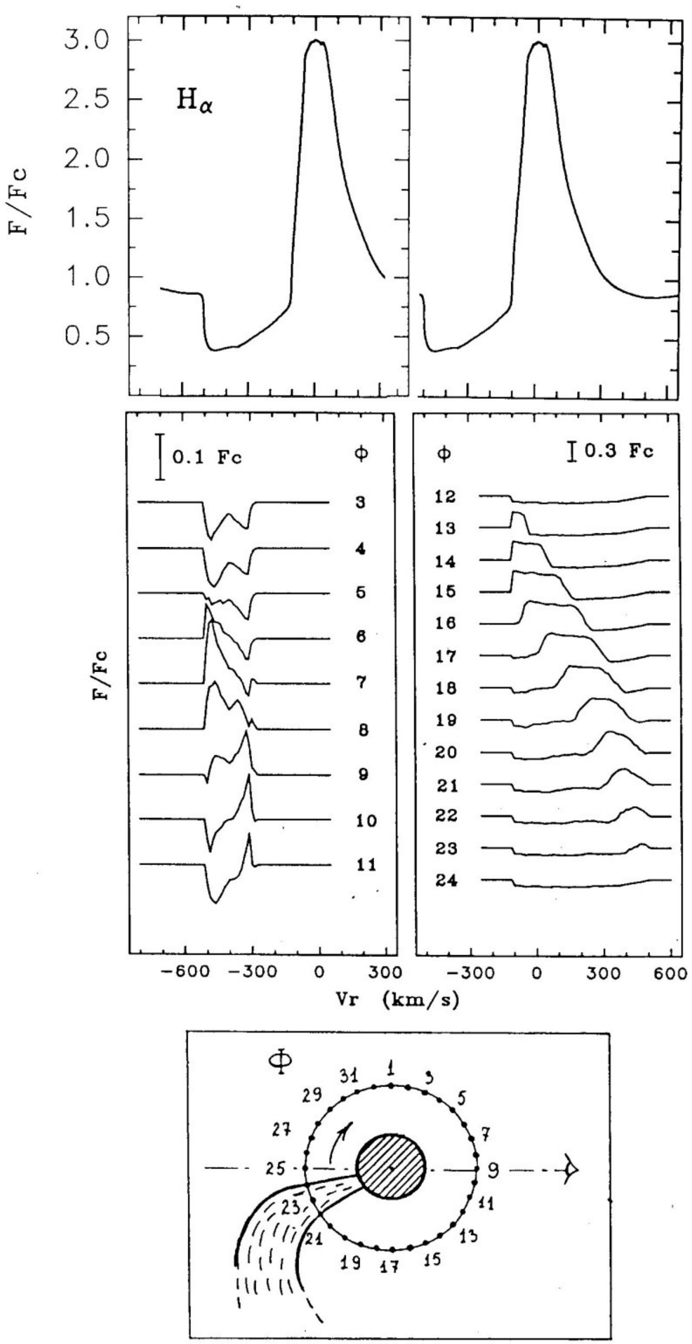
Pogodin, 1994, A&A, 282, 141



c

←SERVs

Wind kinematics: outflow moves with a) acceleration, b) deceleration
c) acceleration if r<Rm, deceleration if r>Rm + rotation

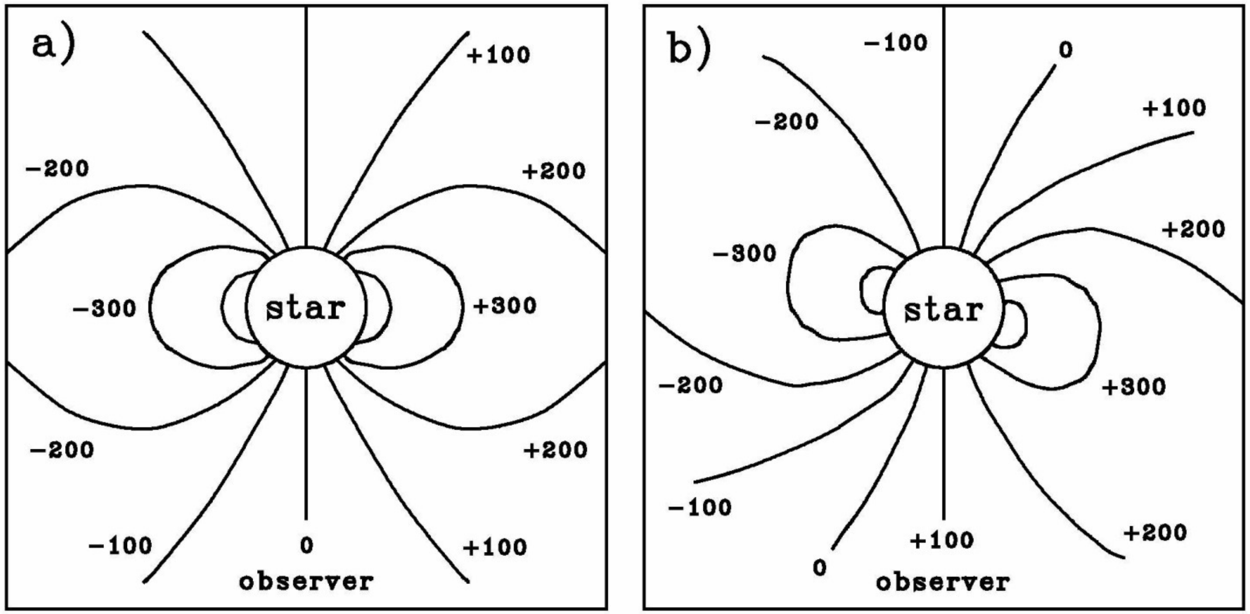


An example of **model calculations** of the profiles forming in the wind containing a rotating stream at different phases of its rotation.

We can see, that when the rotating outflowng stream moves near the line of sight (Φ from 3 to 11) the standing waves on the residuals are observed, and when it is far from the line of sight (Φ from 12 to 24) - the waves are running.

The parameters of this particular model are presented in Pogodin et al., 2019, Astrophysics, 62, 18

We can assume that the standing intensity waves on the residuals in the region of the red absorption component of the HeI 5876 line are originated similarly to those observed in the blueshifted PCyg absorption components of lines forming in the winds. But the local streams rotate not in outflowing but in accretion gaseous flows.



a
Keplerian accretion disk

b
the same disk + accretion with Vr = 100 km/s

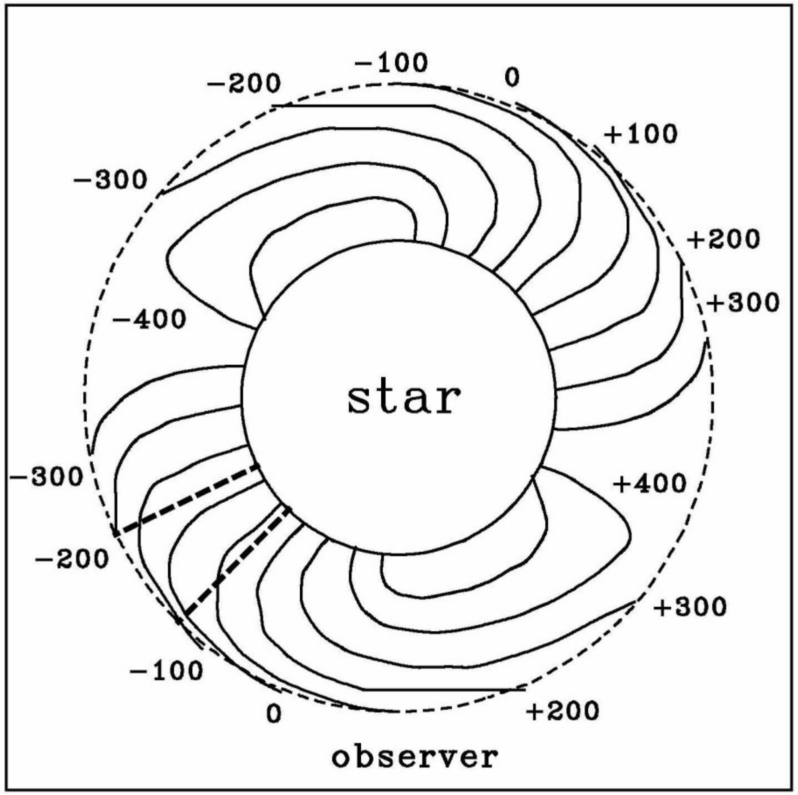
But:

SERVs near the line of sight are not orthogonal to it.

No standing waves on the residuals can be seen

The situation is different if we assume that accretion takes place in the magnetospheric regime.

In this case the gas inside the magnetosphere has a specific kinematics. Guided by the magnetic field accretion streams rotate rigidly with the star and the gas moves toward the star in the free fall regime.



We consider a simple case when the disk is oriented “edge-on” and the magnetic axis lies in the disk plane.

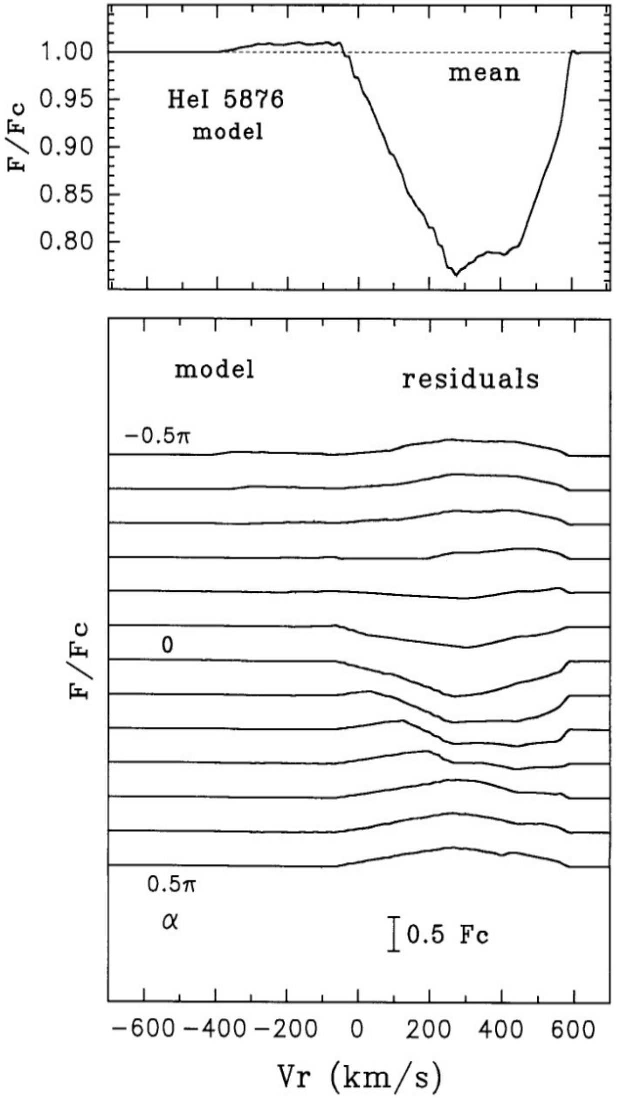
The accretion flows are concentrated inside two streams directed toward the magnetic poles (one of them is shown in the figure).

In this case the SERVs near the line of sight is oriented orthogonally to this line.

So the appearance of standing waves on the residuals in the region of the red absorption can be expected.

Results of our model calculations confirm our conclusion.
We used the model corresponding to our case described on the previous slide.

Kinematical parameters of this model are given in
Pogodin et al., 2019, Astrophysics, 62, 18



It is a simple two-dimension model with:

a) Source function in the helium line
B = 0.1 I star (intensity of stellar continuum)
b) The accretion gas is optically thick in the line ($\tau >> 1$)
c) The angle between the accretion stream and the line of sight "α" is changed from $-\pi/2$ to $+\pi/2$ with the step $\pi/12$
d) The angle of the conic section of the stream is $\pi/8$

In the general case the spatial and kinematical structure of the magnetospheres has to be much more complex.

But a character of SERVs orientation has to be similar.

It is connected with particular kinematics of gas inside the accretion streams:

1. Its radial velocity has to be at the minimum near the outer boundary of the magnetosphere and at the maximum close to the stellar surface, because this gas moves in the free fall regime.
2. Its rotation velocity, on the contrary, has to be maximal at the outer boundary of the magnetosphere and minimal near the stellar surface, because the stream rotates rigidly with the star.

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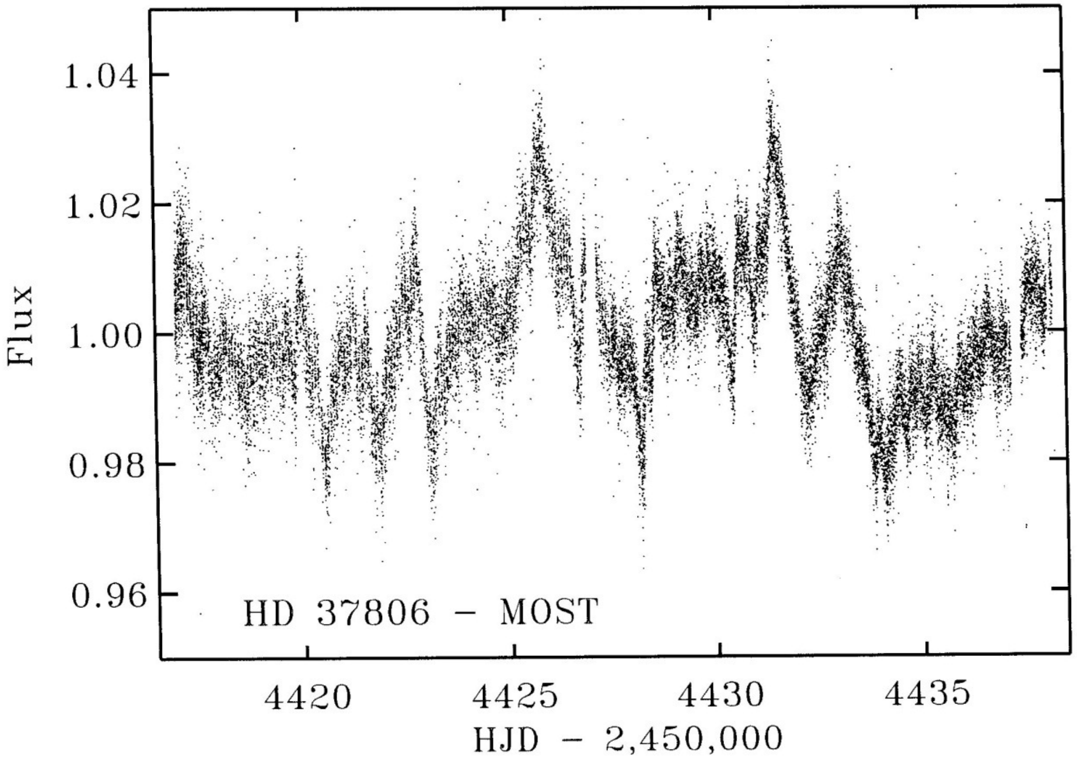
As a result of our investigation we have made the following conclusions:

1. The existence of magnetosphere in HD 37806 is confirmed by a large extension of the red edge of the absorption component of the HeI 5876 profile, observed on some dates.
2. Also, it is confirmed by a specific type of the short-term variability of the HeI 5876 line in the form of standing intensity waves in the region of the red absorption component of the line profile.

At last, we'd like to show the light curve of HD 37606, based on the data from the satellite MOST (Microvariability & Oscillations of STars) during 21 days (Rucinski at al., 2010, A&A, 522, 113).



The authors argue that the data show a weakly definite cyclic signal with a period of about 1.5 days, which can correspond to the rotation period.

Such phenomenon can be a result of an existence of a hot spot on the stellar surface in the region of its contact with the accretion stream moving inside a magnetosphere.

Therefore, this result speaks in favour of our conclusion about existence of a magnetosphere in HD 37806.

Thank you for your attention!