Light variations due to wind blanketing in O stars

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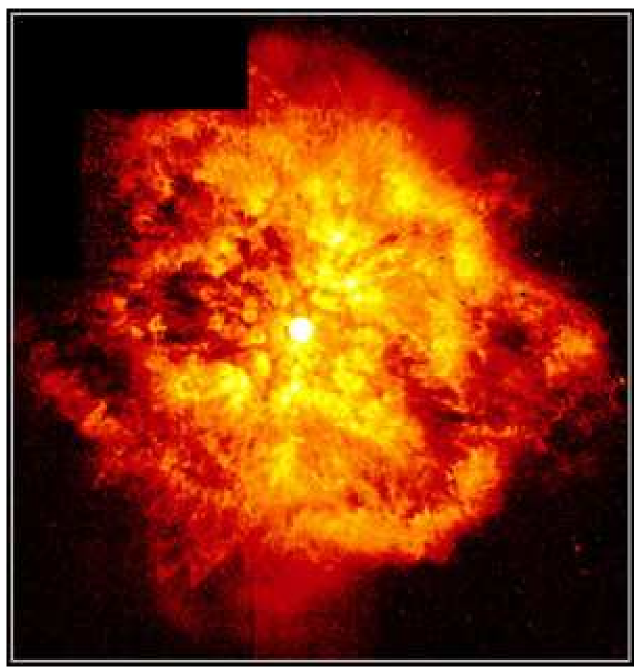
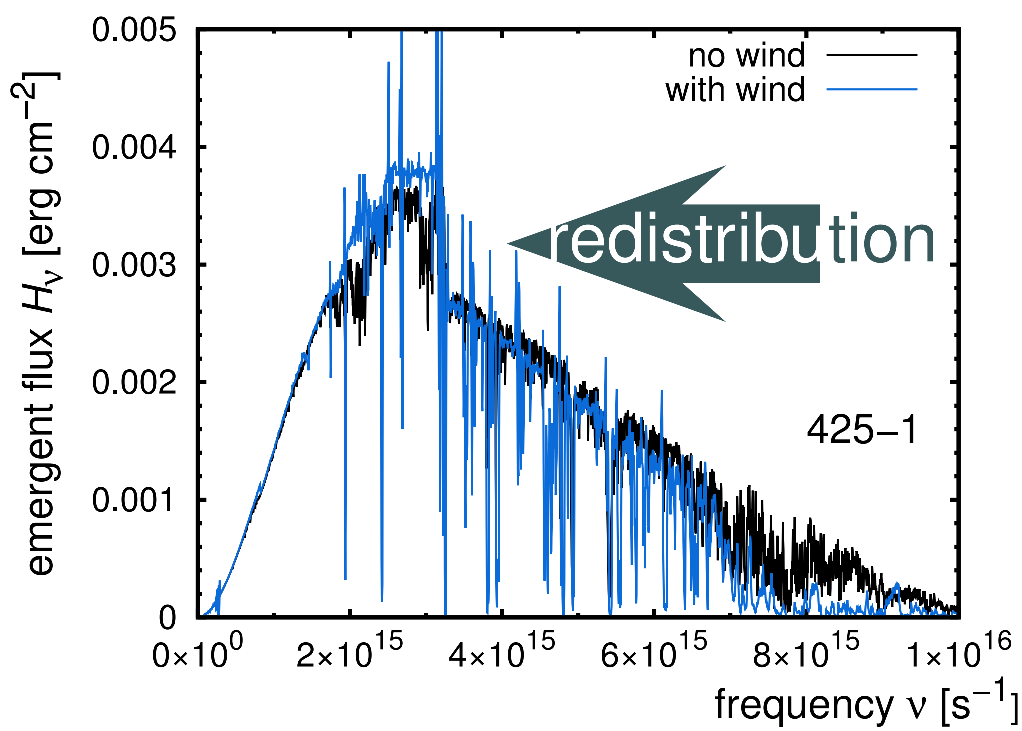
Stellar wind of hot stars

- supersonic flow from hot stars
- accelerated due to the absorption (scattering) of radiation mainly in the resonance lines of such elements like C, N, O or Fe
- most important wind parameters are mass-loss rate $\dot{M}$ and terminal velocity v_∞



Wind blanketing

- radiation reflected back to the stellar photosphere from the wind: *wind blanketing*
- line and continuum absorption in the wind
- change of the structure of the photosphere and of the emergent flux (Abbott & Hummer 1985)



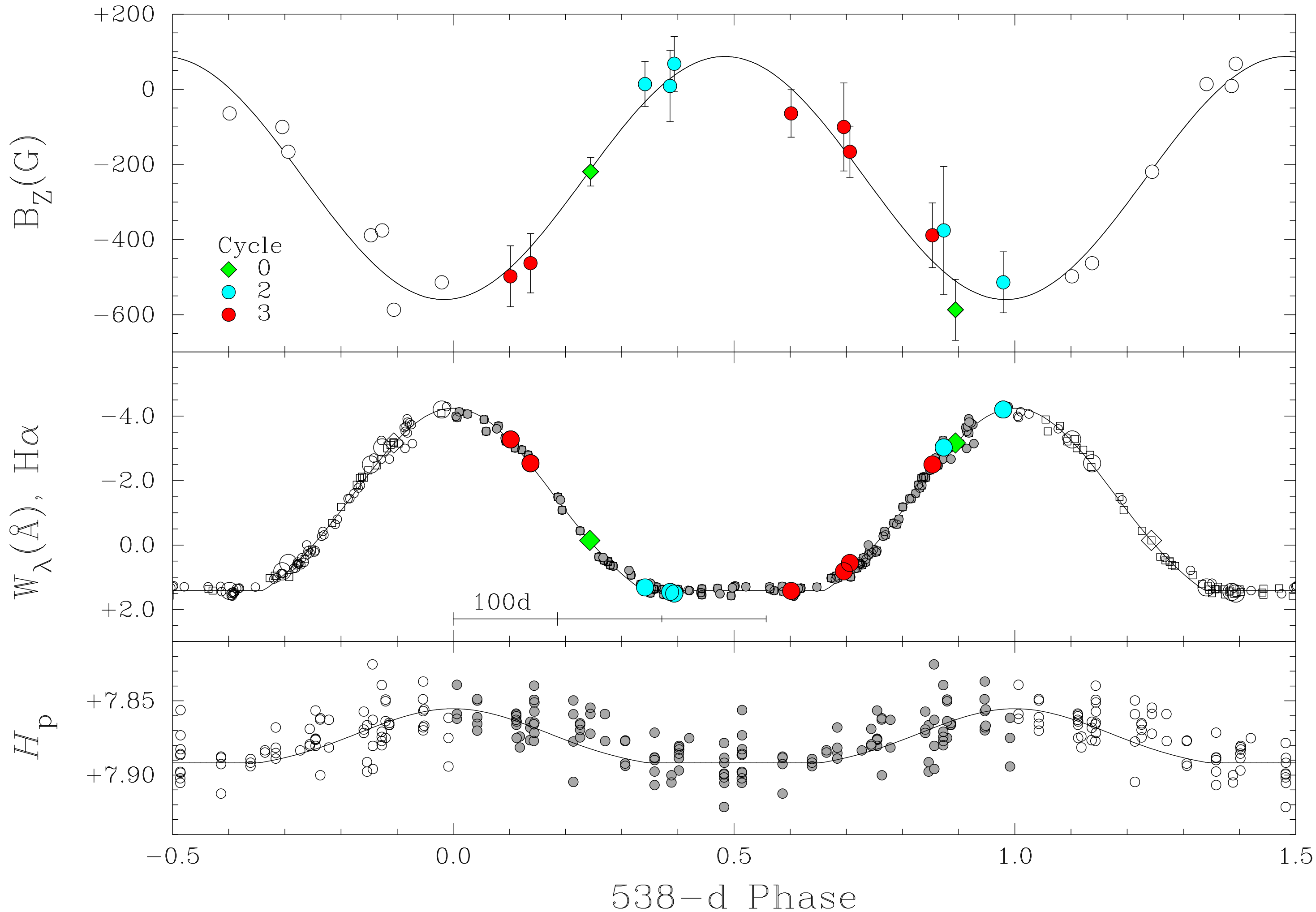
Photometric variations

- wind variability $\Rightarrow$ variability of wind blanketing $\Rightarrow$ photometric variability
- possible causes of the wind variability
  - stellar magnetic field
  - wind instabilities

HD 191612

- spectral type O6.5f?pe
- effective temperature $T_{\rm eff} = 36\,000\,\rm K$
- spectroscopic variations with period ~ 540 d (Walborn et al. 2004)
- photometric variations with period ~ 540 d (Nazé 2004)
- detection of magnetic field (Donati et al. 2006)

HD 191612: rotational variations



Wade et al. (2011)

Nature of observed variations

- stellar rotation: magnetic field variations
- magnetic field dominates the wind ($\beta < 1$)
- wind flows along the magnetic field lines (ud-Doula & Owocki 2002)
- strength of the wind varies across the stellar surface, $\dot{m}(\Omega) \sim \cos^2\theta_\mathrm{B}$, θ_B is the tilt of the magnetic field

$\Rightarrow$ variations of B_z, Hα and X-ray emission (Wade et al. 2011, Nazé et al. 2016)

- are there any observable consequences of variable wind blanketing?

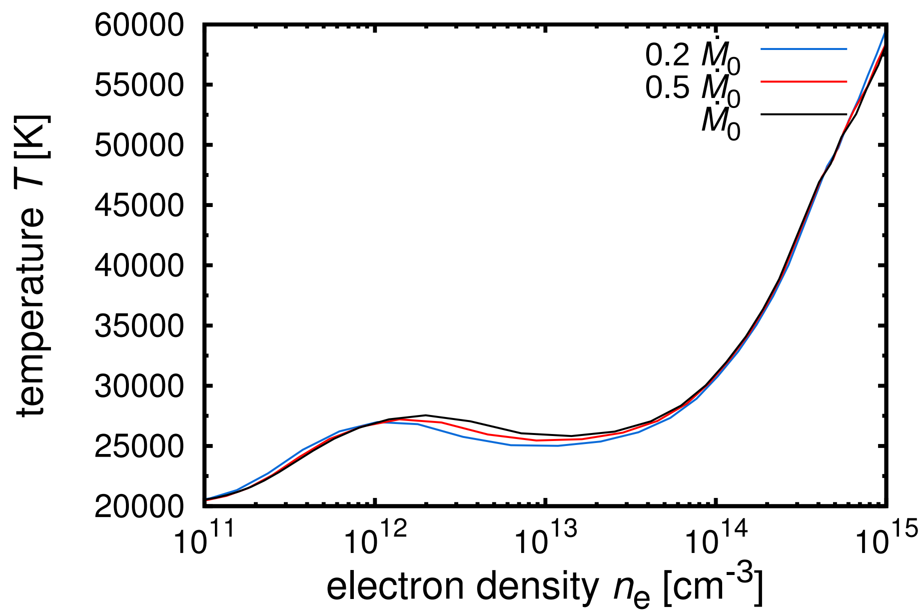
METUJE global models

- models of the stellar photosphere and wind
- spherically symmetric stationary models
- occupation numbers calculated using statistical equilibrium (NLTE) equations
- radiative field calculated using the comoving-frame (CMF) radiative transfer equation
- solution of hydrodynamical equations with CMF radiative force and NLTE heating/cooling term

(Krtička & Kubát, in press)

HD 191612: temperature

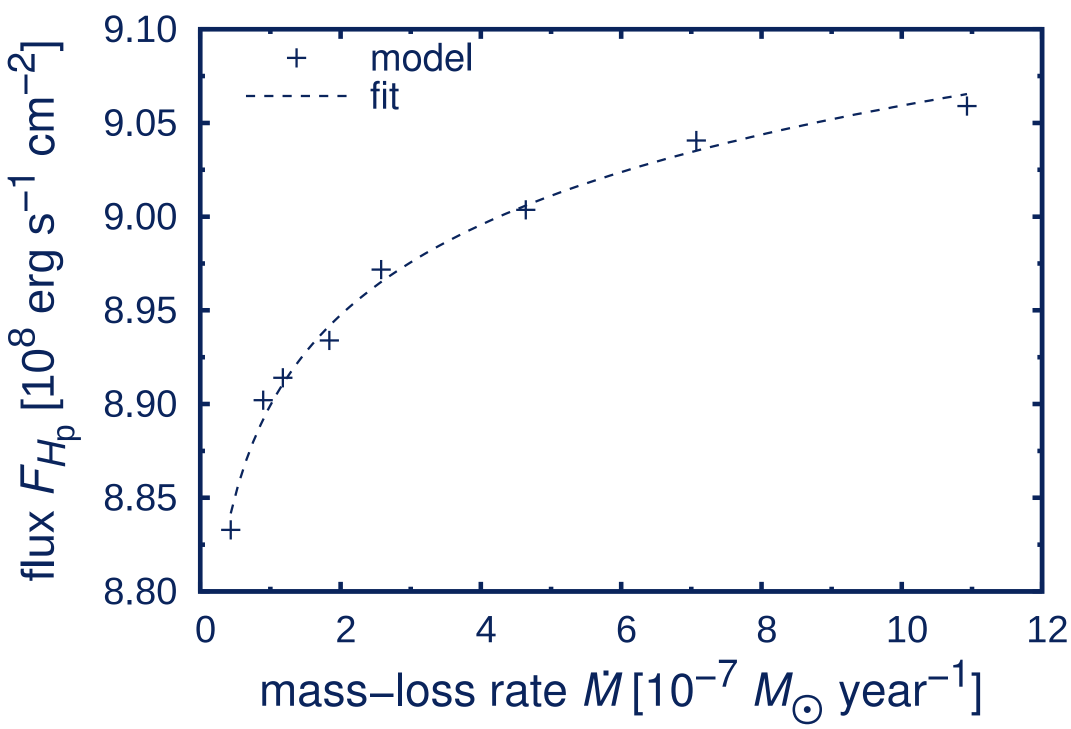
- stellar wind blocks part of the emergent radiation (mainly in far-UV)
- blocked radiation heats the photosphere: *wind blanketing*



- mass-loss rate $M_0 = 2.6 \times 10^{-7}\,\mathrm{M}_\odot\,\mathrm{yr}^{-1}$

HD 191612: emergent flux

- wind blanketing: redistribution of the flux from far-UV to near-UV and optical
- star brighter with increasing mass-loss rate



HD 191612: magnetic field

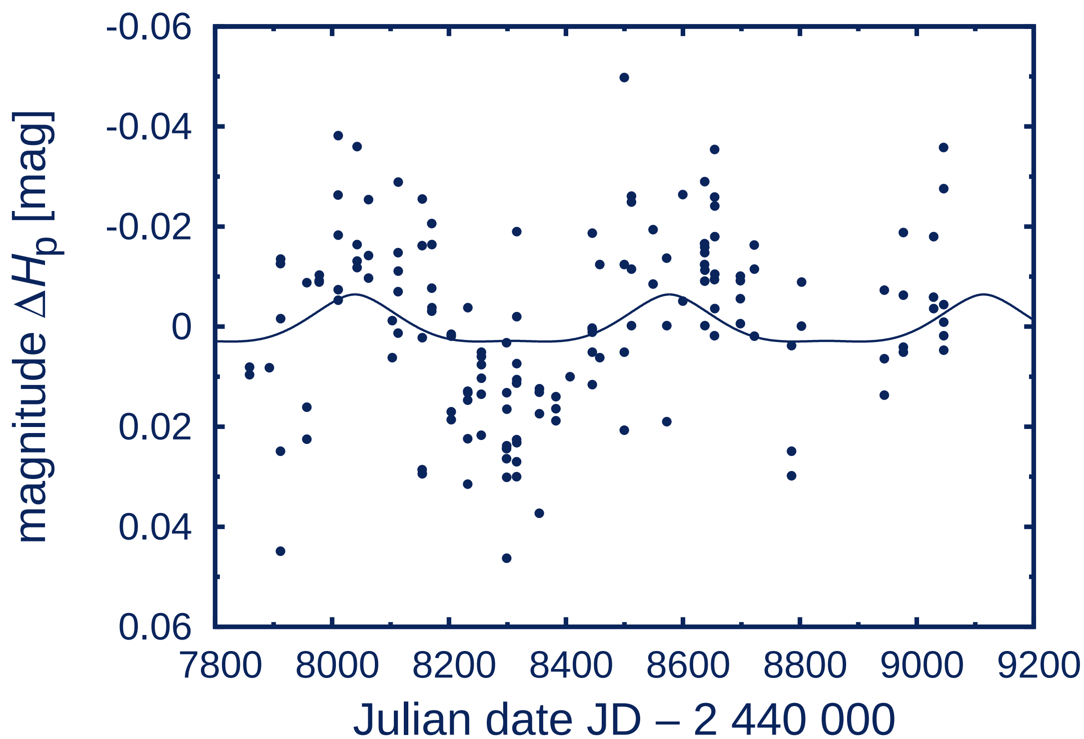
- wind mass-flux depends on the location on the stellar surface (Owocki & ud-Doula 2004)

$$\dot{m}(\Omega) \sim \cos^2 \theta_{\rm B}$$

- $\theta_{\rm B}$ is the tilt of the magnetic field
- regions where the magnetic field is perpendicular to the stellar surface are brighter

HD 191612: light curve

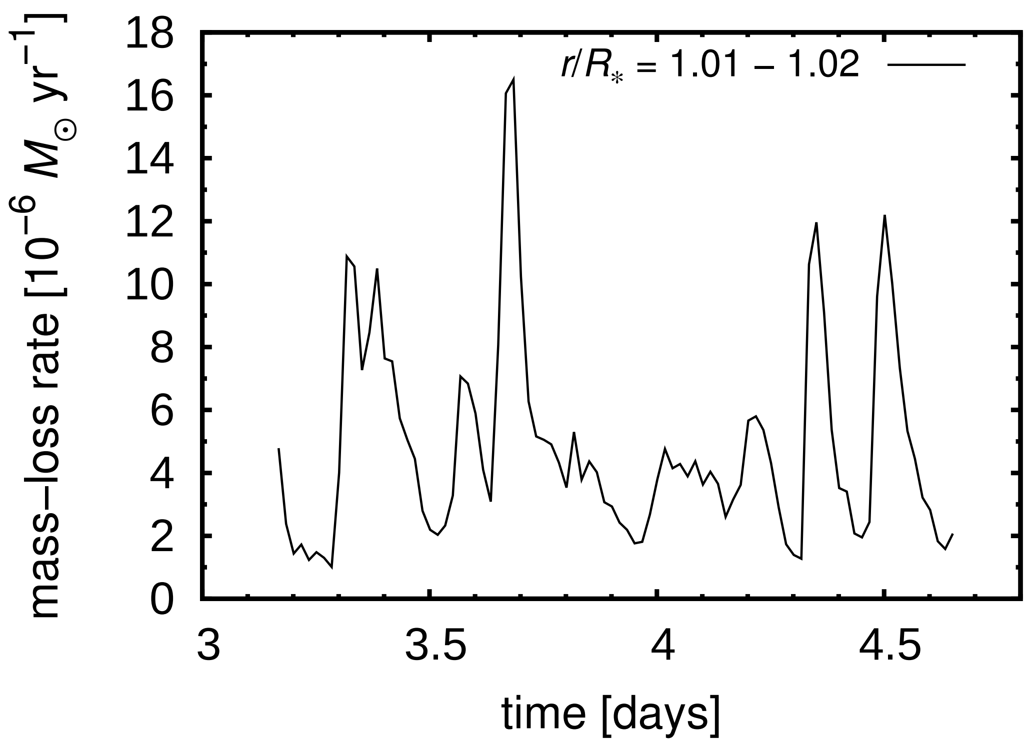
- light curve due to the modulation of wind blanketing by the magnetic field (Krtička 2016)



- remaining light variability due to wind absorption (Wade et al. 2011)

Line-driven wind instability

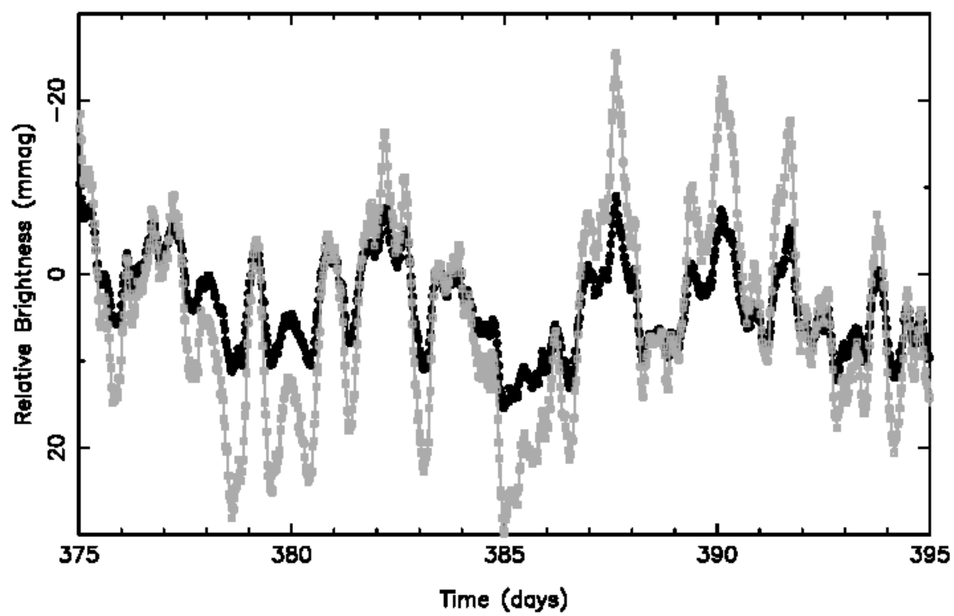
- wind variability due to line driving instability (Owocki et al. 1988, Feldmeier et al. 1997)



- variability of the mass-loss rate (averaged over $r/R_* = 1.01 - 1.02$, Feldmeier et al. 1997)

Line-driven wind instability

- wind variability due to line driving instability (Owocki et al. 1988, Feldmeier et al. 1997)
- can wind variability explain stochastic light variations observed in some O stars?



HD 188209 (O9.5Iab, *Kepler*, Aerts et al. 2017)

Line-driven wind instability

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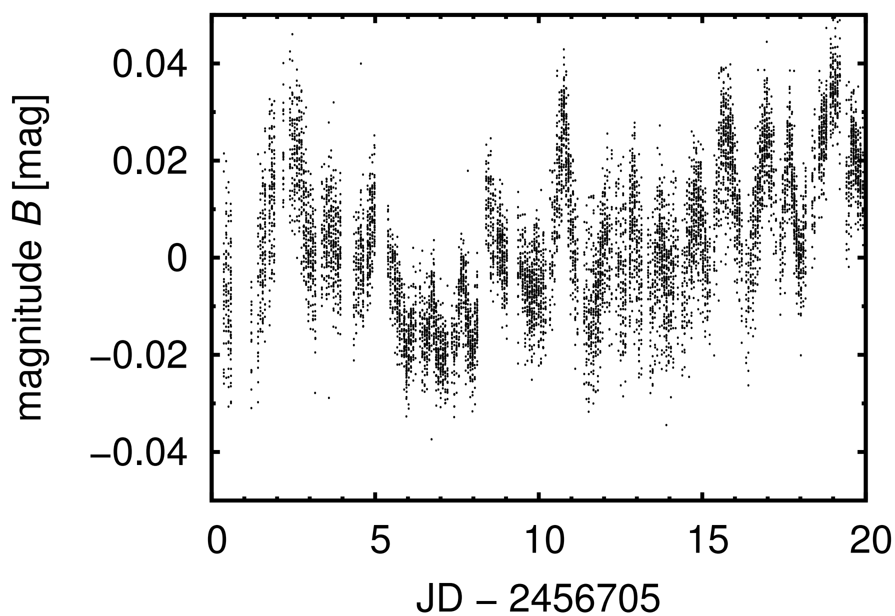
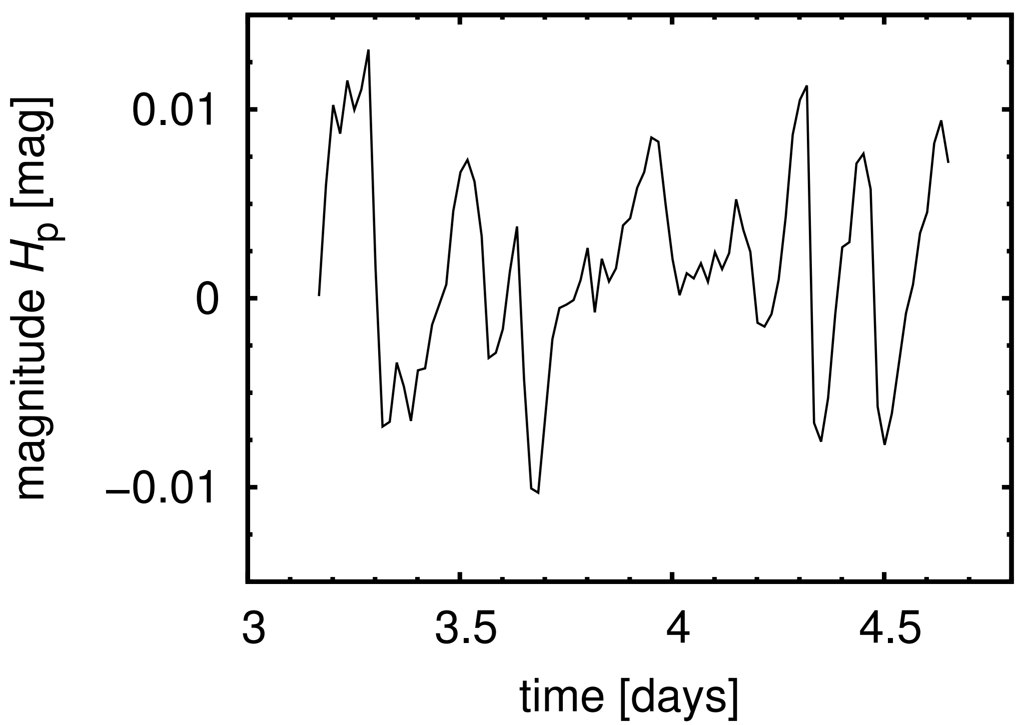


HD 37128 (ϵ Ori, B0Ia, BRITE)

Light variability

- wind variability due to line driving instability (Owocki et al. 1988, Feldmeier et al. 1997)

⇒ variable wind blanketing

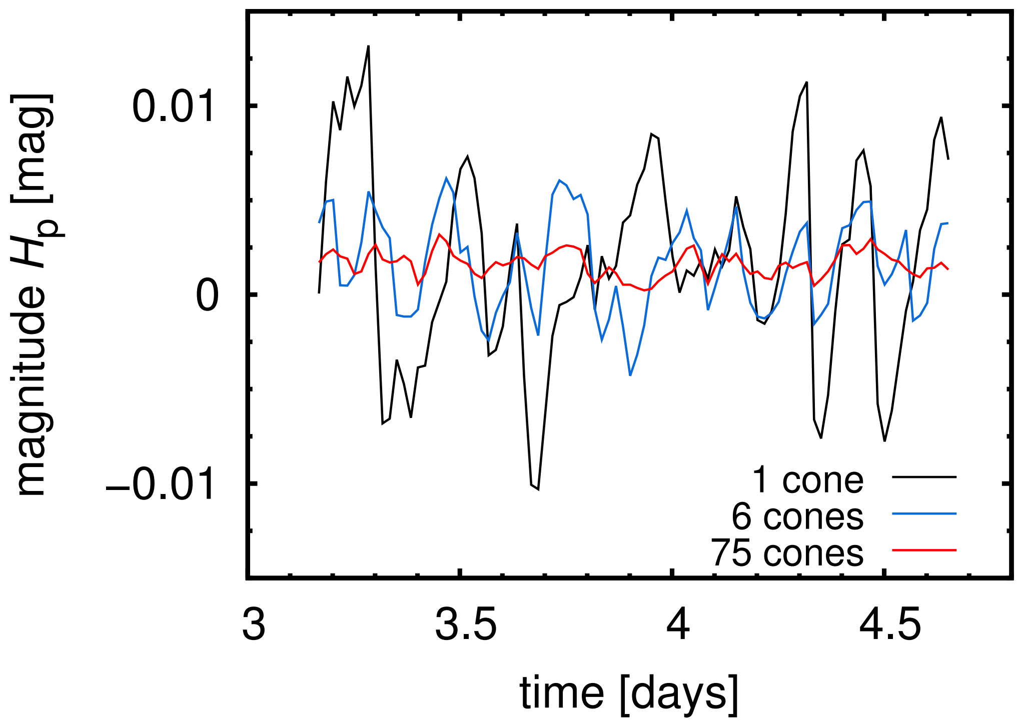


- light variability due to variable wind mass-loss rate and wind blanketing

Light variability: more cones

- wind variability due to line driving instability (Owocki et al. 1988, Feldmeier et al. 1997)

⇒ variable wind blanketing for random time offset in each cone



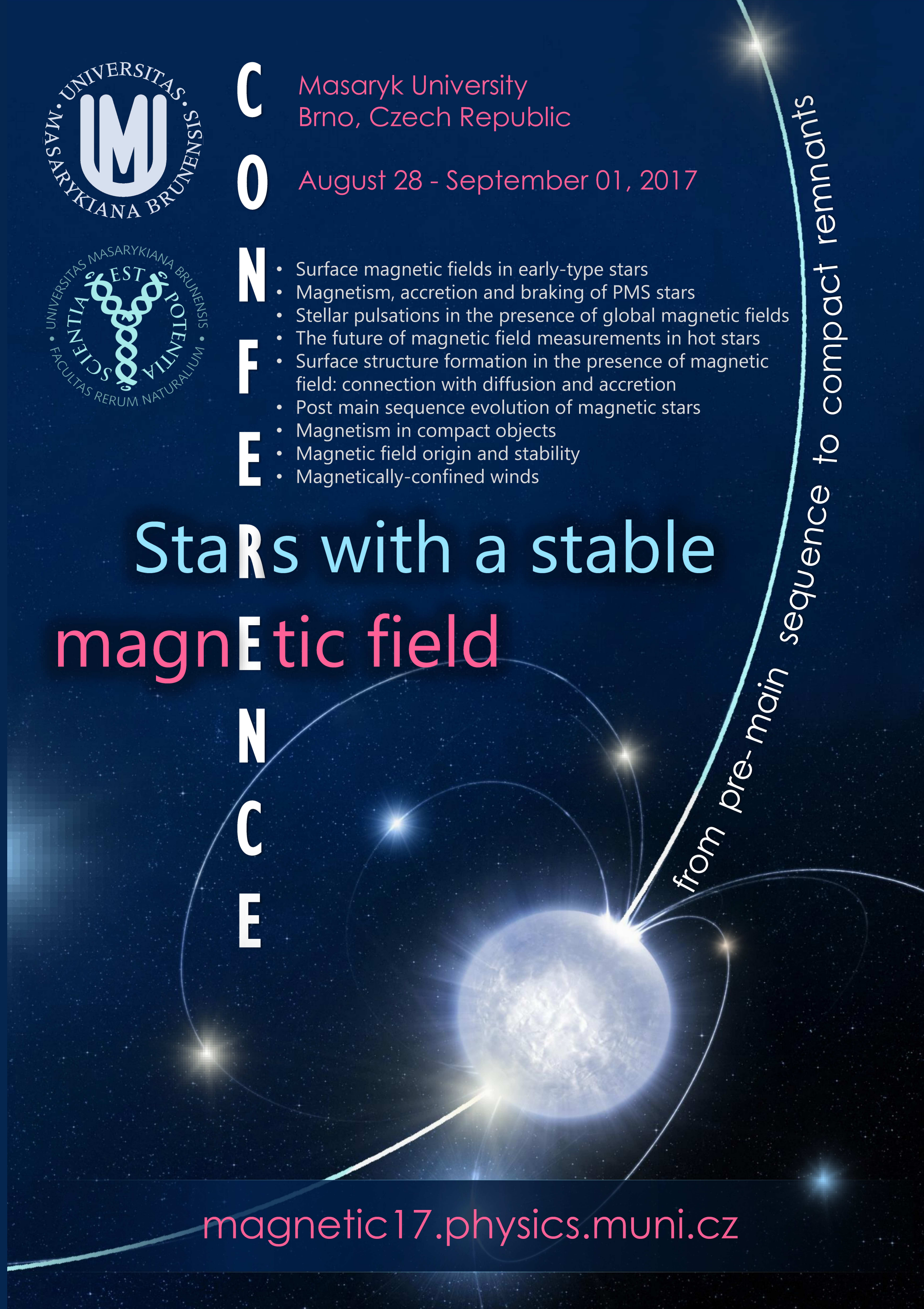
⇒ variability observable for low number of cones

Conclusions

- hot star wind blocks part of the emergent flux: *wind blanketing*
- part of the blocked flux redistributed to the visual region

$\Rightarrow$ photometric variability for variable wind mass-loss rate

  - rotational variability in magnetic O stars
  - stochastic variability due to wind instabilities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