Study of winds of hot massive stars

Proposals for bachelor, master, or doctoral theses

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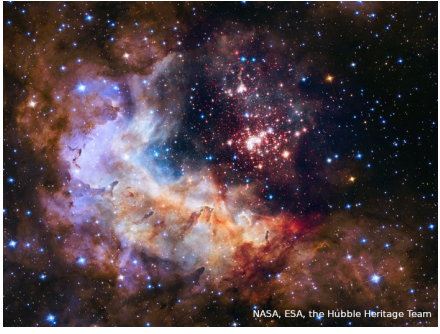
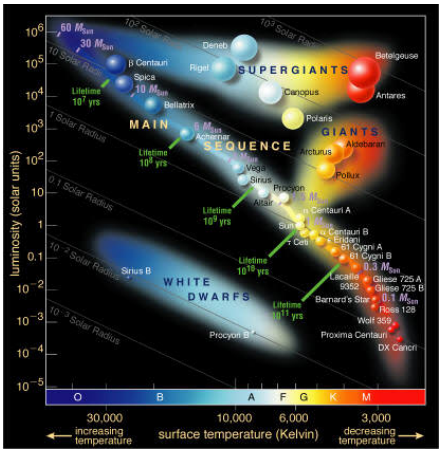
Astronomický ústav AV ČR



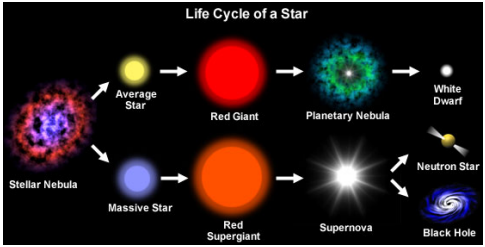
Hot massive stars - basic properties

- **MASSIVE** – $M \gtrsim 8$ [$M_\odot$]
- **EXTREMELY LUMINOUS** – $L \gtrsim 10^3$ [$L_\odot$]
- **HOT** – $T_{\rm eff} \gtrsim 20\,000$ [K]
- **SPECTRAL TYPE** – **OB-type**
  Massive stars in short-lived transition phase (WR, LBVs, BSGs, and B[e]SGs)
- **SHORT LIFETIMES** – $\sim 10^6$ yr
- **SPECTACULAR DEATH VIA SUPERNOVA EXPLOSION OR GAMMA-RAY BURST**
  Remnant: neutron star or black hole
- **STRONG WIND (MASS LOSS)**
  Mass-loss rate – $\dot{M} \sim 10^{-6}$ [$M_\odot$/yr]
  Terminal velocity – $\sim 10^2 - 10^3$ km/s



Why to study winds of hot massive stars?

- Understanding of the evolution and fate of massive stars in the universe. For that we need to know:
  - accurate mass-loss recipes, and
  - $\dot{M} = \mathrm{f(Z)}$ - dependence of mass loss on metallicity.
- Understanding the nature of different types of supernovae, neutron stars and black holes (BH).
- A better understanding of the progenitors of gravitational waves - the masses of BH mergers (LIGO/Virgo: Abbott et al. 2016; Abbott et al. 2020).



XShootU collaboration: ULLYSES & XSHOOTER

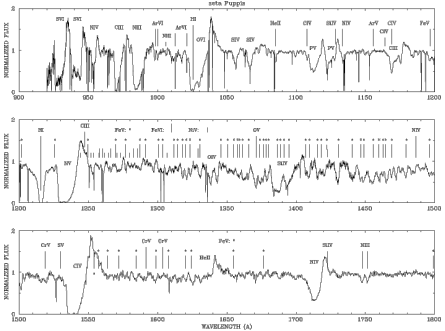
https://massivestars.org/xshootu/

- 14 Working Groups
- **WG4 - Wind Structure**
  Point of Contact:
  Brankica Kubátová

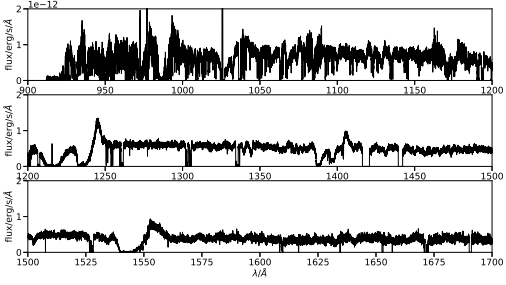
- **The NASA Hubble Space Telescope (HST)** - uniformly observed sample: spectral type, luminosity class, and metallicity for massive OB stars in **SMC** (Z=0.5 $\mathbf{Z}_\odot$), **LMC** (Z=0.2 $\mathbf{Z}_\odot$), **NGC 3109** (Z=0.1-0.2 $\mathbf{Z}_\odot$), and **Sextans A** (Z=0.1 $\mathbf{Z}_\odot$).
- Spectral types **O2-B1.5**, **supergiants B2-B9**, **11 WR stars** (4 close binary systems); about 240 stars.
- **HST observations** (FUV: 937-1792 Å+ archive data; NUV: 1607-3119 Å; OPT: 2900-5700 Å; NIR: 5240-10270 Å); **XSHOOTER observations** (UVB: 300-559.5 nm; OPT: 559.5-1024 nm; NIR:1024-2480 nm).
- **All Observed data have been reduced and they are available to the community - the data can be used for your bachelor, master, or PhD theses.**

Topic for bachelor thesis

- **UV, optical, and/or IR Spectroscopy of OB-type Stars at different metallicities**
  - Using XShootU and archival data (IUE, FUSE, HST, ESO).
  - Understanding diagnostic lines for stellar and wind parameters (mass-loss rate, terminal velocity, and clumping) determination.



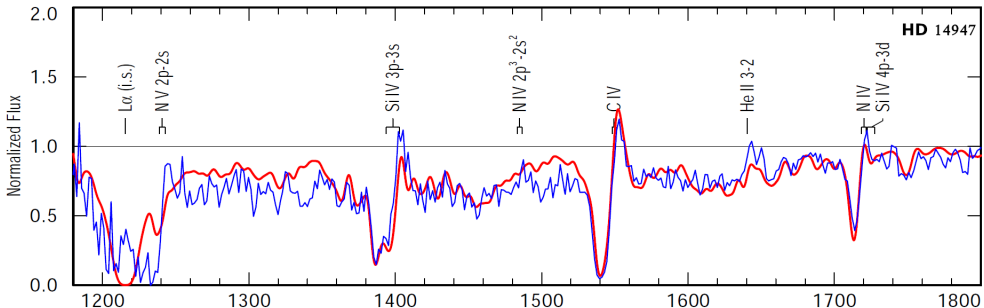
Merged spectrum of Copernicus and IUE UV high-resolution observations of the supergiant ζ Puppis (Pauldrach et al., 1994).



HST observation of the Sk-69 50.

Topic for master thesis

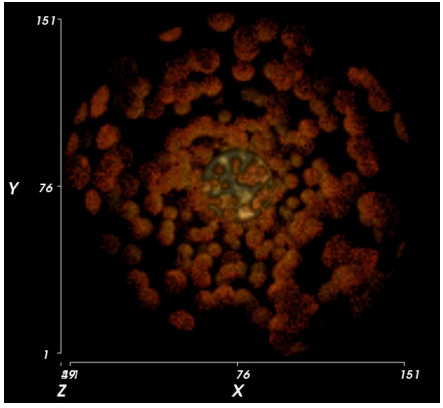
- **Quantitative spectroscopy of OB-type stars**
  - Spectral modelling
  - Using optical, UV, IR archival data (XShootU and archival data).
  - Using one of NLTE stellar atmosphere codes (FASTWIND, PoWR, or CMFGEN).
  - Determination of stellar and wind parameters.



Šurlan et al., 2013, A&A, 559, A130

Topic for PhD theses

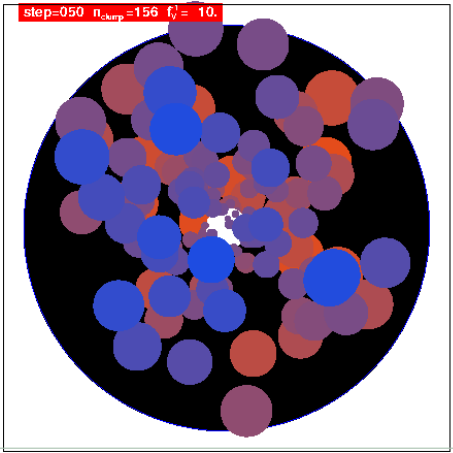
- **Modelling the variability of the resonance line profile due to clump evolution**

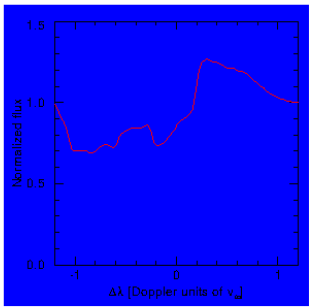


3D distribution of clumps in a wind - result of a 3D Monte Carlo radiative transfer code.

Topic for PhD theses

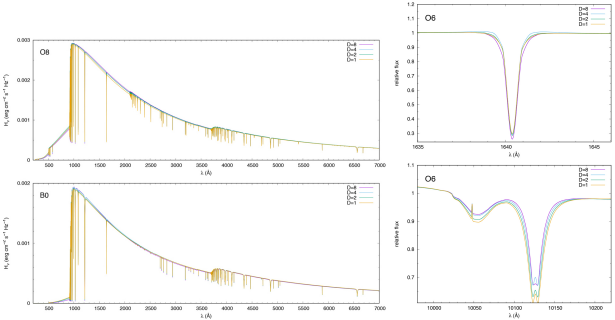
- Study how the time evolution of different clump distributions and clump properties can generate variability in the resonance line profile.
- Comparison with observations.

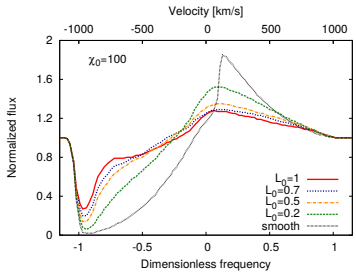




Topic for PhD theses

- **Other types of theoretical studies**
  - Contribution to the development of sophisticated radiative transfer and/or hydro-dynamic codes for stellar atmospheres and wind modelling (e.g., Šurlan et al., 2012, A&A, 541, A37; Kubát & Kubátová, 2021, A&A, 655, A35; Krtička, Kubát & Krtičková, 2022, A&A, 659, A117).
  - Outputs: spectral energy distribution, line profiles or wind structure (T, ρ, V).





Contacts

- For all questions and further discussions about topics for bachelor, master, or PhD theses, please contact:

  - **Mgr. Brankica Kubátová (née Šurlan), Ph.D.**
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  - **doc. RNDr. Jiří Kubát, CSc.**
    jiri.kubat@asu.cas.cz

- We will be happy to share our knowledge and experience with you and to help and to lead you to successfully finishing of your study.