On the nascent wind of nearby oxygen-rich AGB stars: a brief review

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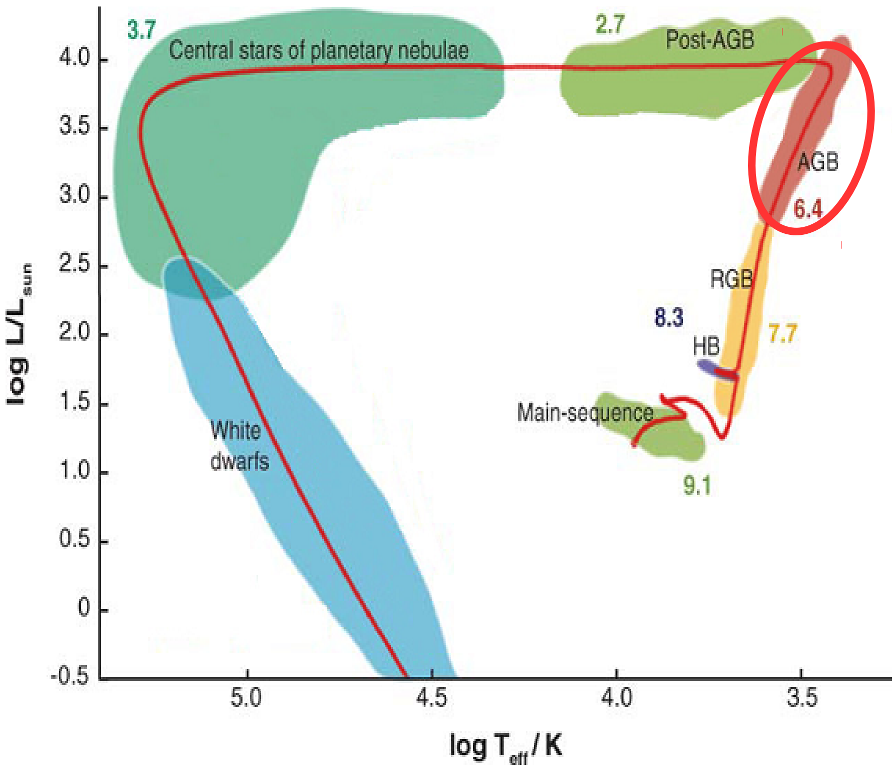
Asymptotic Giant Branch (AGB) stars

AGB stars are Red Giant stars with a degenerated Carbon/Oxygen core surrounded by burning Helium and Hydrogen shells. Their initial mass is 0.8-8 M_O.



Mass loss rate ~ 10^{-8} to 10^{-4} M_O/yr.

On this stage, the CSE often evolves from a spherical shape to very irregular morphology. Studying AGB stars helps in understanding the symmetric breaking mechanism of the morphologies.

O-rich and C-rich AGB stars

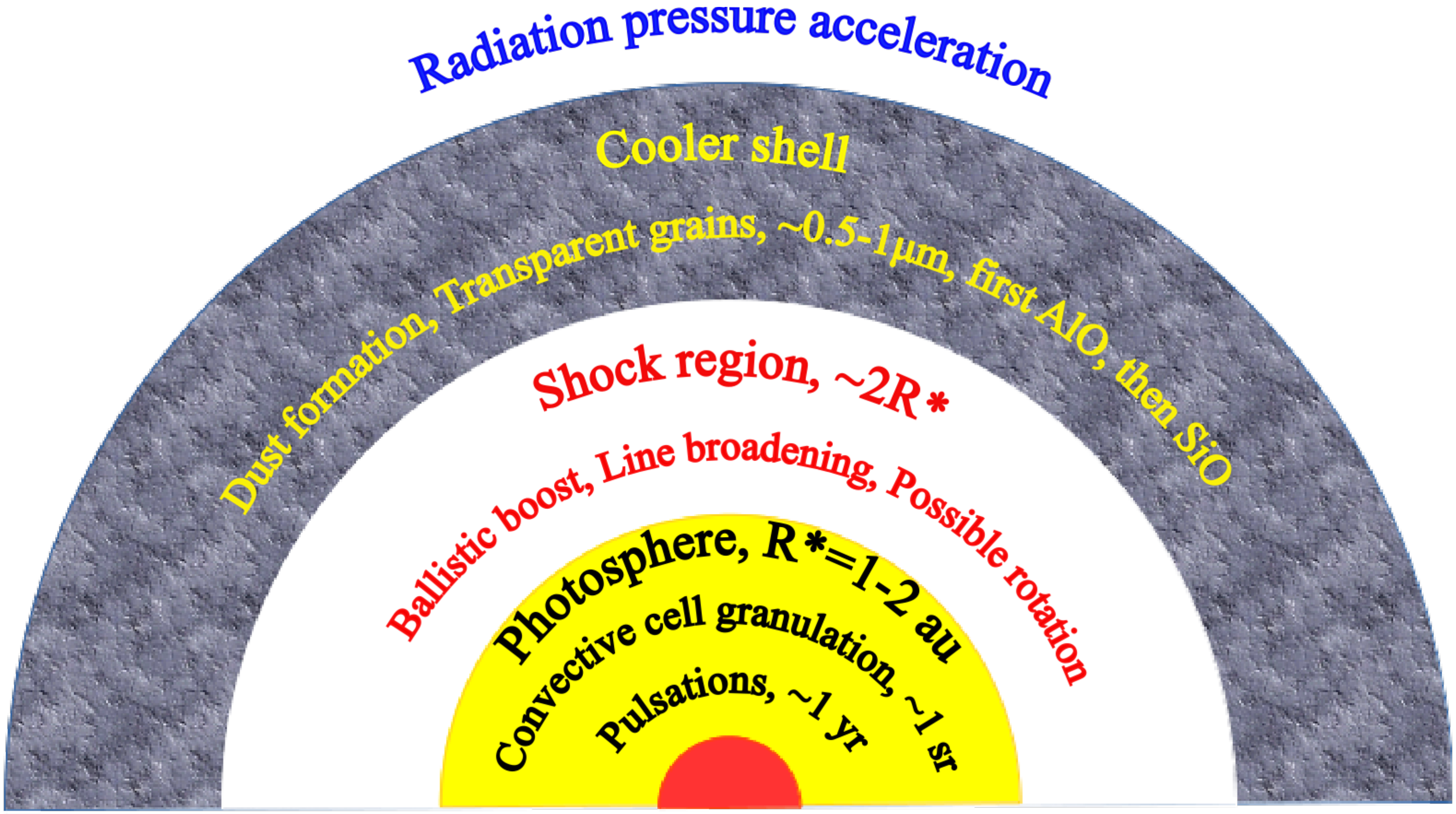
Most C and O atoms combine to form CO molecules. Depending on which of C and O is in excess, one talks of Oxygen-rich ($C/O<1$) or Carbon-rich ($C/O>1$) AGB stars.

Oxygen rich AGB stars (S or M type): in addition to CO, main molecules are TiO, SiO, OH, H_2O,..., dust particles are aluminum oxides or silicates.

Carbon rich AGB stars (C type): in addition to CO, main molecules are CN, C_2, HCN,..., dust particles are amorphous carbon or silicon carbide.

O-rich AGB stars are usually younger than C-rich AGB stars: they may become C-rich in a later phase of their evolution

The commonly accepted mechanism governing the formation of the nascent wind in oxygen-rich AGB stars combines an initial boost above the photosphere, given by shocks resulting from stellar pulsations and convective cell granulation, with a subsequent acceleration fuelled by the radiation pressure of the star on dust grains.



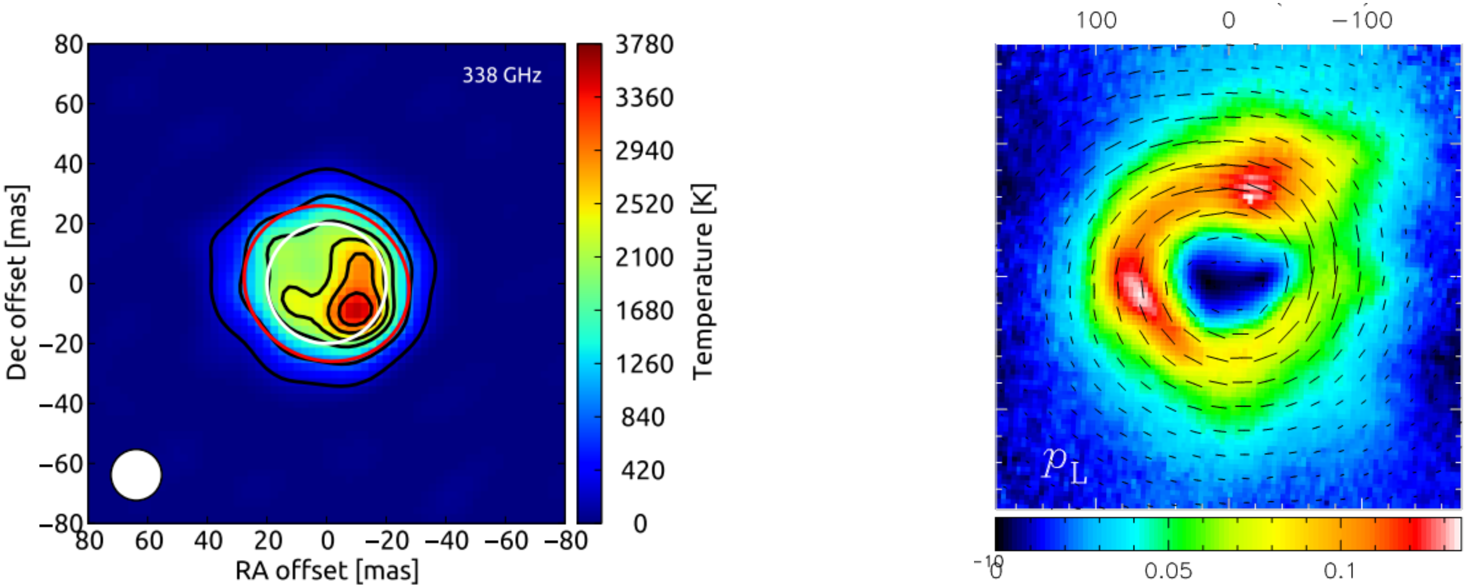
We study six nearby stars, for which detailed analyses of visible and infrared observations at the VLT and of millimetre observations at ALMA are available, to assess the extent to which the validity of this picture is currently corroborated.

	D (pc)	**P (days)**	**Mass (Sun)**	**MLR (Sun*10^-7)**
L2 Pup	64	141	0.7+.012?	0.12
O Cet	100	333	2+0.7	0.7
W Hya	104	361	1.0-1.5	1.3
R Leo	114	310	0.7	1.6
R Dor	59	332	0.7-1.0	2
EP Aqr	119	110	1.7	1.6

ALMA (mm) observations of continuum emission often display variability and hot spots interpreted as the effect of shocks induced by pulsations and convection.

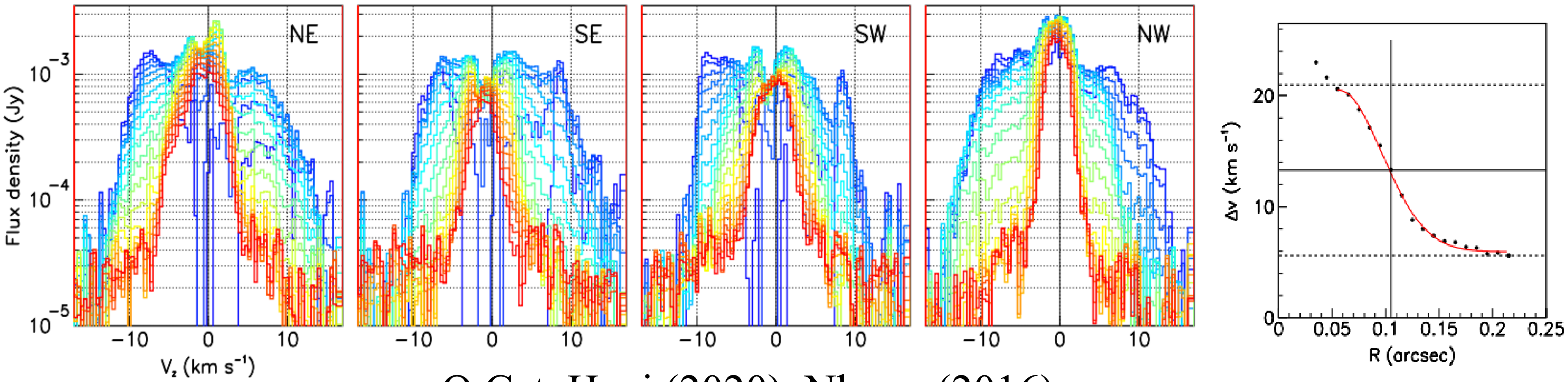
VLT (visible and IR) observations of a dusty layer around the photosphere display both inhomogeneity and variability. Evidence for large transparent grains close to the photosphere (0.1 to 0.5 microns, mostly Al_2O_3).

Time scale is weeks to months

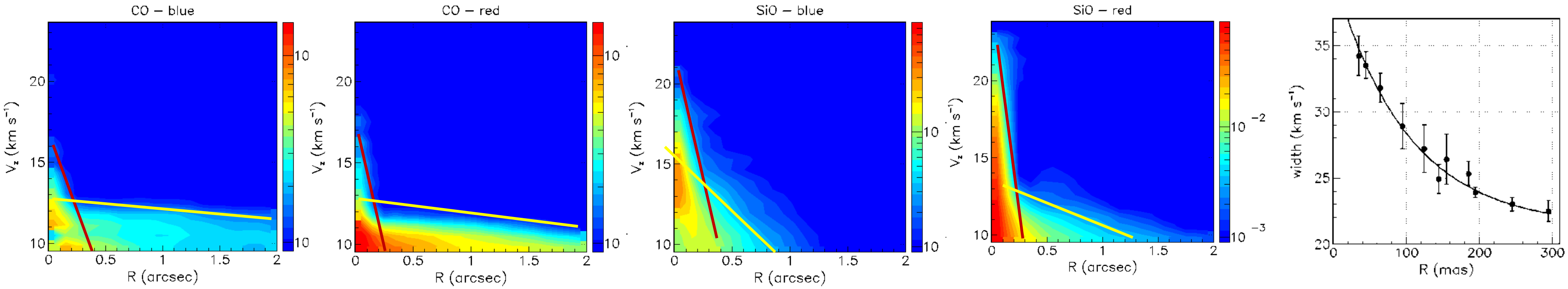


W Hya (2016): Vlemmings (continuum), Ohnaka (VLT/Sphere/Zimpol)

Close to the star, high velocity wings in the spectra of line emissions (ALMA) are interpreted as revealing the shocked region

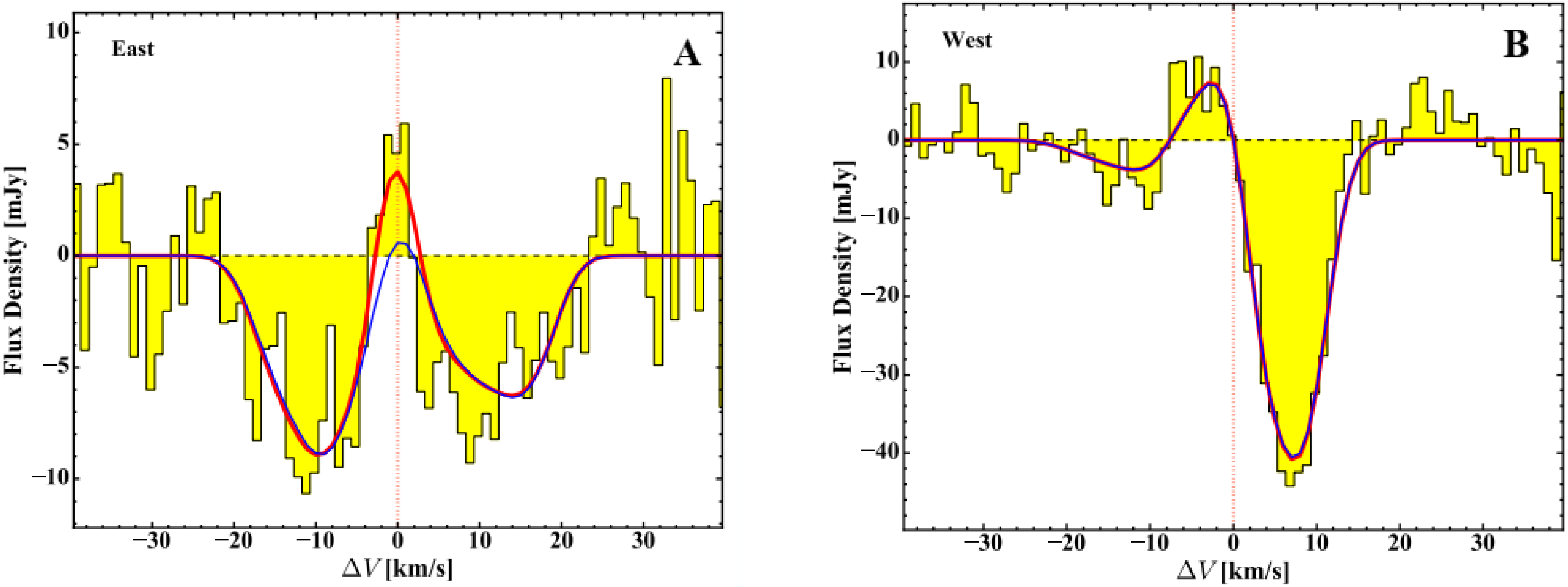


O Cet, Hoai (2020), Nhung (2016)

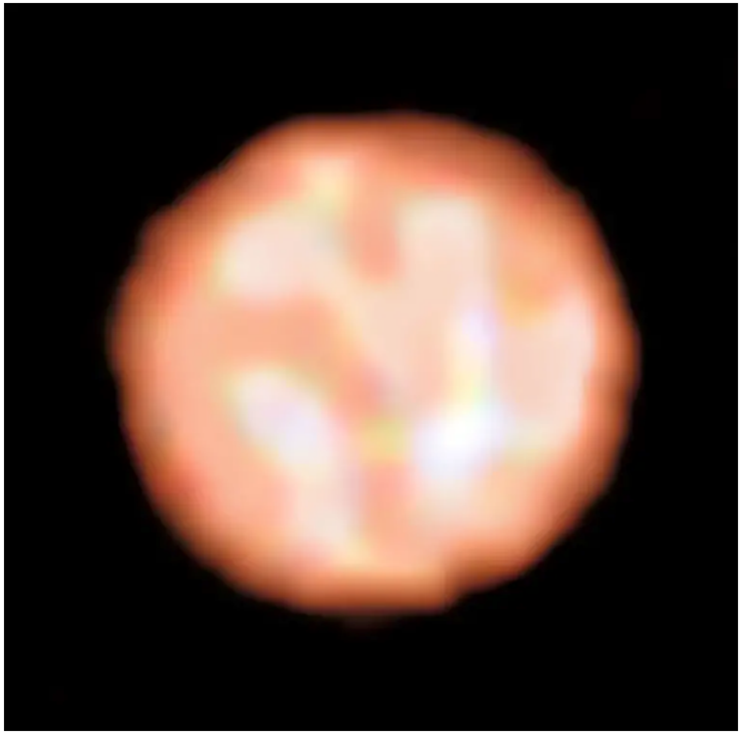


EP Aqr, Nhung (2023)

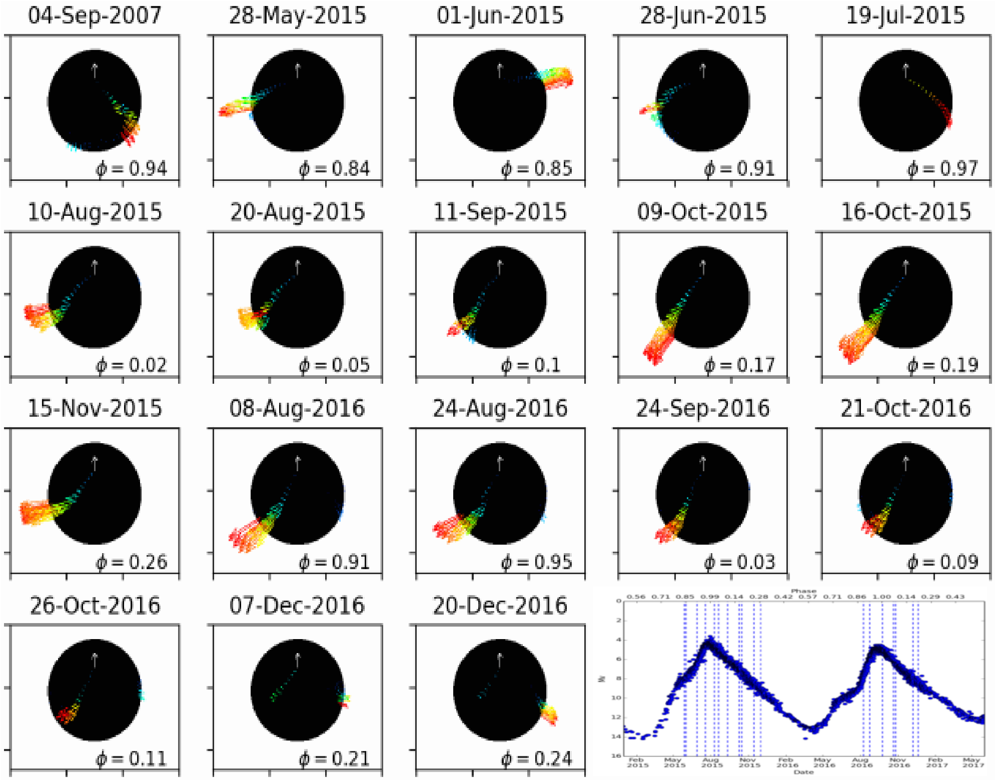
However, direct evidence has only been obtained on W Hya by Vlemmings et al. (2017) using ALMA CO(*v*=1,3-2) line emission



Other direct evidences not part of our review include the observation of granulation on *π1* Gruis (VLT/PIONIER, Paladini 2018) and of an asymmetric and variable velocity field on *χ* Cygni (spectropolarimeter NARVAL, Pic du Midi, Lopez Ariste 2019)

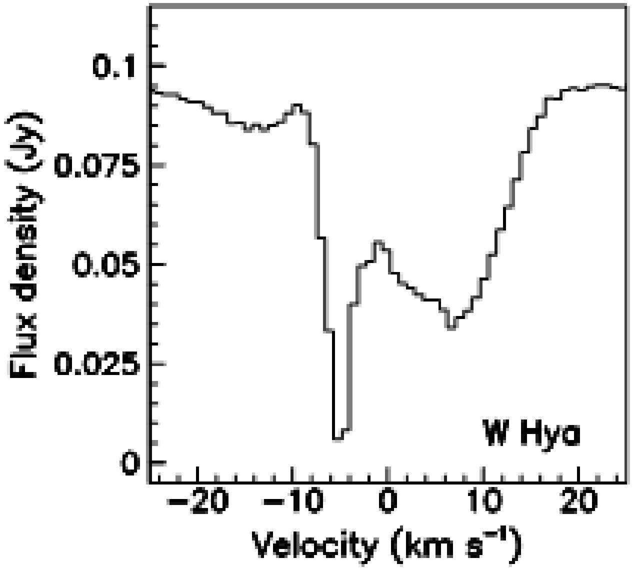


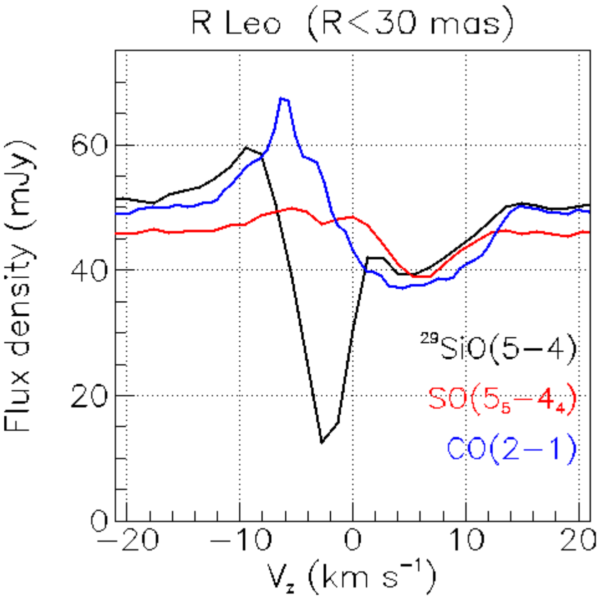
π1 Gruis

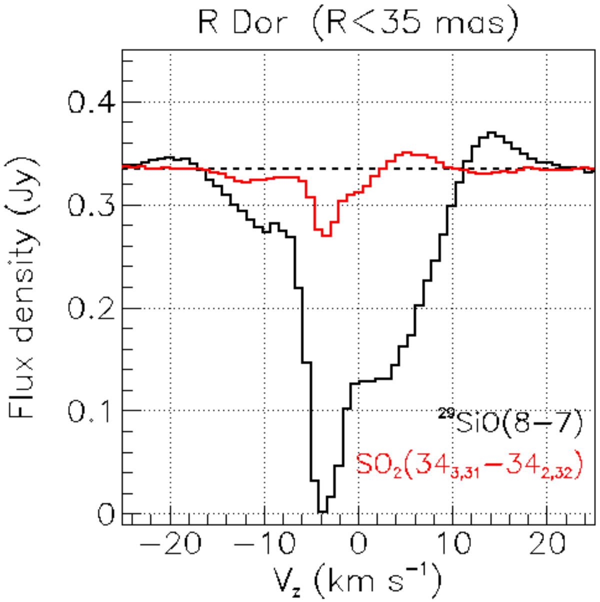


χ Cygni

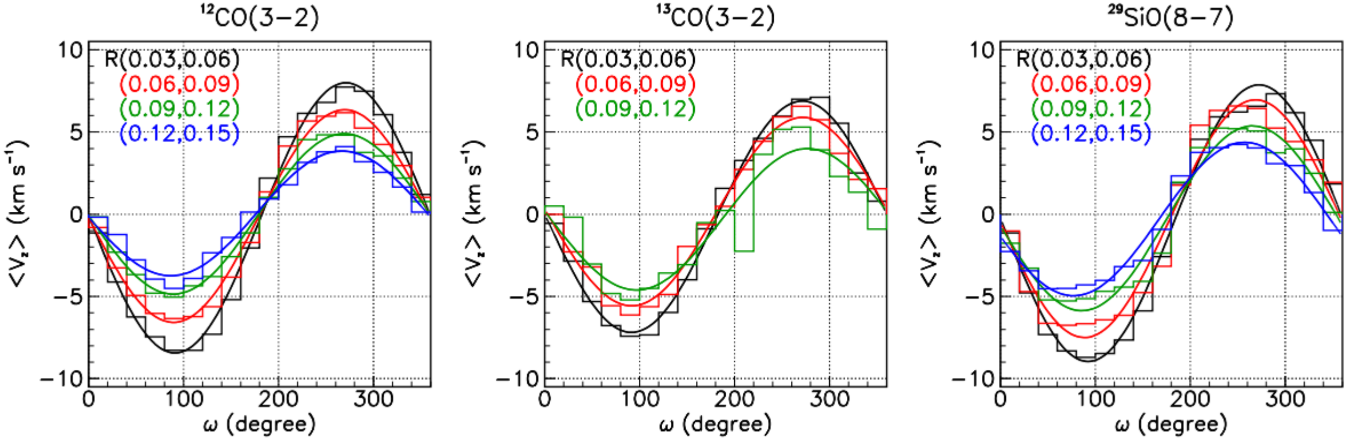
Molecular line absorption spectra over the stellar disc give evidence for both in-falling and outflowing gas in the shocked region. The terminal velocity is revealed as a blue-shifted peak.



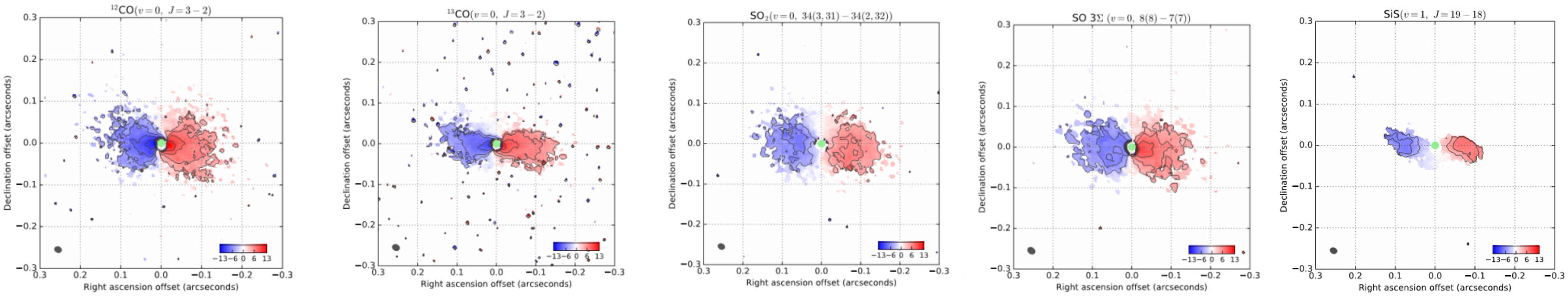




Rotation is often observed close to the star, particularly strong in L_2 Pup where a gas and dust disc is observed to surround the star, possibly related to a planetary companion orbiting it at ~2 au distance (Kervella 2016)

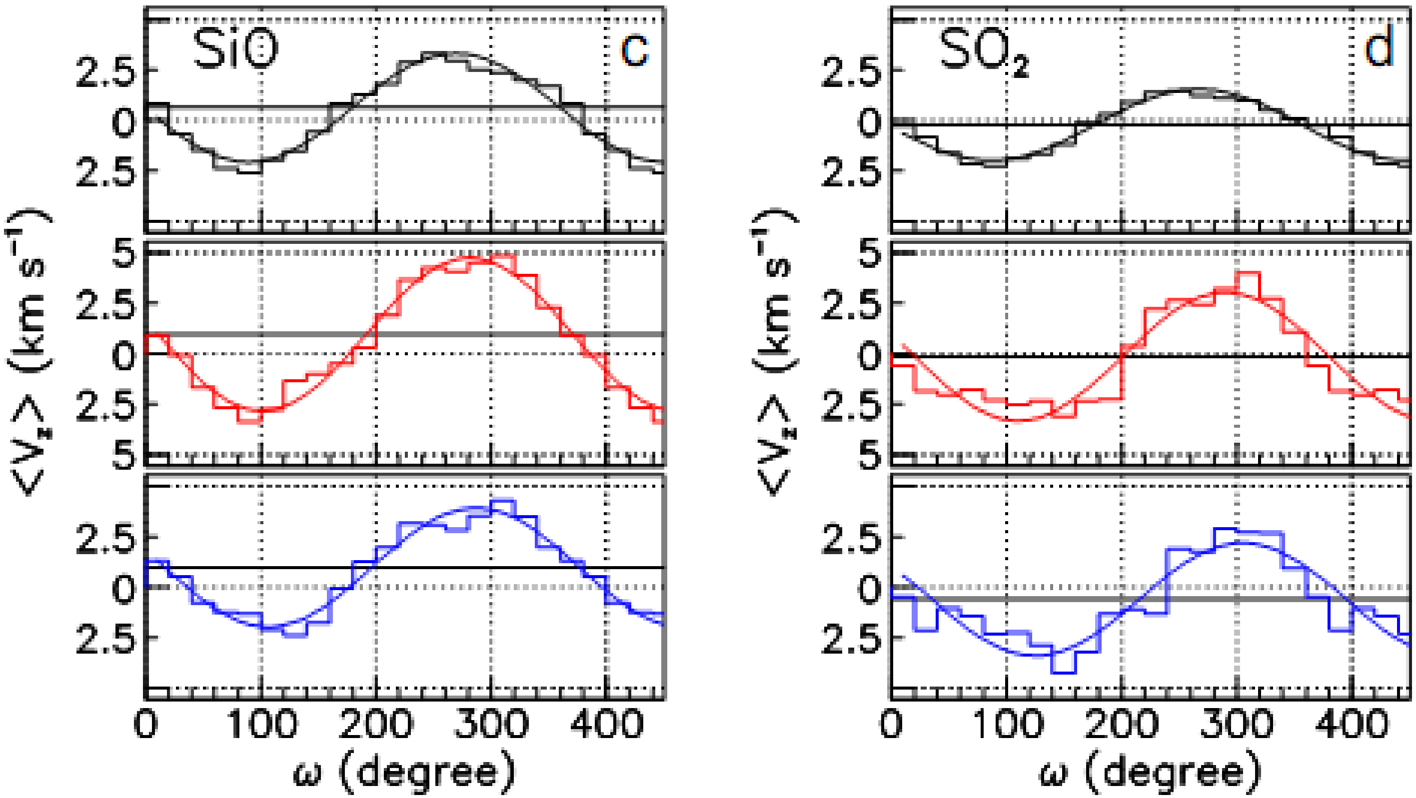


^{12}CO(3-2), ^{13}CO(3-2) and SiO(8-7), Hoai (2022)



^{12}CO(3-2), ^{13}CO(3-2), SO$_2$($34_{3,31-2,32}$), SO(8-7), SiS(v=1,19-18), Kervella(2017)

In other stars, rotation is confined close to the star, with velocity at a few km/s scale, and usually interpreted as caused by the presence of a planetary companion, close to the photosphere or recently engulfed



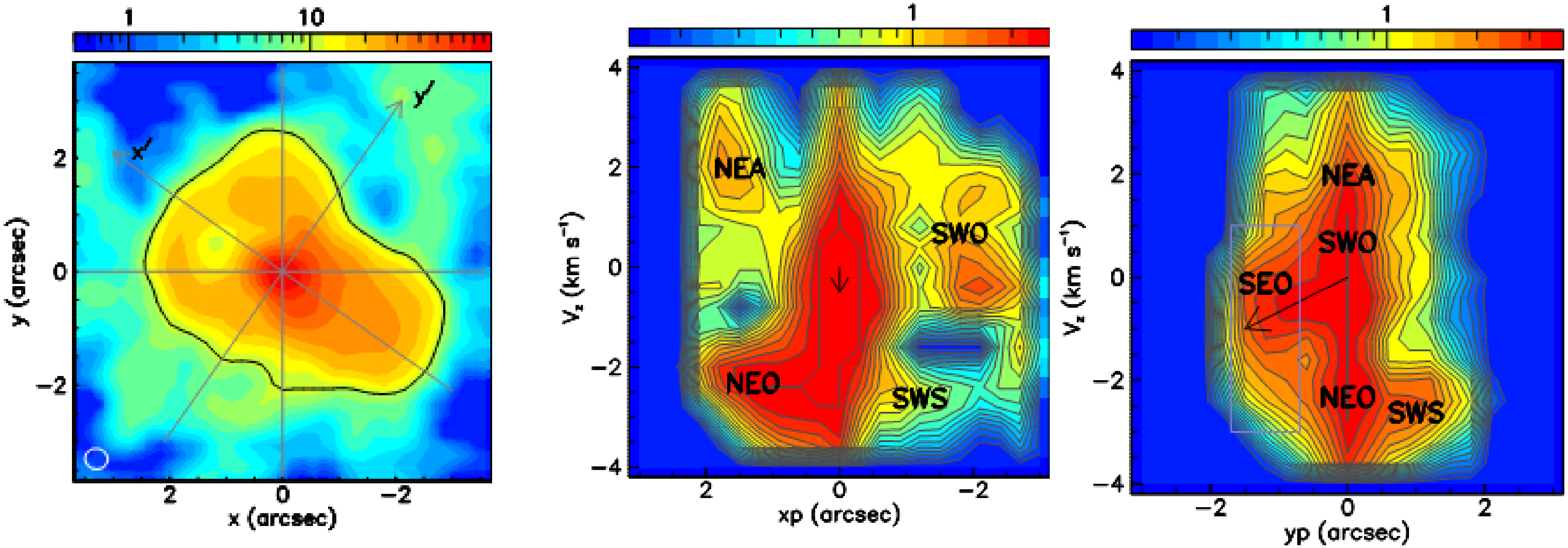
3<R<6 au

6<R<9 au

9<R<12 au

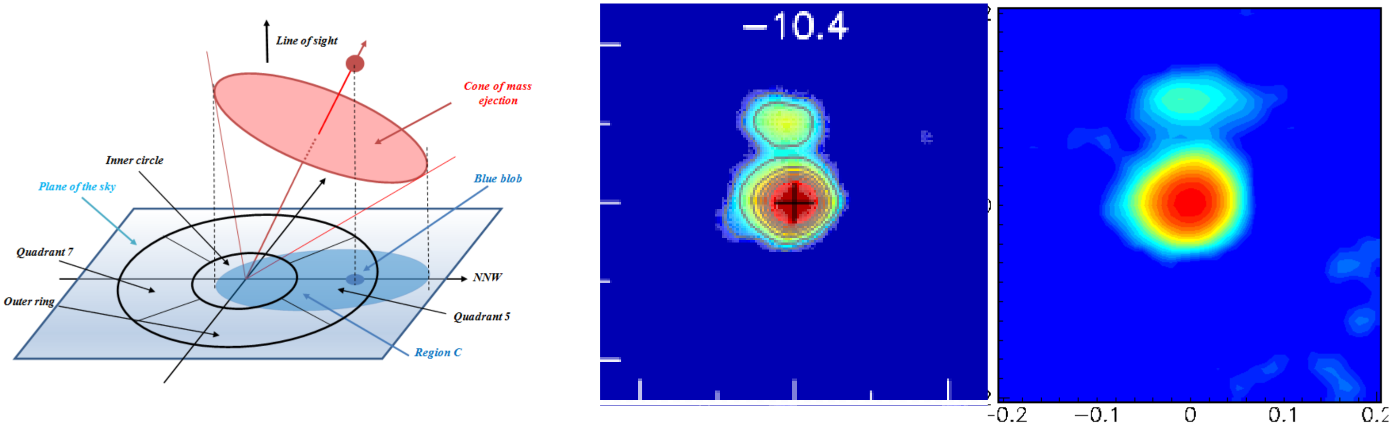
R Dor, Hoai (2020), Nhung (2021)

Gas outflows are seen to cover steradian scale solid angles and point for decades in the same direction. Mass loss is found to be enhanced over periods of several years. An interpretation in terms of convective cells faces the difficulty to reconcile such time scales with the much faster variability observed over the stellar disc.

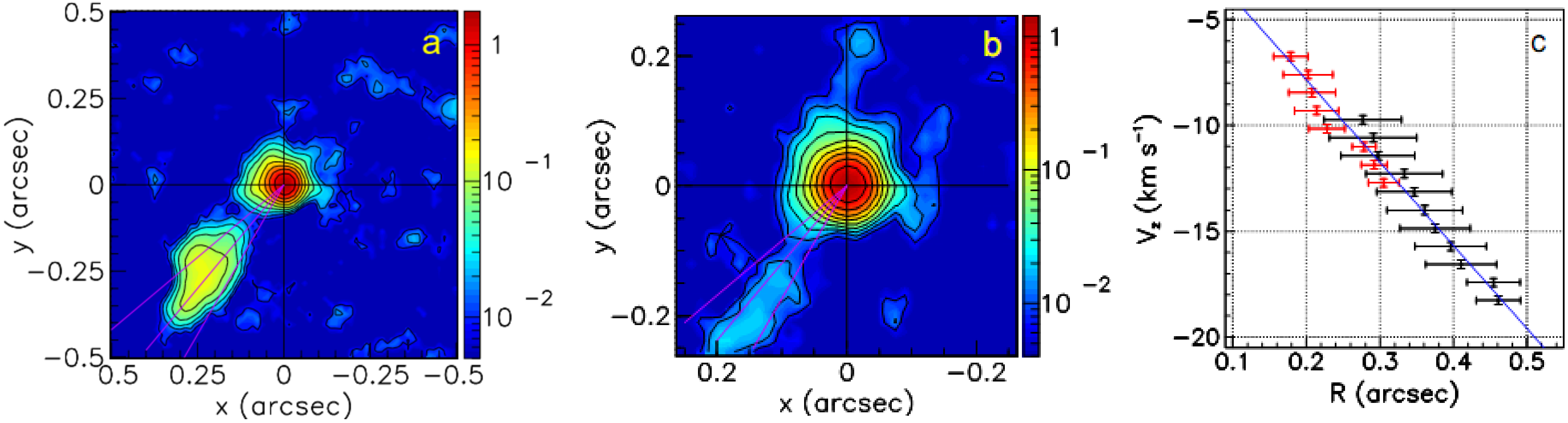


o Cet, Nhung (2022)

Occasional mass emissions of short duration are also observed. It is not clear whether they are or not of a fundamentally different nature



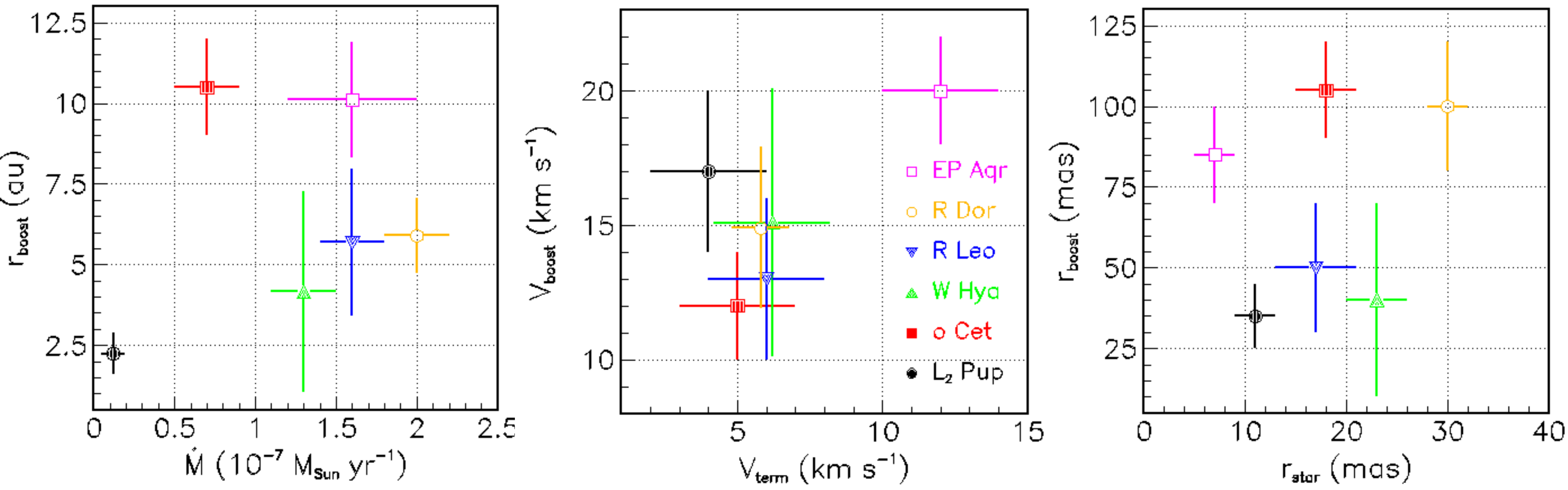
W Hya, Hoai (2022), ^{29}SiO(8-7) and CO(3-2) channel maps



R Dor, Hoai (2020), Nhung(2021), ^{29}SiO and SO$_2$ emissions

Summary and conclusion

The diversity of observations, each star appearing as a singular case, makes it difficult to identify common features with confidence.



The presence of rotation near the photosphere, and of planetary or stellar companions orbiting the mass-losing star, seem to have little impact on the formation of the nascent wind.

In general, observations support current ideas on the mechanisms presiding over the formation of the nascent wind, but quantitative confirmation is still lacking.

In particular the dependence on stellar phase of the morpho-kinematics at stake near the photosphere needs to be studied and the apparent contradiction between its high variability and the persistence of anisotropy at large distances over many decades needs to be understood.

The complexity of the dynamics at stake cannot be ignored and the importance of the time dependence of the mass-loss rate needs to be taken in proper account when attempting a global description of the evolution of the CSE.

THANK YOU FOR YOUR ATTENTION!