Hα emission stars in the Gaia-ESO survey

Tomaž Zwitter, Gregor Traven, Sophie Van Eck, Janez Kos, GES collaboration

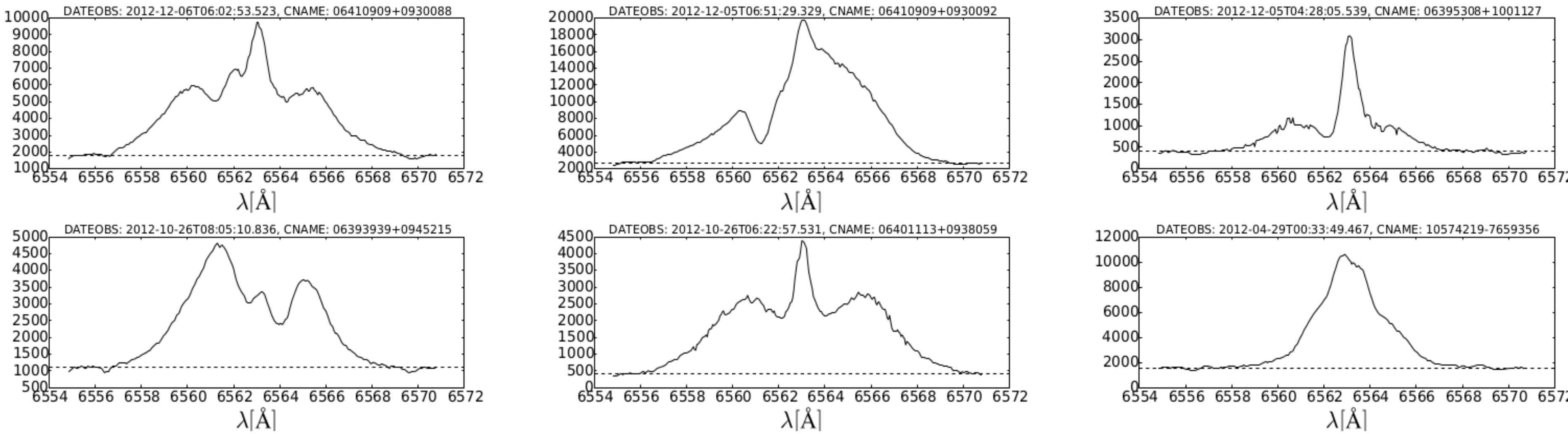
- The title is much too ambitious, will be just a report on activities of WG14.
- A lot of work is being done by other WGs (WG12: Lanzafame et al. 2014, talks of Sara Bonito and Antonio Frasca yesterday): not part of this talk.

<u>Talk plan</u> (Traven et al. 2014, revised version):

- Morphological parametrization of Hα profiles.
- Categorization of Hα profiles.
- Are categorizations stable with time, so that a single observation of an object is enough to categorize the type of its profile?
- This is NOT about membership of clusters (hot topic of this conference), but I will mention how Hα emission and properties of the interstellar medium in front of the cluster can help with membership tests.

Spectra morphology

Hα spectra (HR15N) of 12392 stars observed with Giraffe from iDR 2.1 and 3 were searched for intrinsic emission which was found in 3690 objects.

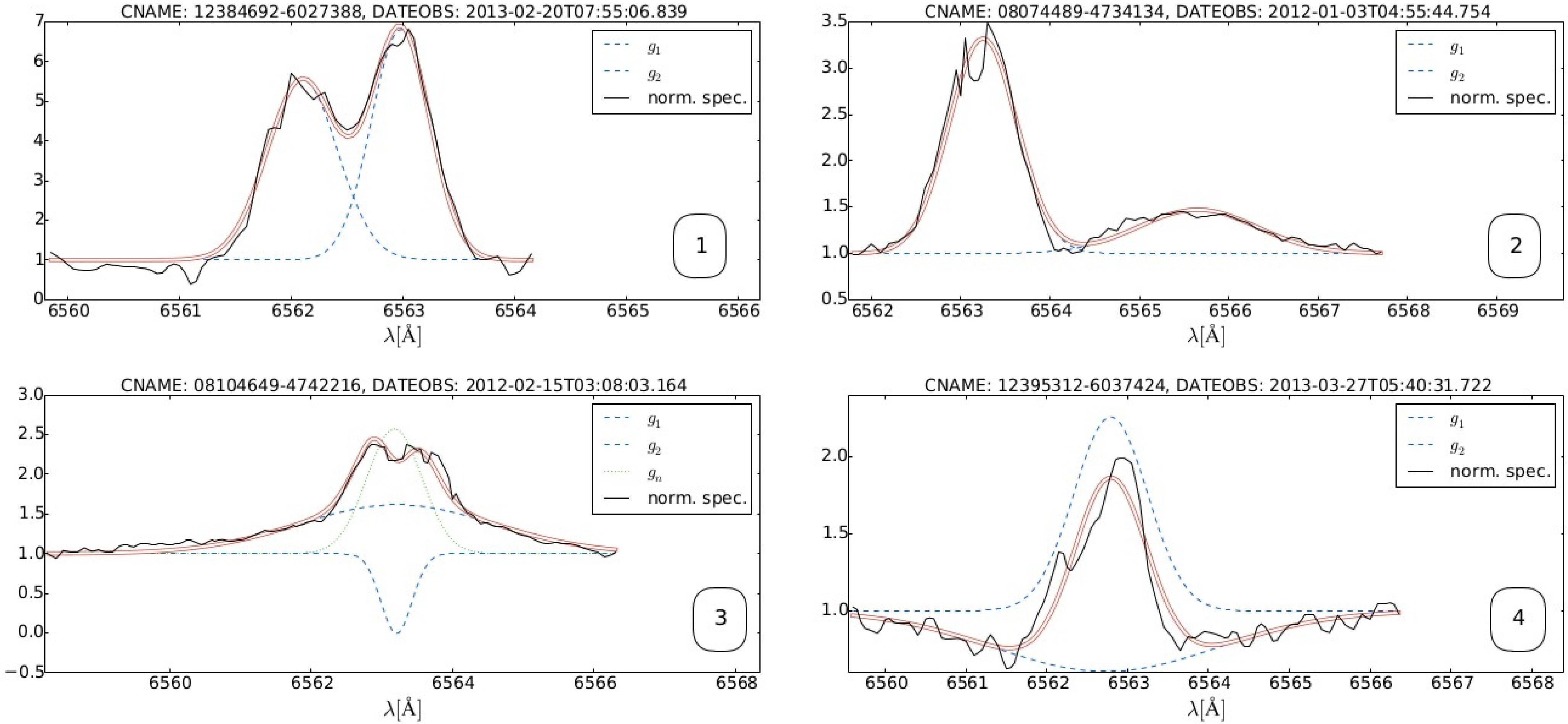


Examples of GES spectra with Hα in emission before normalization and sky subtraction, plotted in heliocentric wavelengths. Dashed lines mark the adopted continuum level.

A simple morphological scheme to fit these lines was adopted using:

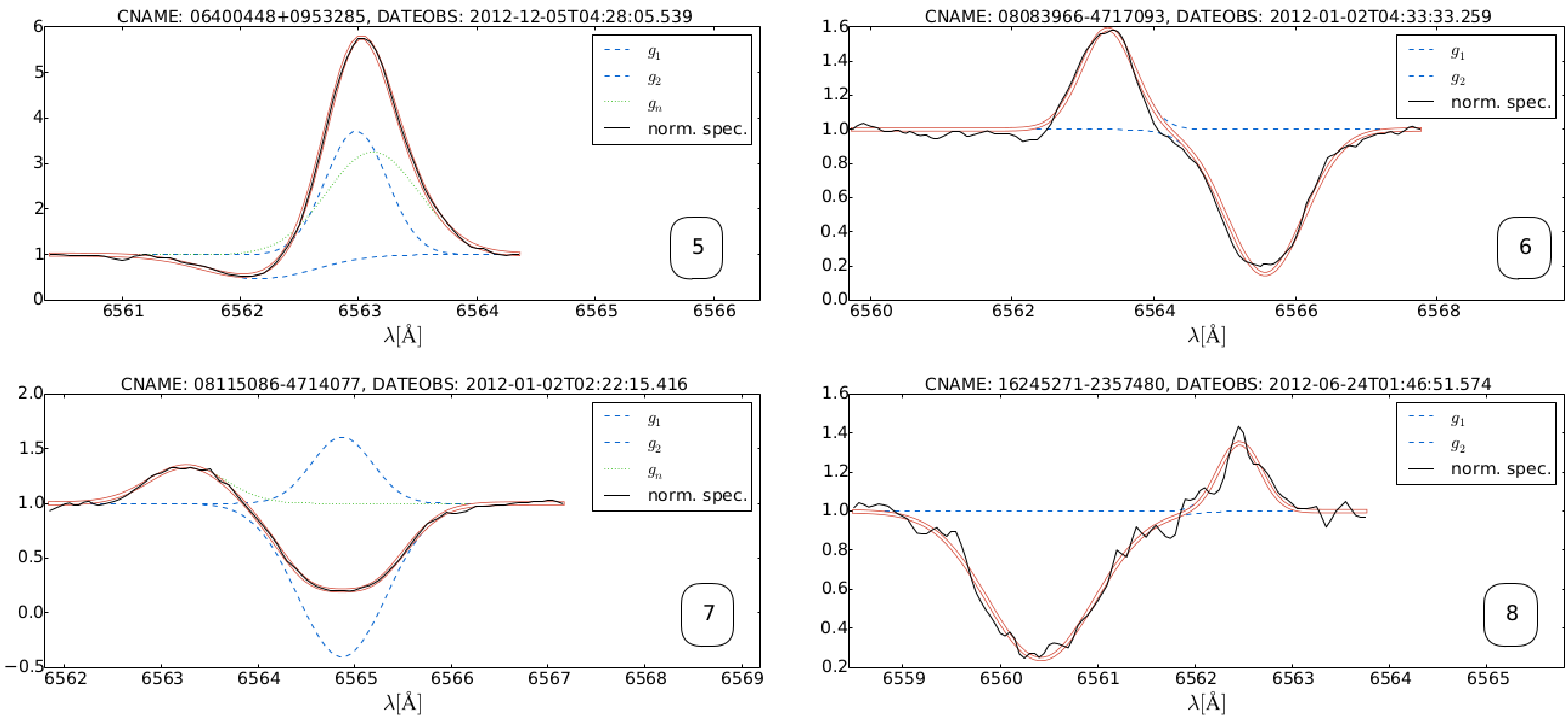
- one or two Gaussians representing the intrinsic emission/absorption, and
- an optional third one representing the nebular component (4049 spectra out of 22035), with position & width (nearly) fixed by [N II] emission lines in the object spectrum or Hα present in the sky spectra from the region surrounding the object.

Examples of morphological fits



This simplified morphological scheme allows an adequate fit to most observed Hα profiles.

Examples of morphological fits



This simplified morphological scheme allows an adequate fit to most observed Hα profiles.

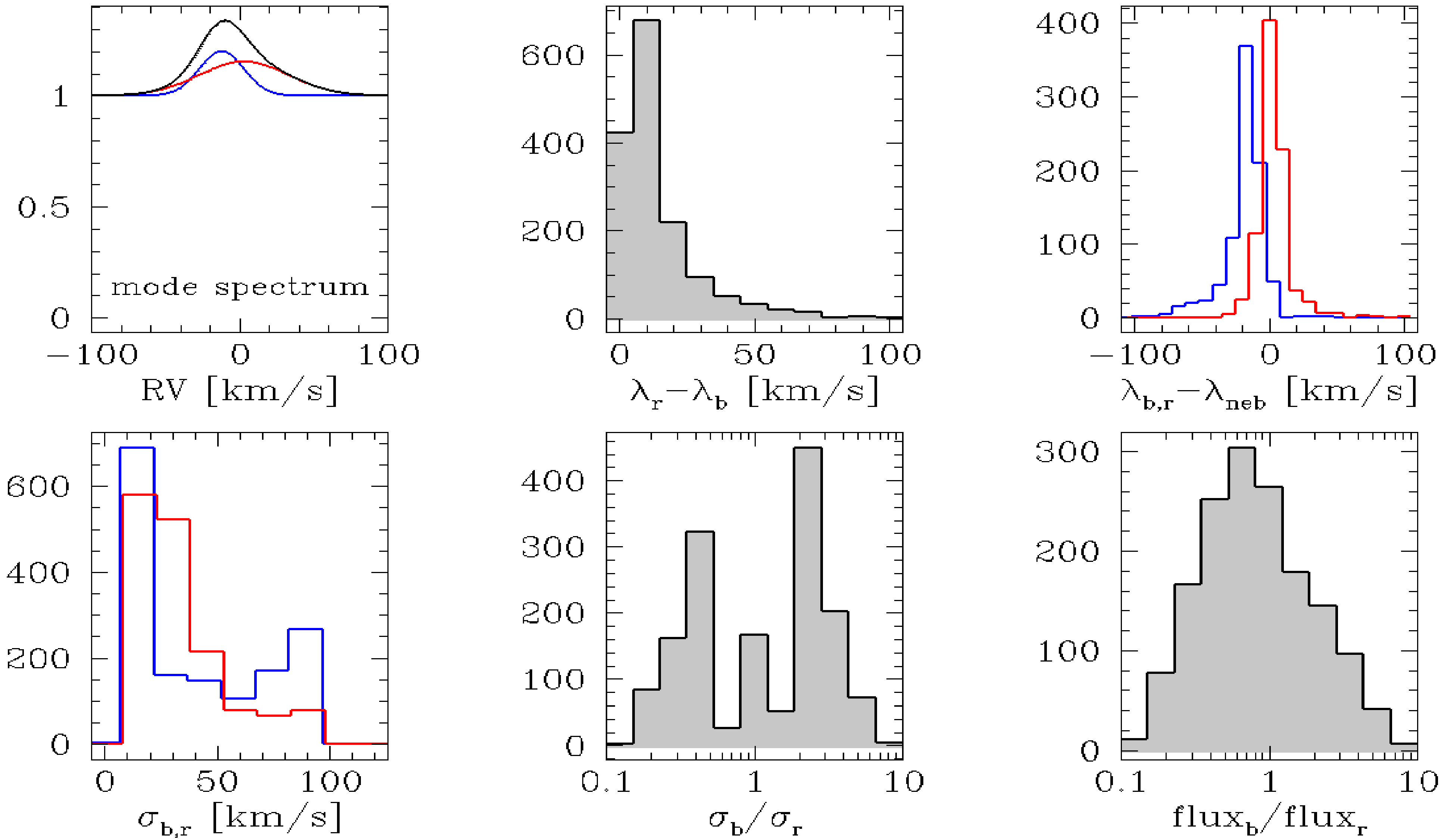
Classification of morphological fits

8 categories are established which have some correspondence to underlying physics.

Category	Components	Condition_1	Condition_2	objects	fraction
single_Em	Em			518	14.4%
Em_blend	Em_1+Em_2	$\lvert\lambda_1-\lambda_2\rvert \leq 0.9\ (\sigma_1^2+\sigma_2^2)^{1/2}$		699	19.4%
sharp-peaks	Em_1+Em_2	$\lvert\lambda_1-\lambda_2\rvert > 0.9\ (\sigma_1^2+\sigma_2^2)^{1/2}$	$\lvert\lambda_1-\lambda_2\rvert < 50$ km/s	364	10.1%
double_Em	Em_1+Em_2	$\lvert\lambda_1-\lambda_2\rvert > 0.9\ (\sigma_1^2+\sigma_2^2)^{1/2}$	$\lvert\lambda_1-\lambda_2\rvert \geq 50$ km/s	121	3.3%
P-Cygni	Em+Abs	$\lambda_{Em}-\lambda_{Abs} > 0.9\ (\sigma_{Em}^2+\sigma_{Abs}^2)^{1/2}$		90	2.5%
InvP-Cygni	Em+Abs	$\lambda_{Abs}-\lambda_{Em} > 0.9\ (\sigma_{Em}^2+\sigma_{Abs}^2)^{1/2}$		353	9.8%
Self-Abs	Em+Abs	$\lvert\lambda_{Abs}-\lambda_{Em}\rvert \leq 0.9\ (\sigma_{Em}^2+\sigma_{Abs}^2)^{1/2}$	$\sigma_{Abs} < \sigma_{Em}$	500	13.9%
Em_in_Abs	Em+Abs	$\lvert\lambda_{Abs}-\lambda_{Em}\rvert \leq 0.9\ (\sigma_{Em}^2+\sigma_{Abs}^2)^{1/2}$	$\sigma_{Abs} \geq \sigma_{Em}$	959	26.6%
				3604	100%

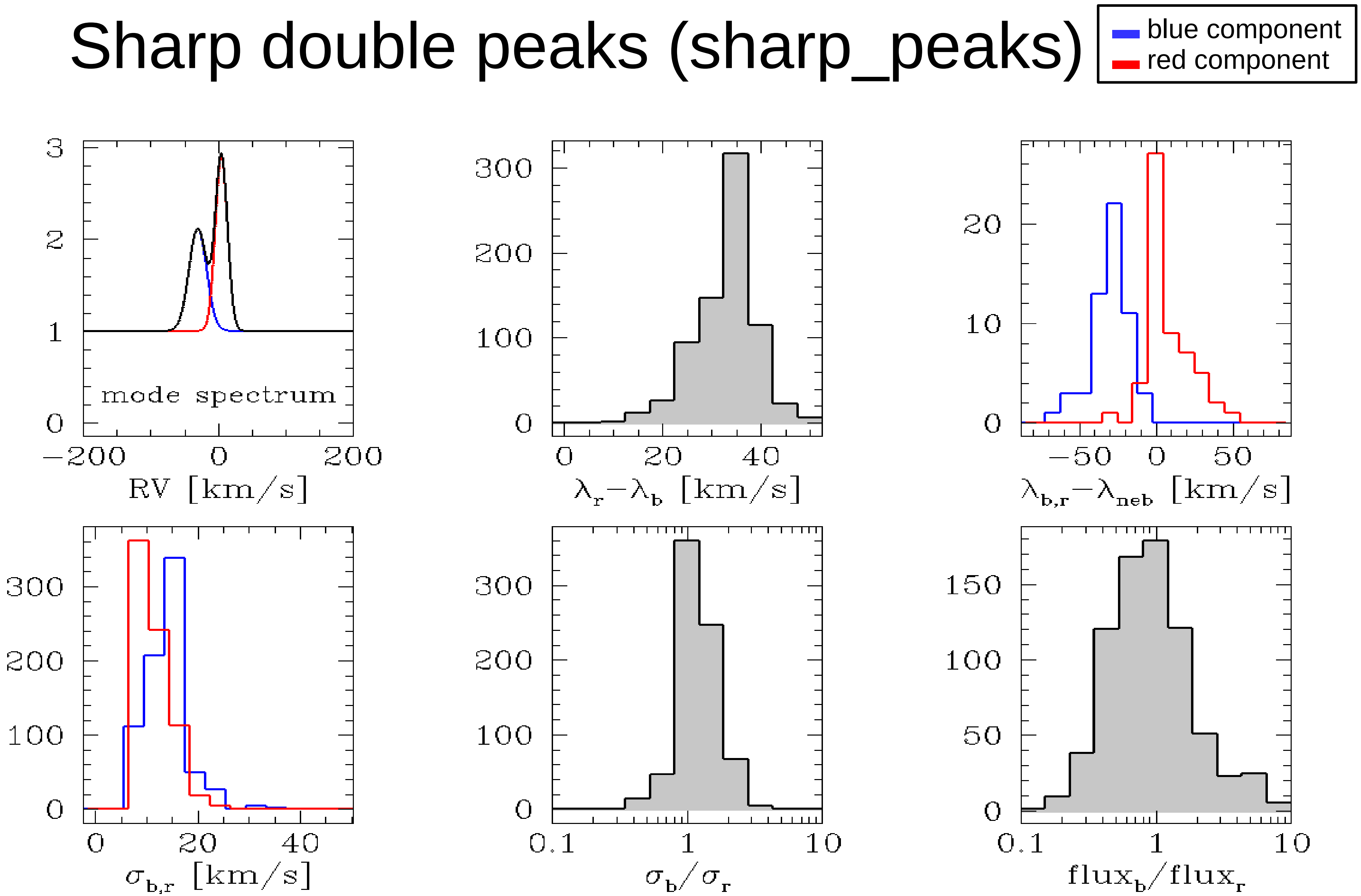
Factor 0.9 satisfies physics arguments and minimizes category changes for repeated observations.

Emission blends (Em_blend)



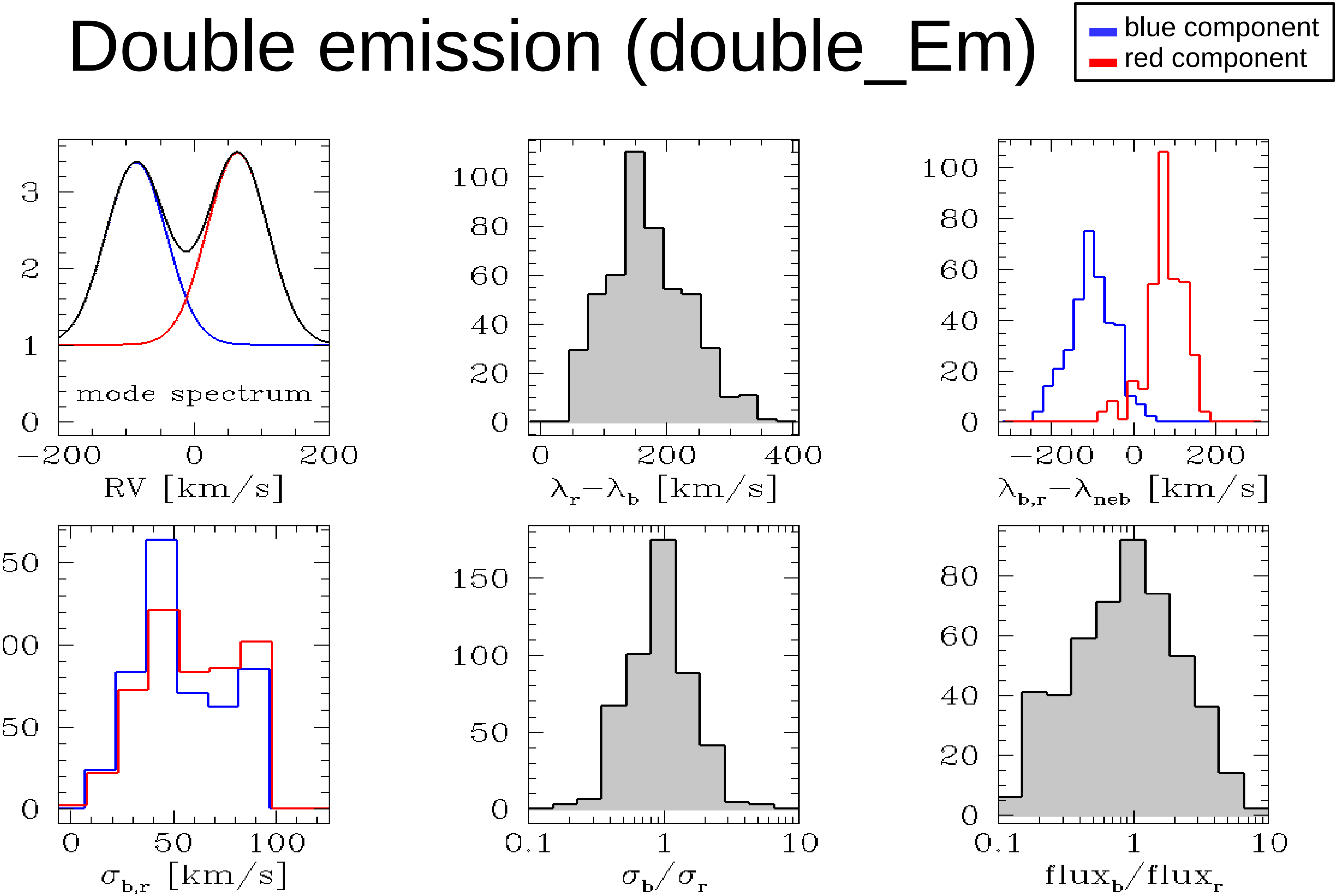
- A slowly falling wing of the profile on either side.
- Widths of components can be very different.
- Red component centred on nebular velocity, so the blue one due to an approaching wind (?).

Sharp double peaks (sharp_peaks)



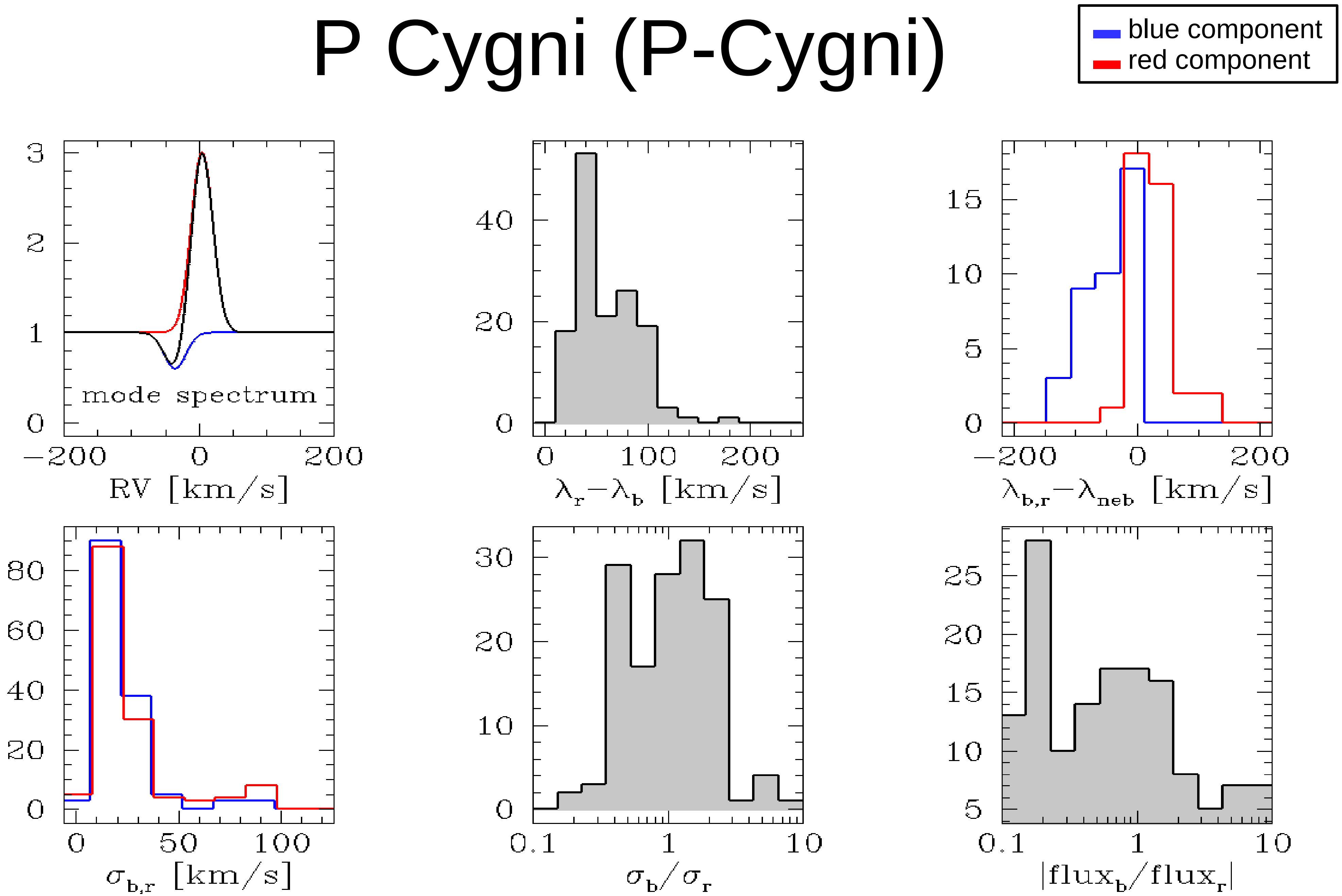
- Peaks at separations between 20 and 40 km/s.
- The redder and sharper component normally centred on nebular velocity.
- Is the red peak of nebular origin and only the blue one is intrinsic (again due to wind)?

Double emission (double_Em)



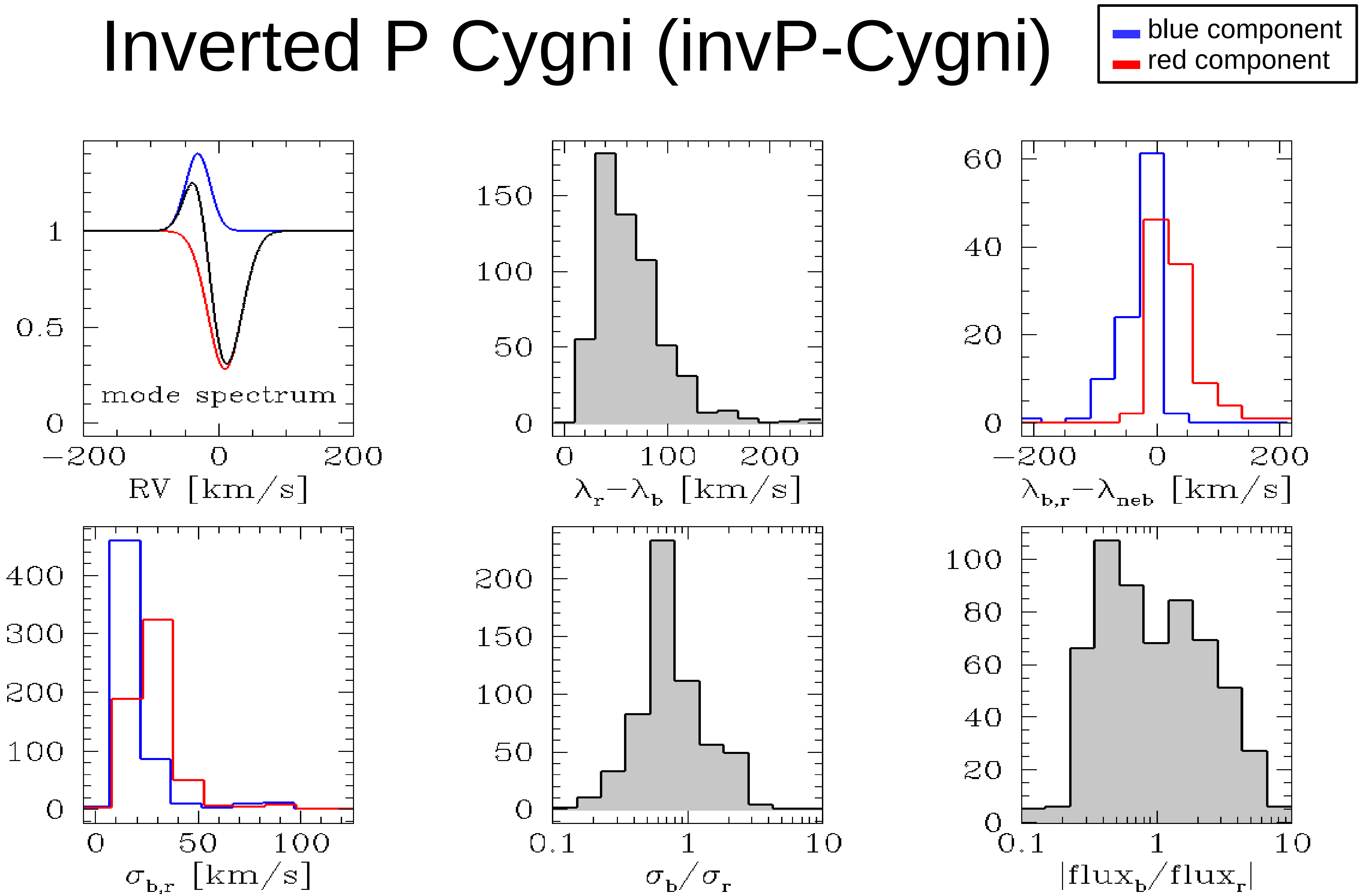
- Peaks at separations between 100 and 250 km/s.
- Widths are between 25 and 100 km/s – well separated peaks.
- Distributions of width and flux ratios are symmetric: (accretion) disks, conic in/outflows (?).

P Cygni (P-Cygni)



- Red peak roughly at systemic (nebular) velocity (as expected).
- Absorption component usually weaker (as expected).
- Terminal expansion velocity up to ≈200 km/s.

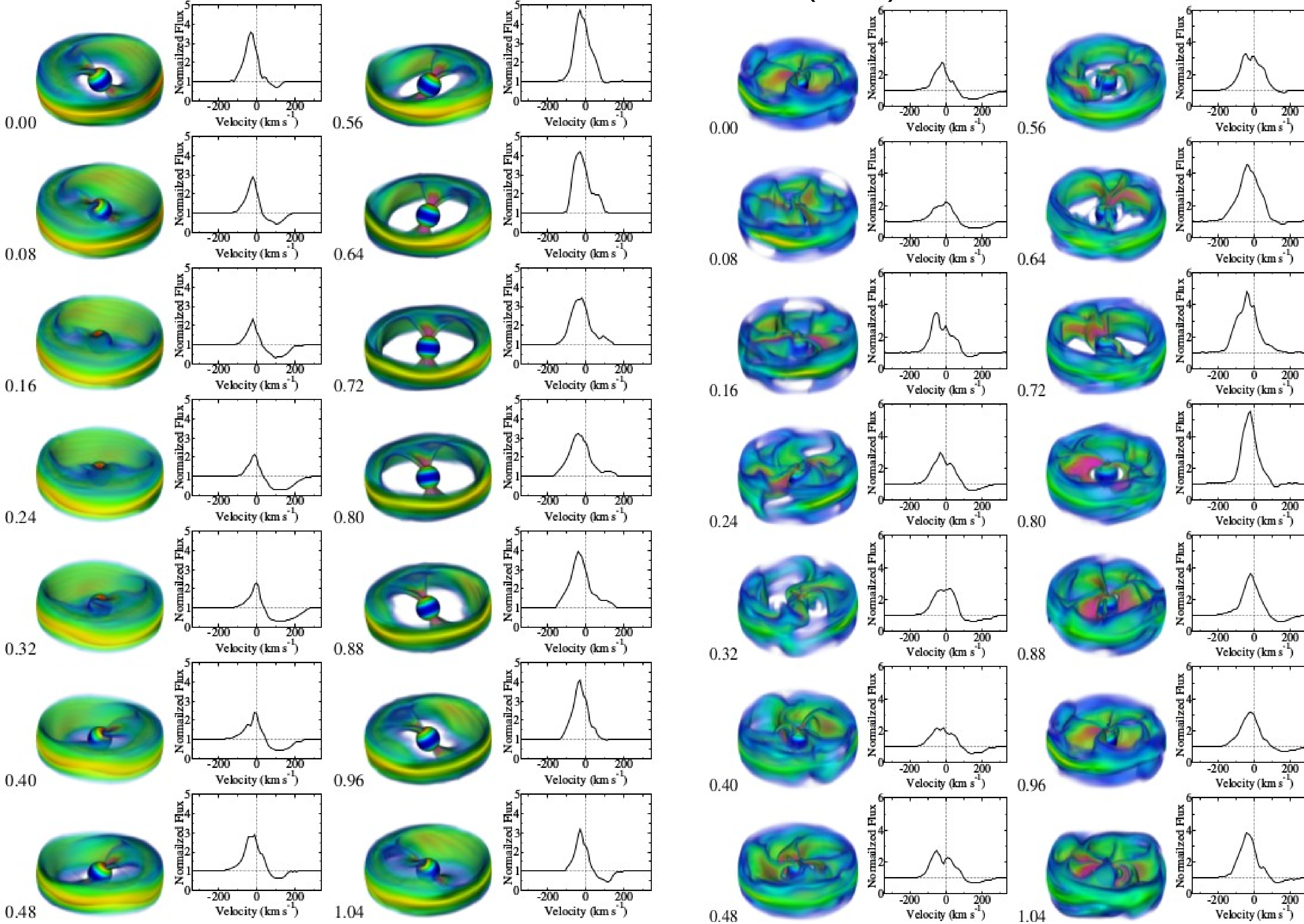
Inverted P Cygni (invP-Cygni)



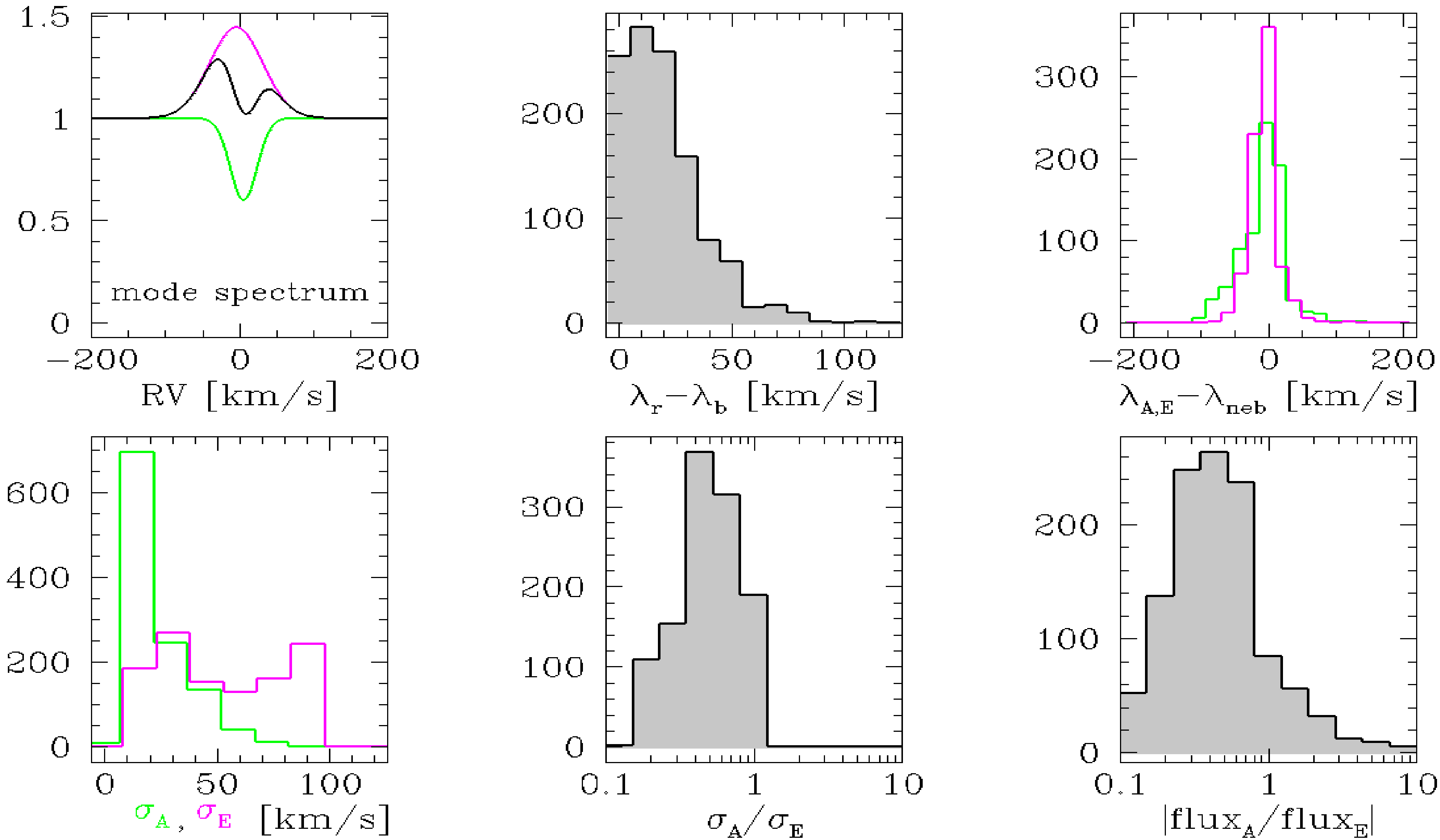
- Absorption is wider, but velocity separation of components is mostly small.
- Flux ratio of emission and absorption has a large span.
- Radial infall is not the only possibility, a ring misaligned vs. the line-of-sight?

Inverted P Cygni in T Tauri stars

Stable accretion   Kurosawa & Romanova (2013)   Unstable accretion

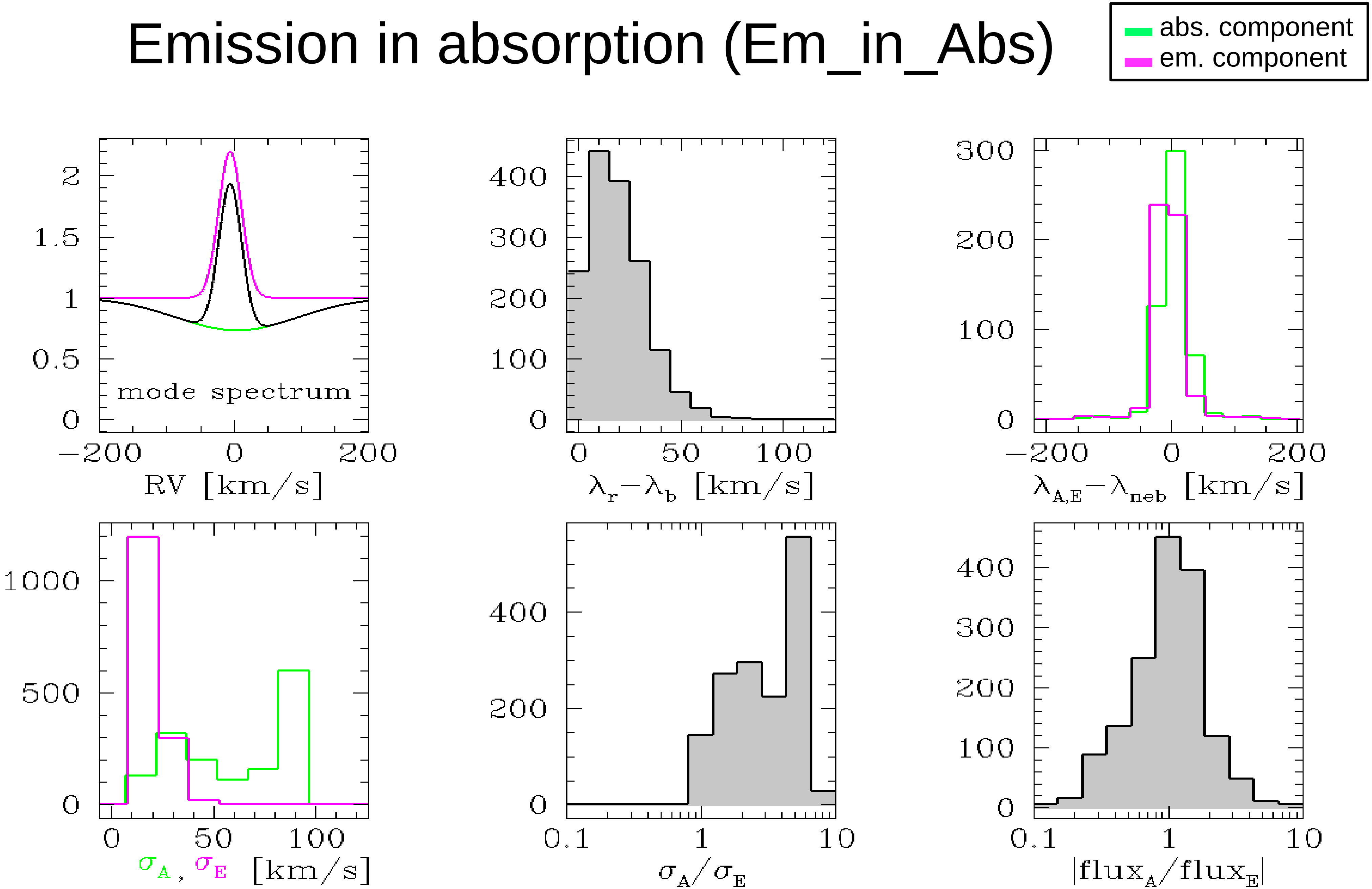


Self absorption (self_Abs)



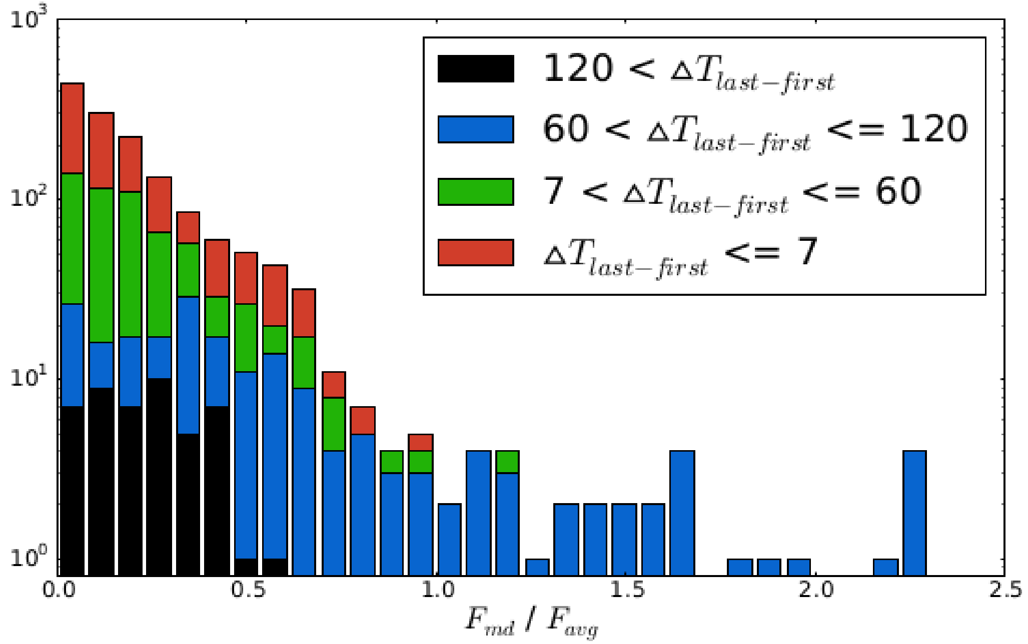
- Emission (magenta) centred on the nebular (=star) velocity.
- Absorption can be a bit blue/red shifted.
- Morphology similar to a shrank version of P-Cyg and inverted P-Cyg profiles.

Emission in absorption (Em_in_Abs)



- Absorption may be normal stellar H alpha absorption.
- Narrow emission (magenta) is moderately blueshifted, unclear why.
- Flux ratio has a large span, either component may be dominant.

Repeated observations



We have more than one Hα spectrum for 1431 out of 4459 unique emission type objects.

Distribution of variability F_{md}/F_{avg} for 1431 objects with more than 1 exposure. The histogram shows four groups of different timespans. F_{md} is the maximum of $(F_{min} - F_{avg}, F_{max} - F_{avg})$ where F_{avg} is the average flux of all exposures for a certain object. Objects with the longest timespan of exposures (white) show little variability, while some of those with the shortest timespan (black) exhibit significant variability. Objects from the second longest timespan group (light gray) display small as well as the largest variability in the histogram.

N exp.	1	2	3	4	5	6	7	8
N spec.	3028	785	295	149	55	17	9	1

N exp.	10	11	12	15	16	18	19	20	21
N spec.	1	2	2	1	4	2	14	90	4

Number of objects with a given number of exposures.

Categorization of repeated observations

Is the proposed classification of a given object with 2 Gaussians stable with time?

If the prevalent category is	---Fractions of categorizations of the same object---						
	Em_blend	sharp_peaks	double_Em	P-Cygni	invP-Cygni	self_Abs	Em_in_Abs
Em_blend	<u>84.9%</u>	1.0%	1.6%	0.5%	0.6%	10.6%	0.8%
sharp_peaks	1.4%	<u>80.9%</u>	0.1%	0.4%	3.9%	3.8%	9.4%
double_Em	5.3%	0.6%	<u>72.0%</u>	1.4%	0.0%	18.4%	1.3%
P-Cygni	1.3%	7.3%	1.3%	<u>68.8%</u>	3.0%	1.8%	16.5%
InvP-Cygni	0.6%	4.8%	0.1%	0.3%	<u>80.7%</u>	3.0%	10.5%
self_Abs	10.6%	4.8%	6.0%	1.0%	2.4%	<u>72.1%</u>	3.1%
Em_in_Abs	0.3%	4.3%	0.1%	1.8%	5.3%	1.9%	<u>86.3%</u>

So in ~81% of the cases the categorization stays stable with time.

Relation to the literature (Simbad, Vizier,...)

See also the talk by Sara Bonito yesterday.

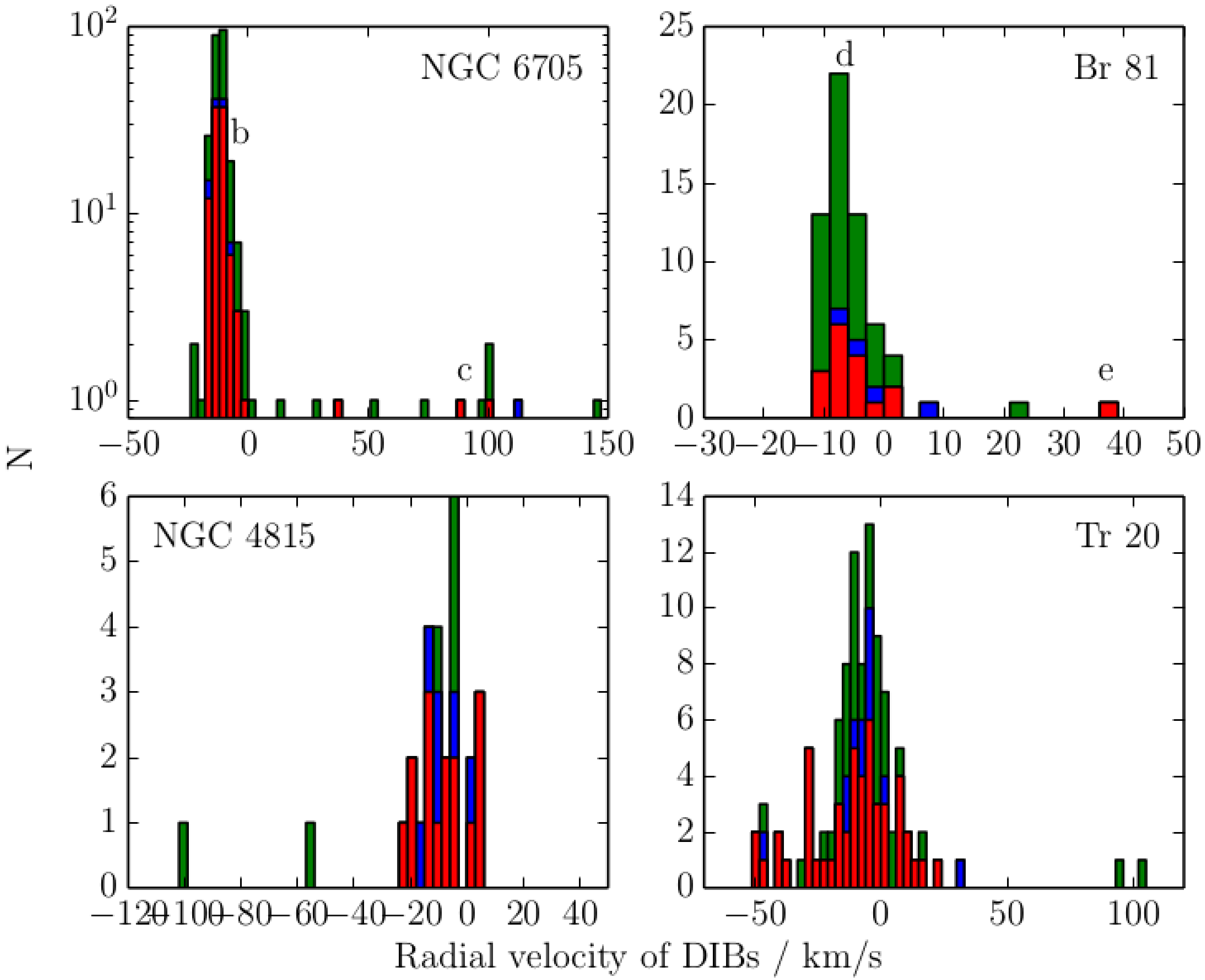
N	otype
1025	Star in Cluster
356	Star
244	Young Stellar Object
198	Variable Star of Orion Type
177	Low-mass star (M<1solMass)
131	Young Stellar Object Candidate
85	Pre-main sequence Star
75	T Tau-type Star
73	Pre-main sequence Star Candidate
61	Emission-line Star
47	Infra-Red source
20	X-ray source
16	Flare Star
5	Variable Star
3	Radio-source
2	Brown Dwarf (M<0.08solMass)
2	Brown Dwarf Candidate
2	Carbon Star

N	otype
2	Cepheid variable Star
2	Eclipsing binary of W UMa type (contact)
2	Herbig-Haro Object
2	Open (galactic) Cluster
2	Red Giant Branch star
2	Variable Star of Mira Cet type
1	Be Star
1	Dark Cloud (nebula)
1	Double or multiple star
1	Eclipsing binary
1	HII (ionized) region
1	millimetric Radio-source
1	Object of unknown nature
1	Rotationally variable Star
1	Spectroscopic binary
1	sub-millimetric source
1	Variable of BY Dra type
1	White Dwarf Candidate

A new method based on the interstellar medium for cluster membership rejection

Histogram of diffuse interstellar band radial velocities.

Likely members as judged by other methods are red.



Kos et al. 2014 (a GES paper).

Relation to cluster membership

Most objects with intrinsic Hα emission are cluster members

↓

Intrinsic Hα emission supports membership.

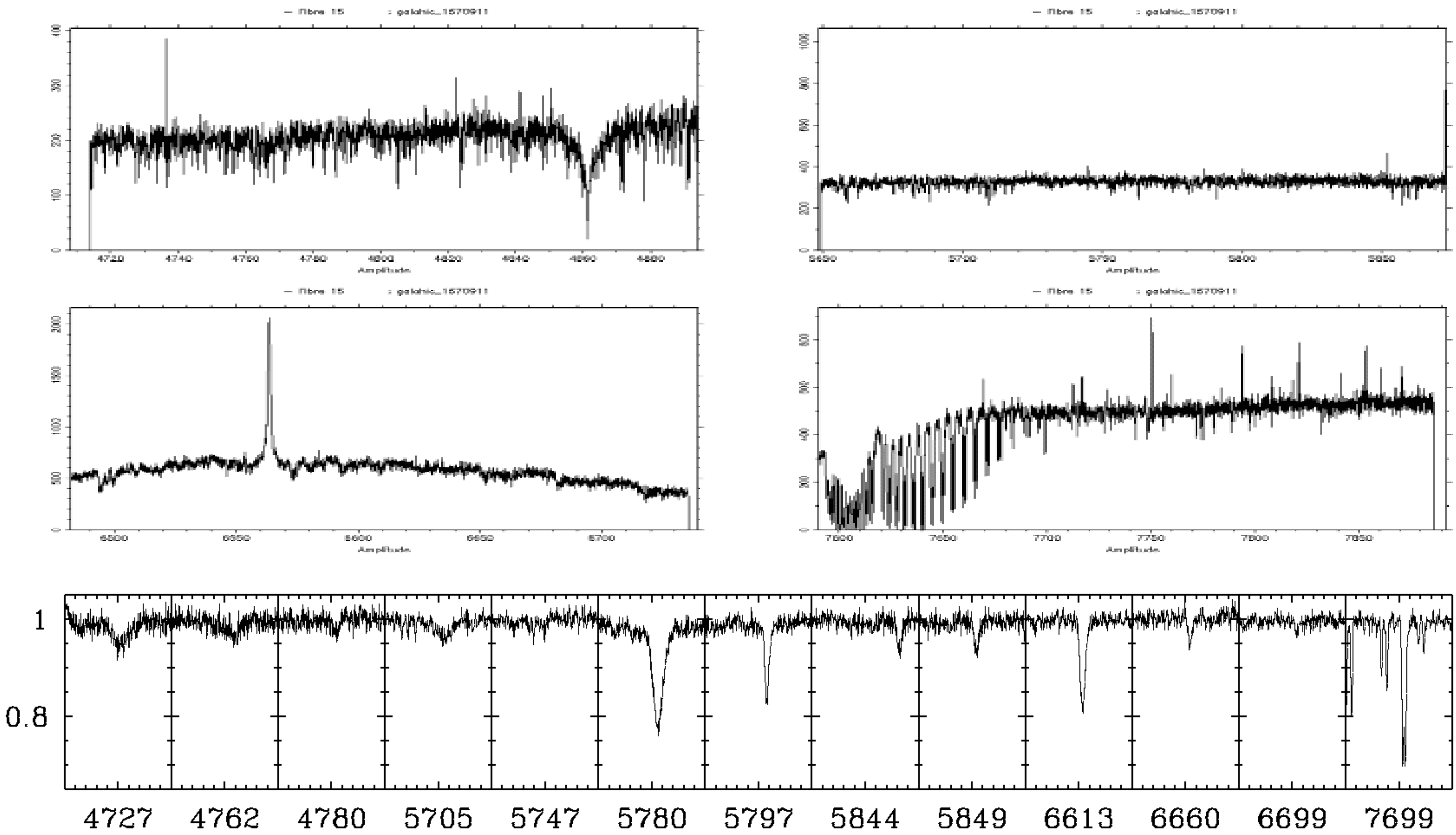
but also a new method (Kos et al. 2014):

Objects with inconsistent diffuse interstellar bands are not cluster members

↓

Study of interstellar medium is an object-independent criterion to reject cluster membership.

Gaia ESO and Hermes-GALAH complementarity:
a T Tauri star and diffuse interstellar bands observed by the latter



See talk by Sarah Martell on Tuesday.

Conclusions

- Morphological fits and parametrization give useful results.
- Some interesting asymmetries in profiles are seen.
- The work will be expanded to hot stars and UVES observations.
- Emission objects generally young, so (recent) cluster members (yesterday's talk od Dan Zucker). Diffuse interstellar bands can help to reject cluster membership and are independent from physics of the object.