

Linear line Spectropolarimetry of Herbig Ae/Be stars



Jorick S. Vink
(Armagh Observatory)

with special thanks to:

Janet Drew

Tim Harries

Rene Oudmaijer

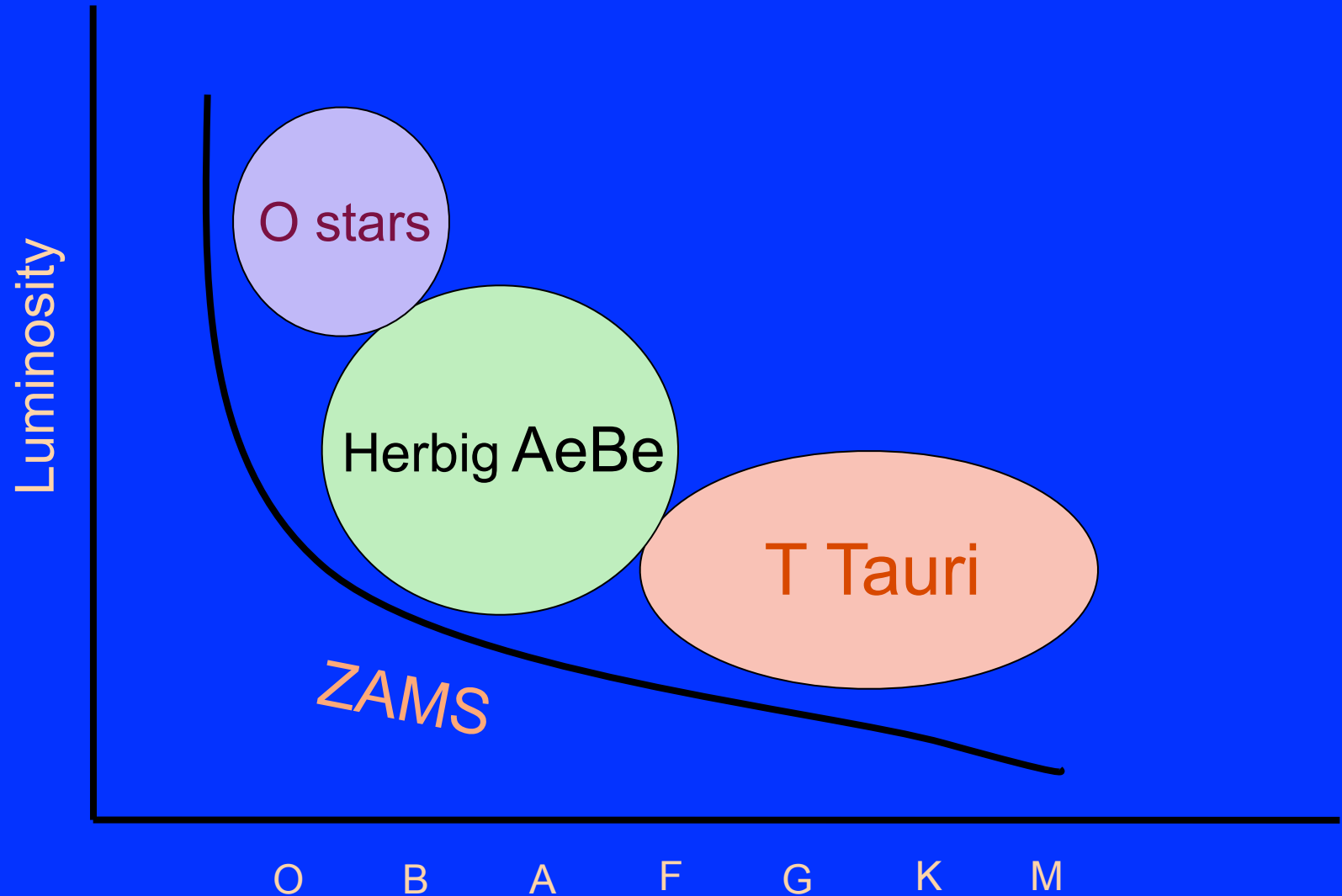
Hugh Wheelwright

Geert Barentsen

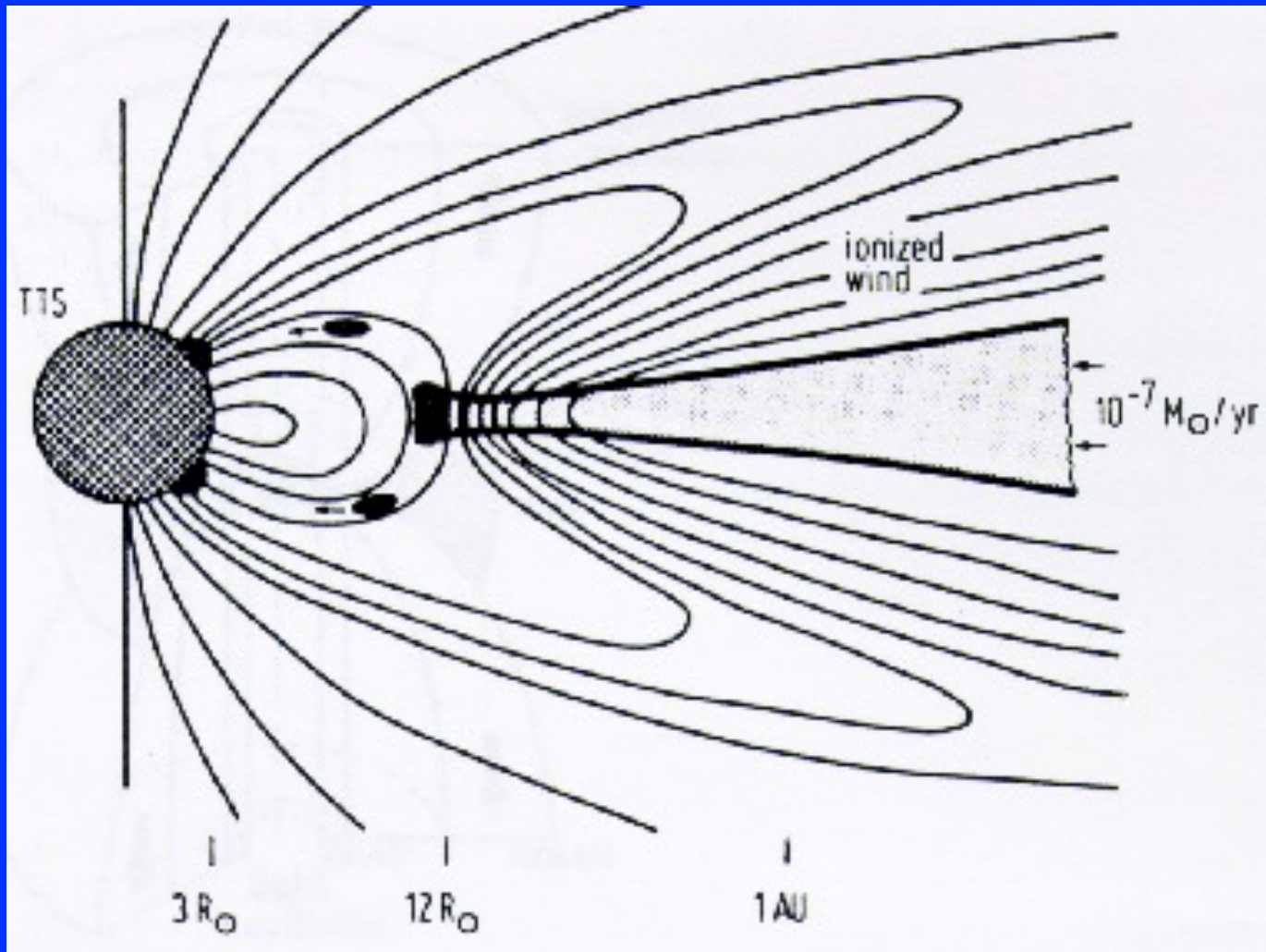
Grainne Costigan

Venu Kalari

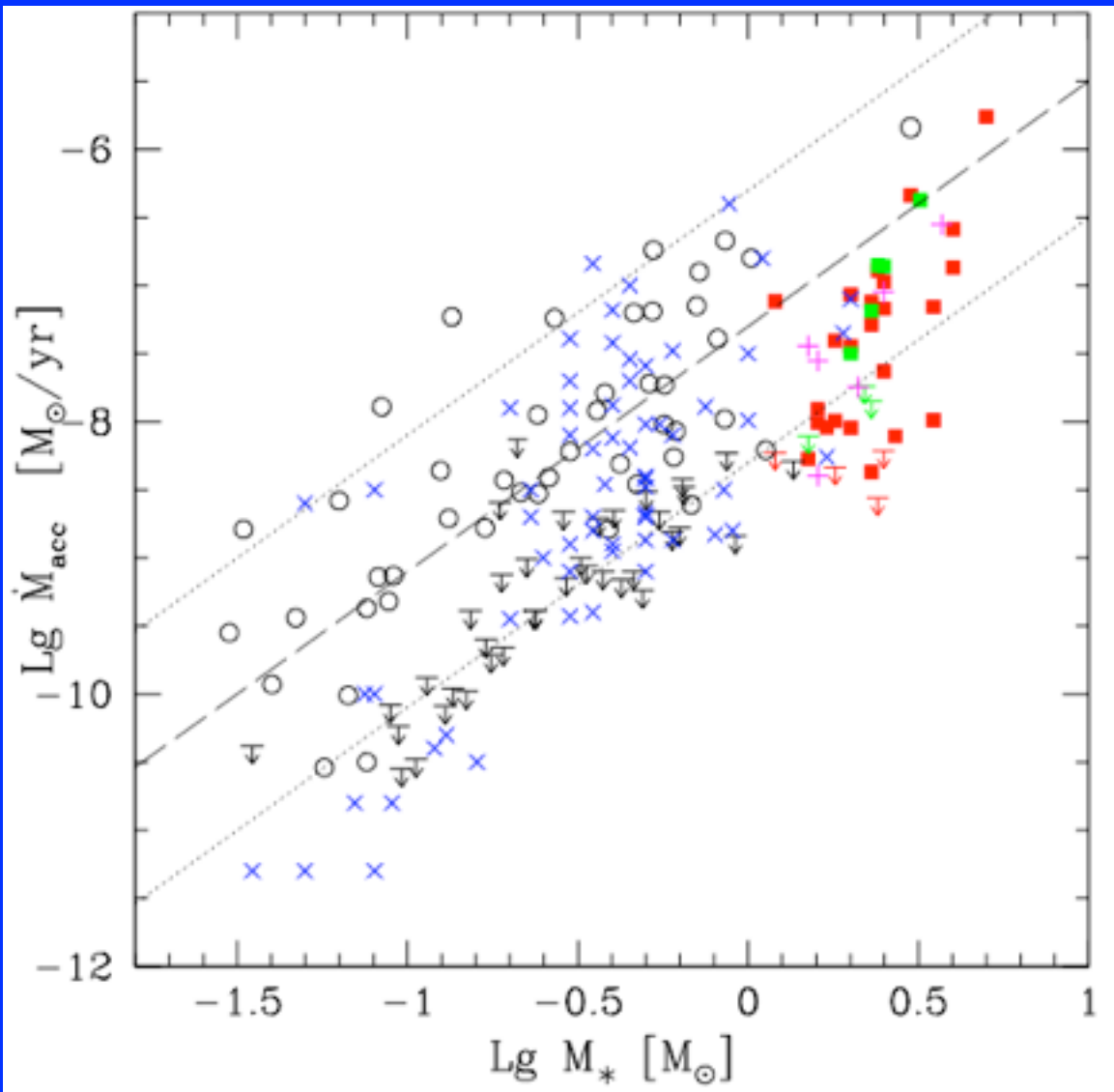
Hertzprung-Russell Diagram



T Tauri stars: Magnetospheric



dM/dt - Mass Relation



(eg. Garcia Lopez et al. 2006)

Questions for Star Formation

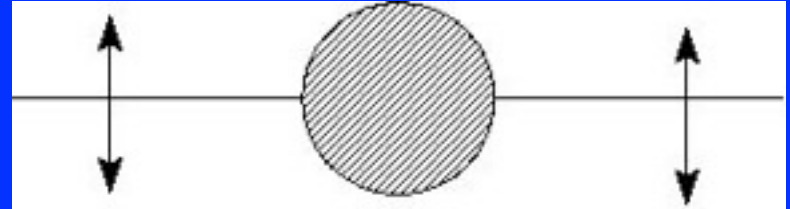
- Do ALL stars form by disk accretion?
- Is there a difference between low- and high-mass star formation?

Outline

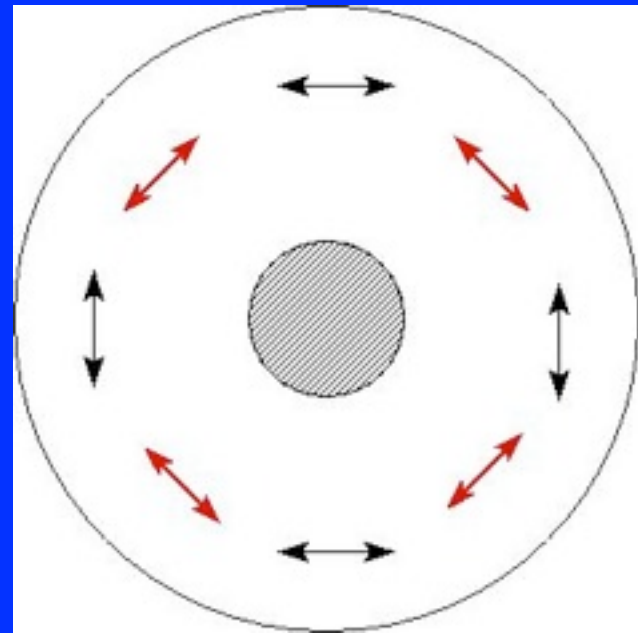
- Tool: Line Polarization versus Depolarization
- Results last decade
- Future Applications

Polarimetry – from disks

$$I$$
$$U = \begin{array}{c} \updownarrow \\ - \\ \rightleftarrows \end{array}$$
$$Q = \begin{array}{c} \nearrow \\ - \\ \searrow \end{array}$$



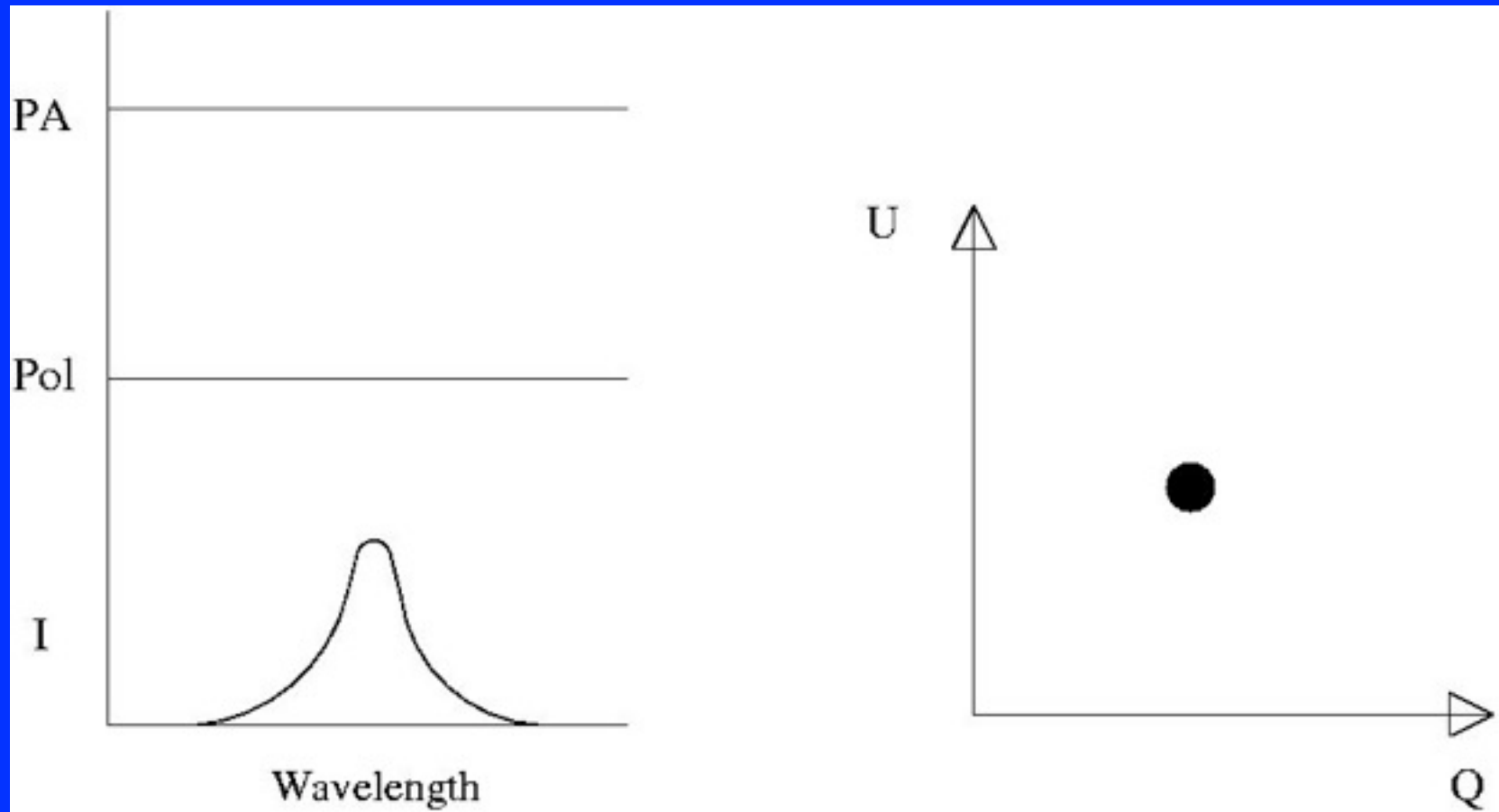
$$P = \sqrt{U^2 + Q^2}$$
$$\theta = \frac{1}{2} \arctan\left(\frac{U}{Q}\right)$$



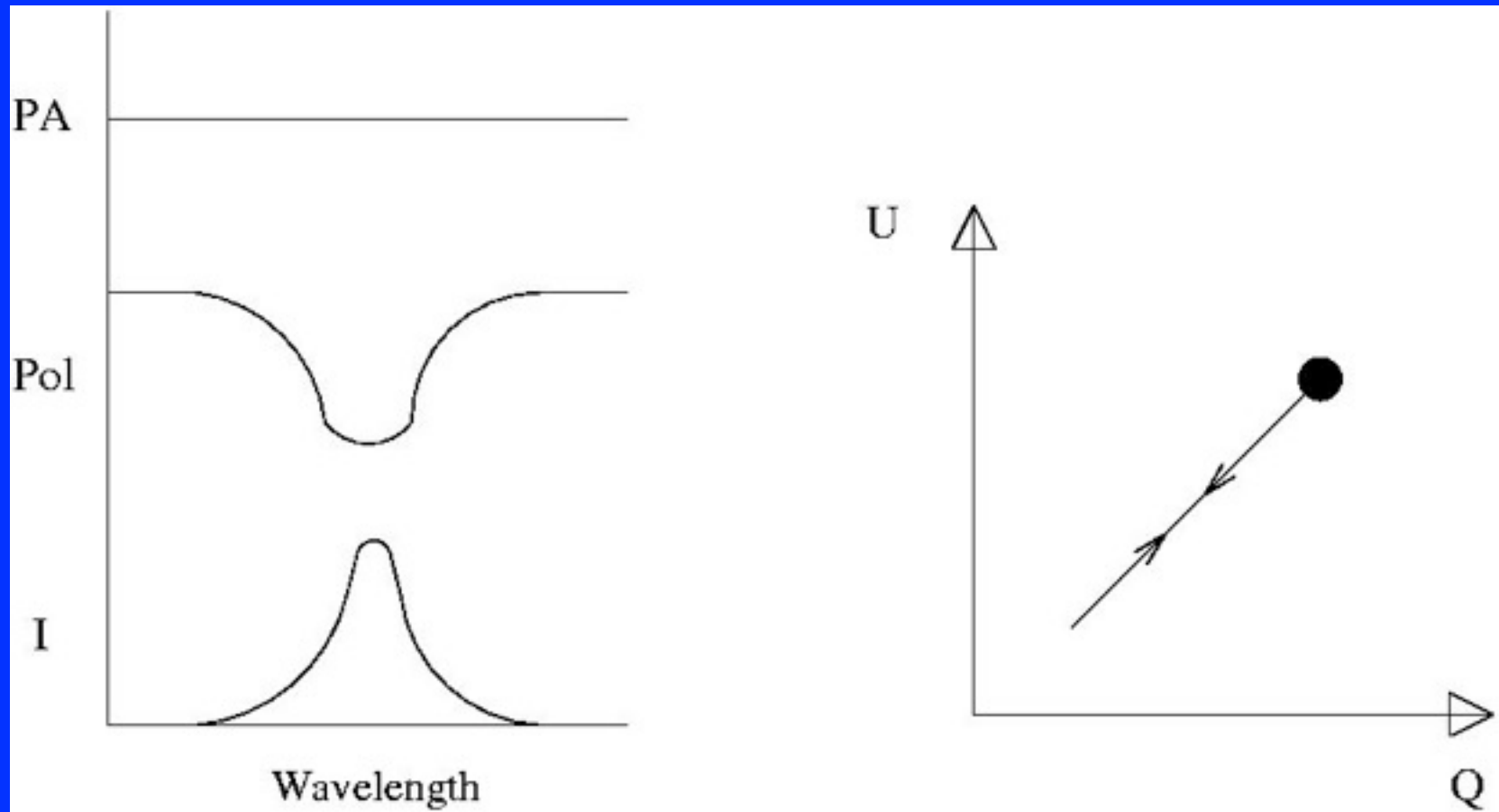
Polarisation across line?

1. No change
2. Depolarisation
3. LINE Polarisation

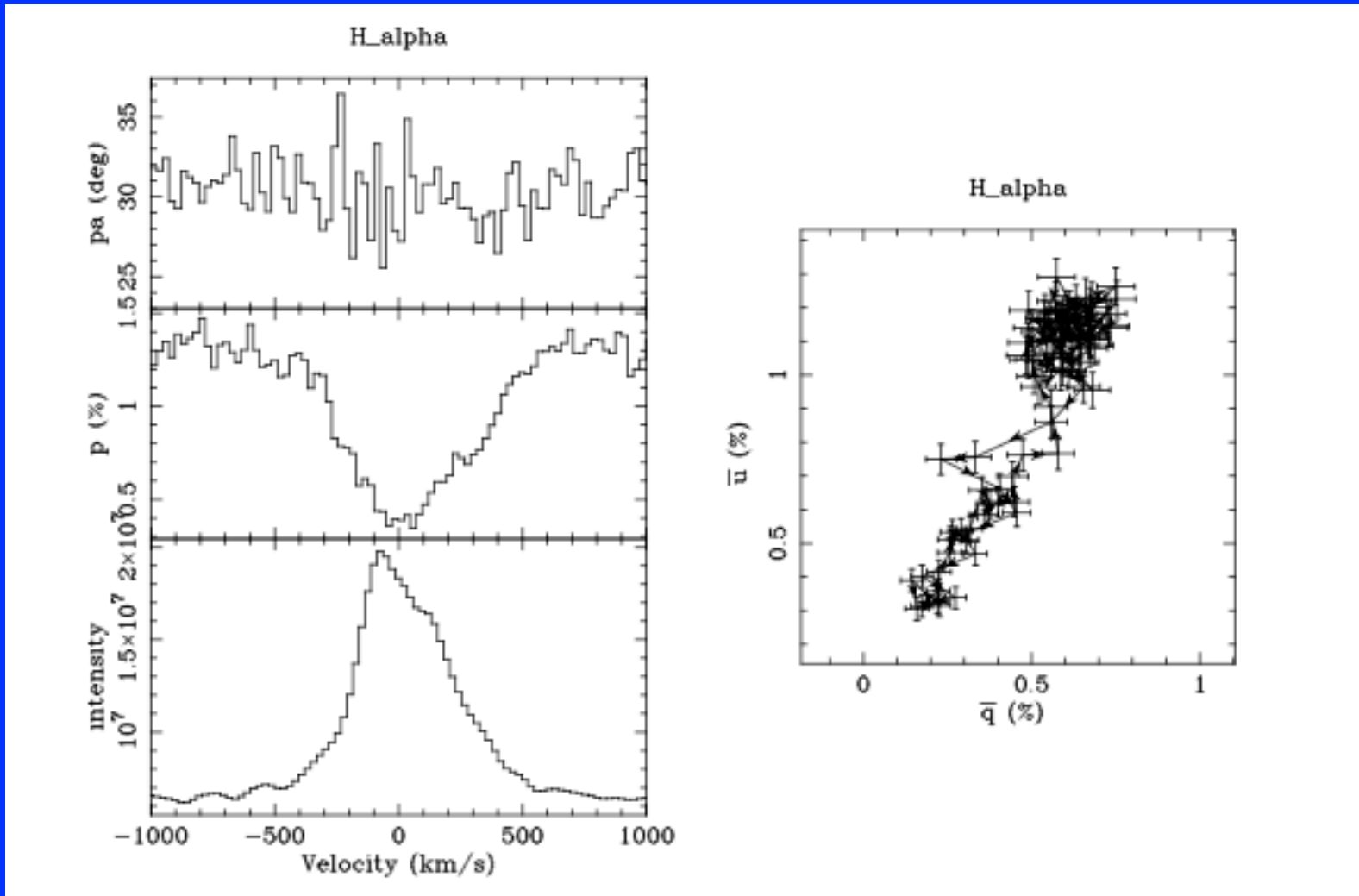
No Polarisation



Depolarisation

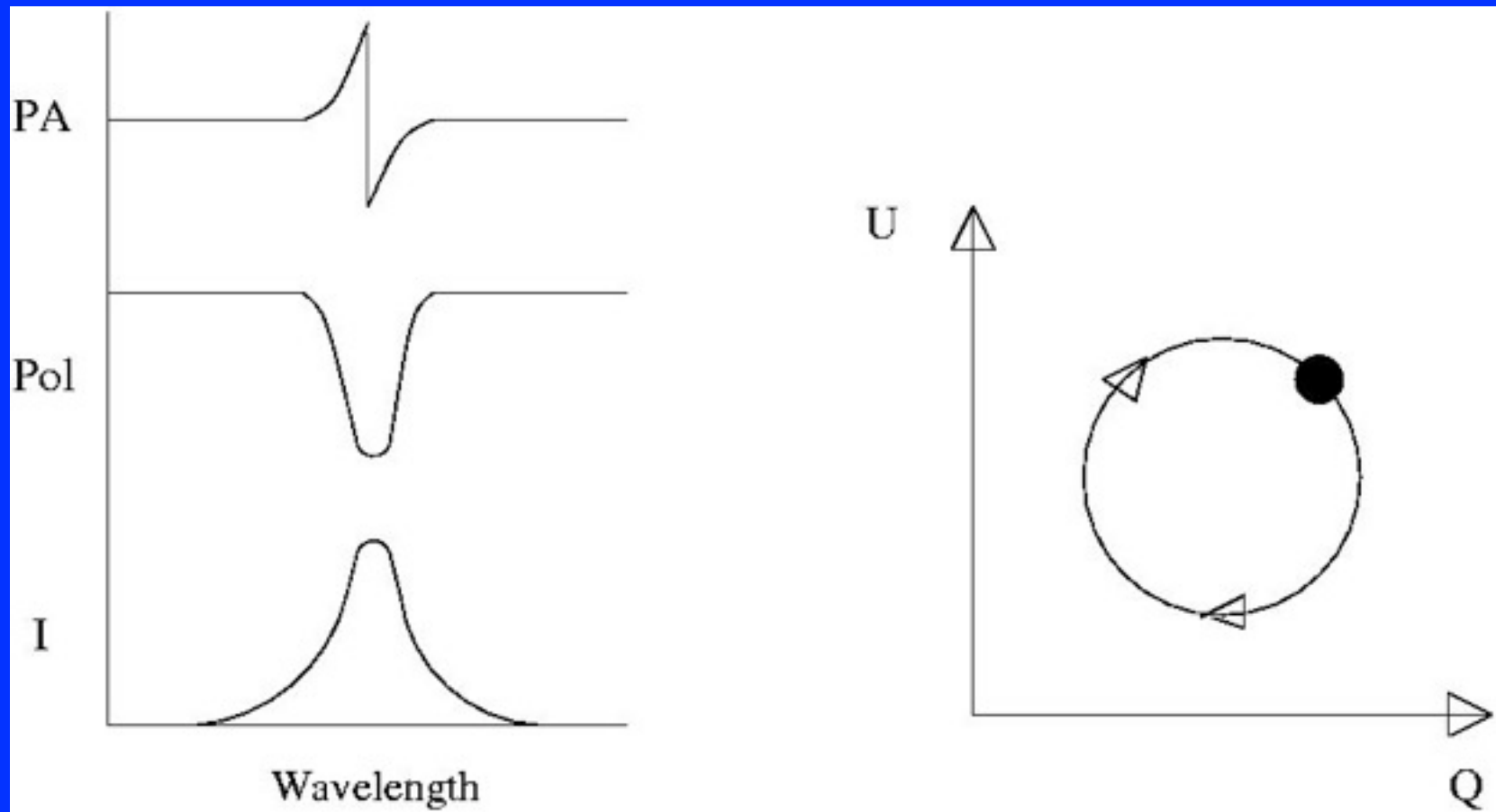


Be star Zeta Tau - it works!



(Oudmaijer 2007)

Line Polarisation – PA Flip



II: Survey Herbig and T Tauris

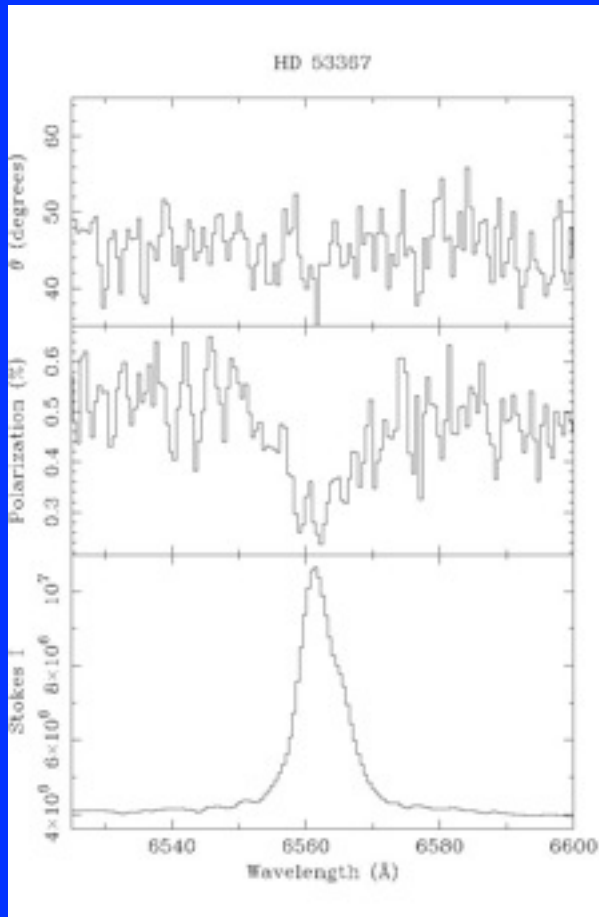
- Herbig Be stars: 12
- Herbig Ae stars: 11
- T Tauri stars: 10

Data: Herbig and T Tauris

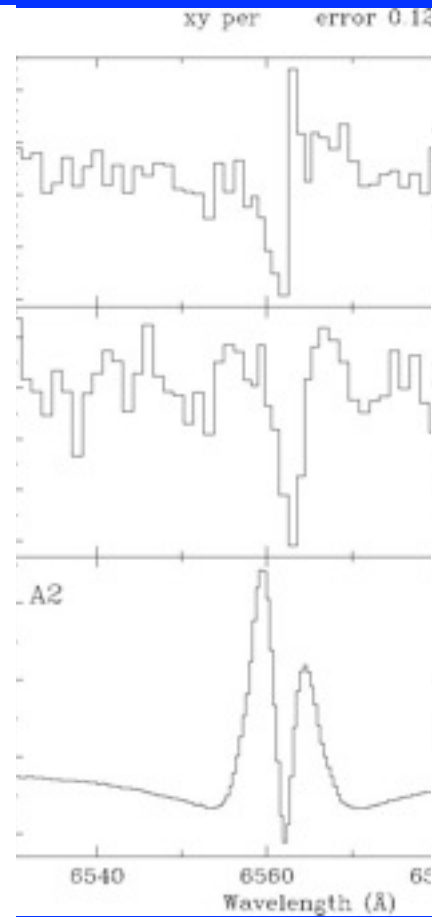
PA

PoI

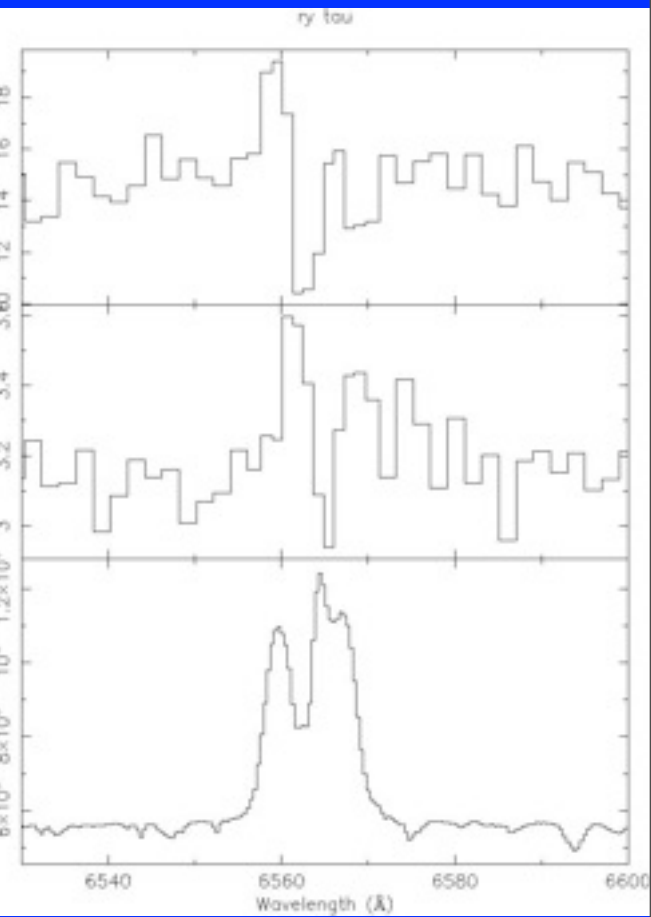
I



Herbig Be



Herbig Ae



T Tauri

Polarisation across line?

1. No change
2. Depolarisation  Herbig Be: 7/12
3. LINE Polarisation



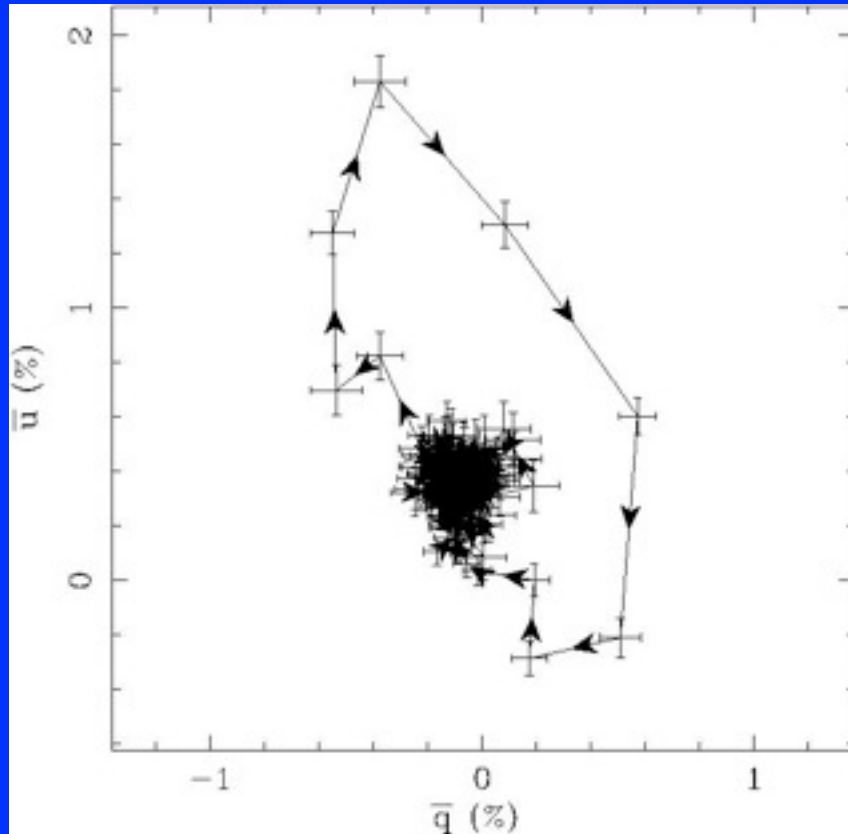
Herbig Ae: 9/11

(Vink et al. 2002)

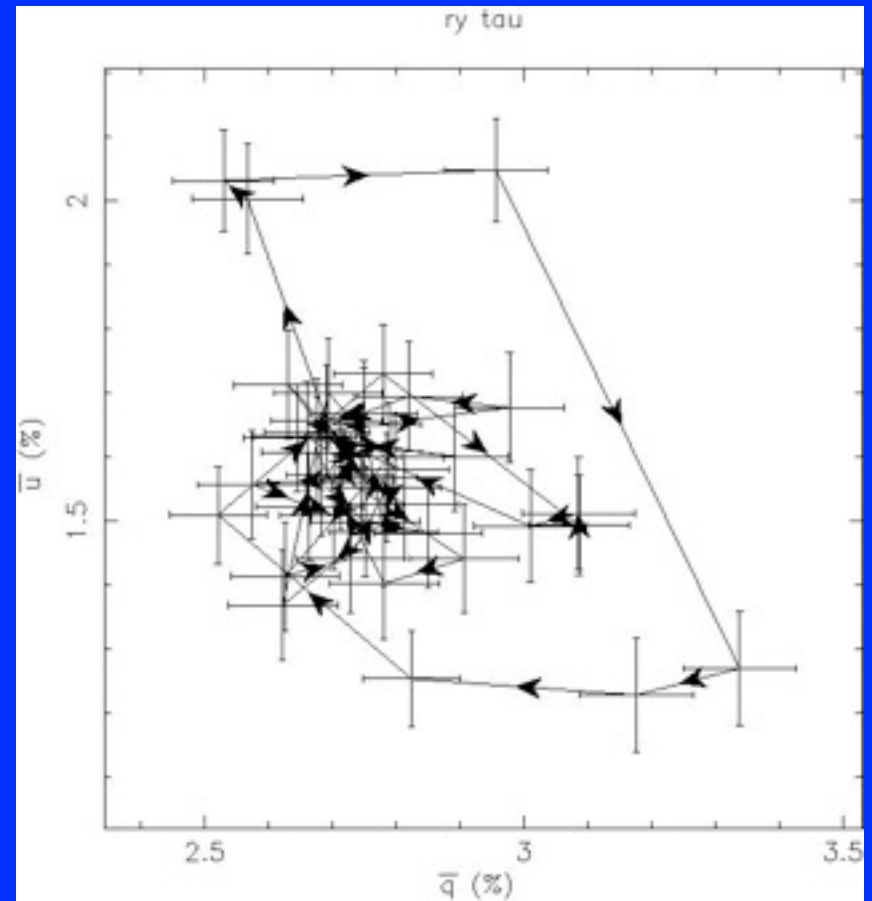
T Tauri: 9/10

(Vink et al. 2005b)

QU: Herbig Ae and T Tauri star



MWC 480

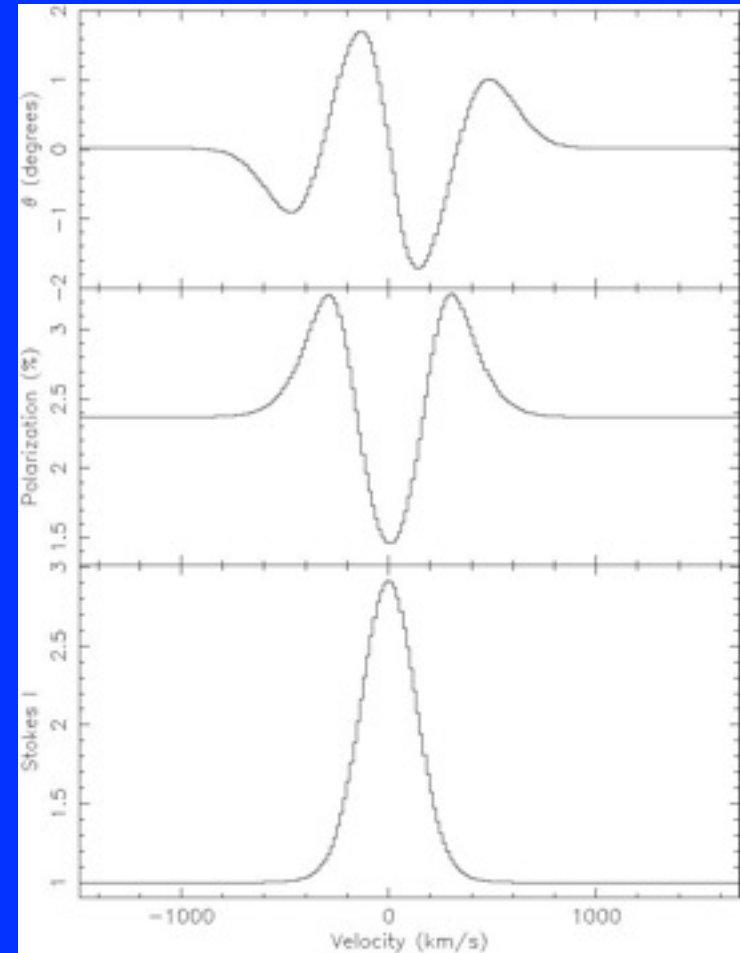
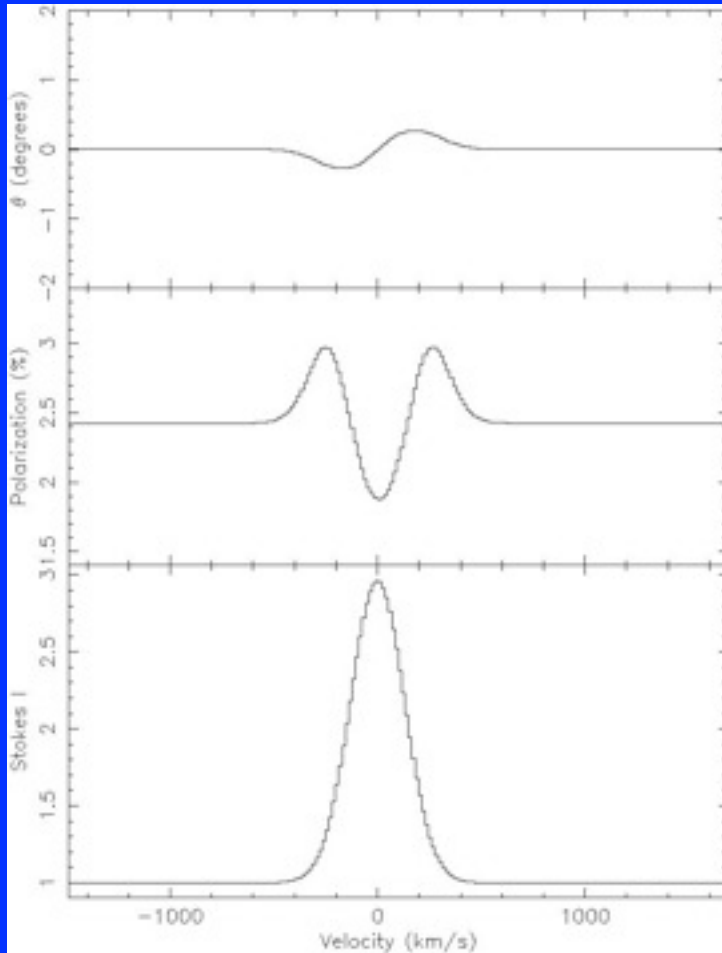


RY Tau

Models of COMPACT line emission

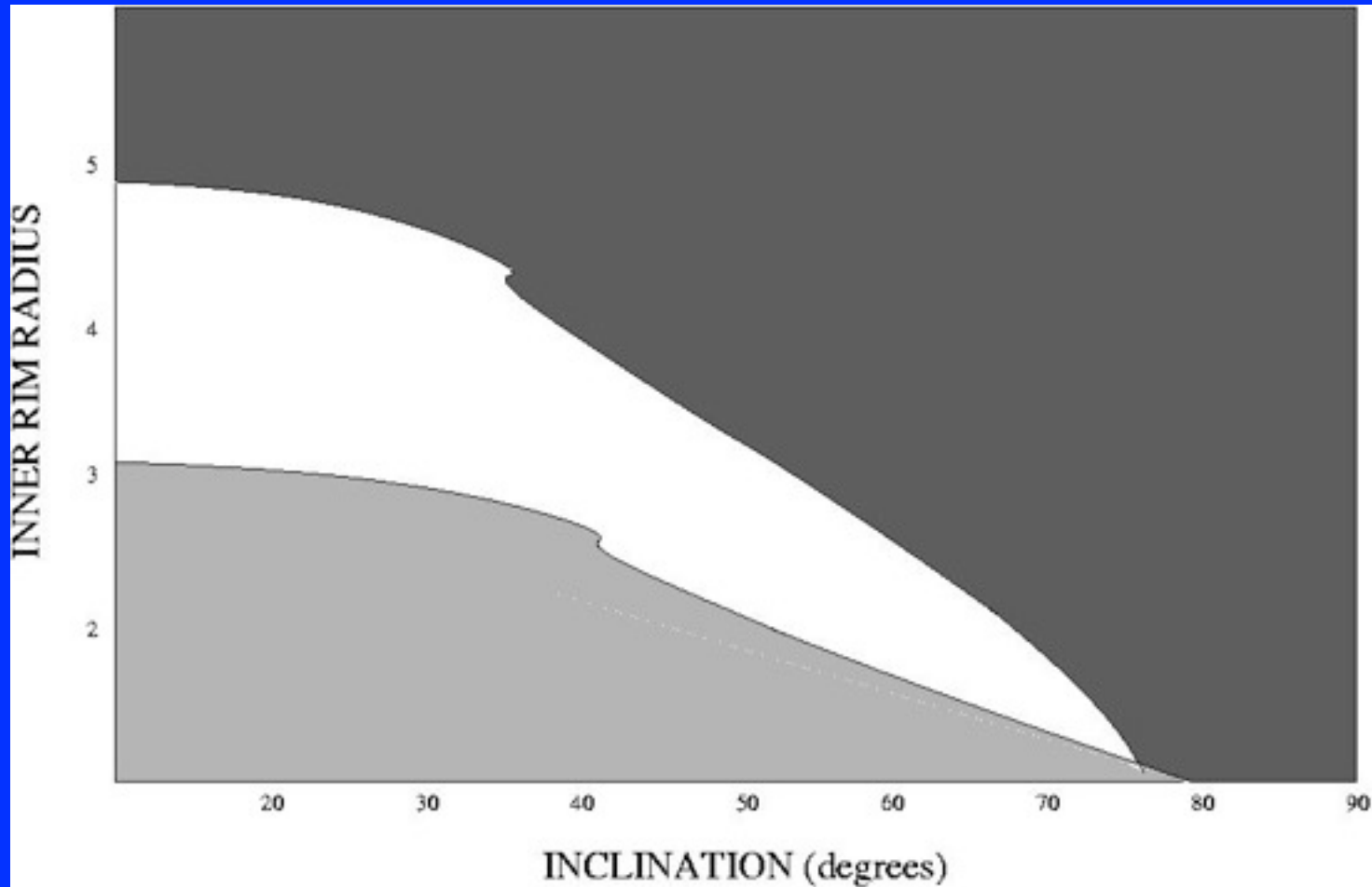
- 3D Monte Carlo
- Keplerian rotating disk
- Scattering only – no line transfer
- With and without an inner hole

With/without a hole



(Vink, Harries & Drew, 2005a, A&A 430, 213)

Constraining the inner disk radius



(Vink et al. 2005a + 2005b)

Imaged disks: position angles

Object	Alt. Name	Type	Disk PA ($^{\circ}$)	Pol. PA ($^{\circ}$)	Δ PA ($^{\circ}$)	
H Ae/Be						
HD 200775	MWC 361	B2	7 ¹	93 ²	86	⊥
MWC 147	V700 Mon	B6	80 ³	168 ²	88	⊥
HD 45677	FS CMa	B2 ⁴	77 ⁵	164 ⁶	87	⊥
BD +40 $^{\circ}$ 4124	V1685 Cyg	B3	110 ⁷	36 ²	74	⊥
MWC 1080	V628 Cas	B0	55 ⁷	75 ²	20	
CQ Tau	HD 36910	F3	120 ⁸	20 ⁹	80	⊥
MWC 480	HD 31648	A3	150 ⁷	55 ⁹	85	⊥
AB Aur	HD 31293	A0	79 ¹⁰	160 ⁹	81	⊥
HD 179218	MWC 614	A0IVe	23 ¹¹	~45 ¹²	22	
T Tauri						
RY Tau	HD 283571	F8	62 ¹³	163 ⁹	79	⊥
SU Aur	HD 282624	G2	127 ¹⁴	130 ⁹	3	
FU Ori	HBC 186	G3	47 ¹⁵	45 ⁹	2	
GW Ori	HD 244138	G5	56 ¹⁶	(60) ⁹	4	
DR Tau	HBC 74	K5	128 ¹⁷	120 ⁹	8	

(Wheelwright et al. 2011)

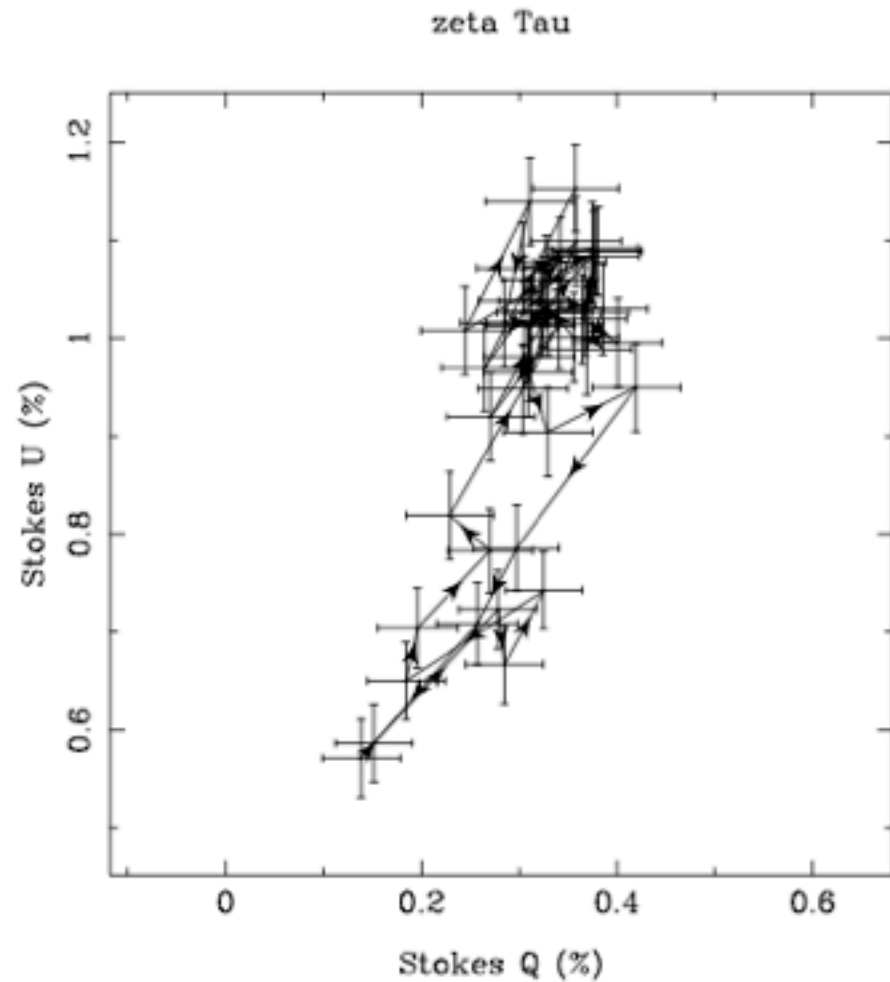
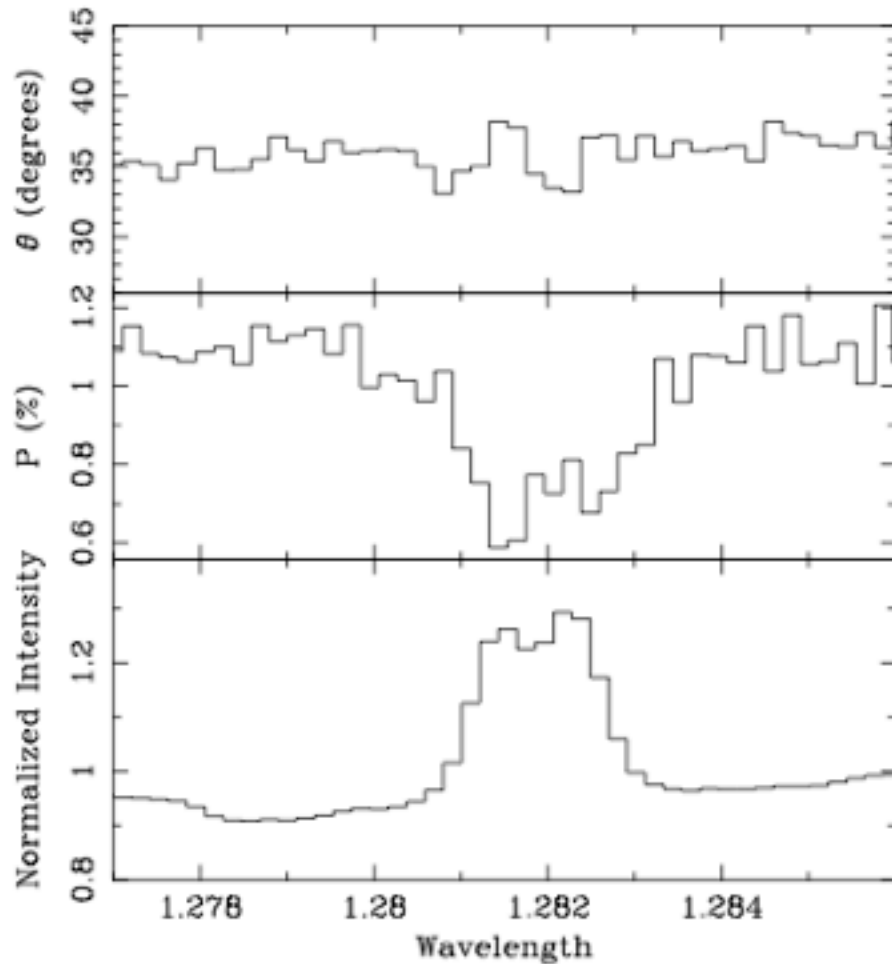
Questions for Star Formation

- Do ALL stars form by disk accretion?
(yes)
- Is there a difference between low and high-mass star formation?
(yes)

Future Spectro-polarimetry

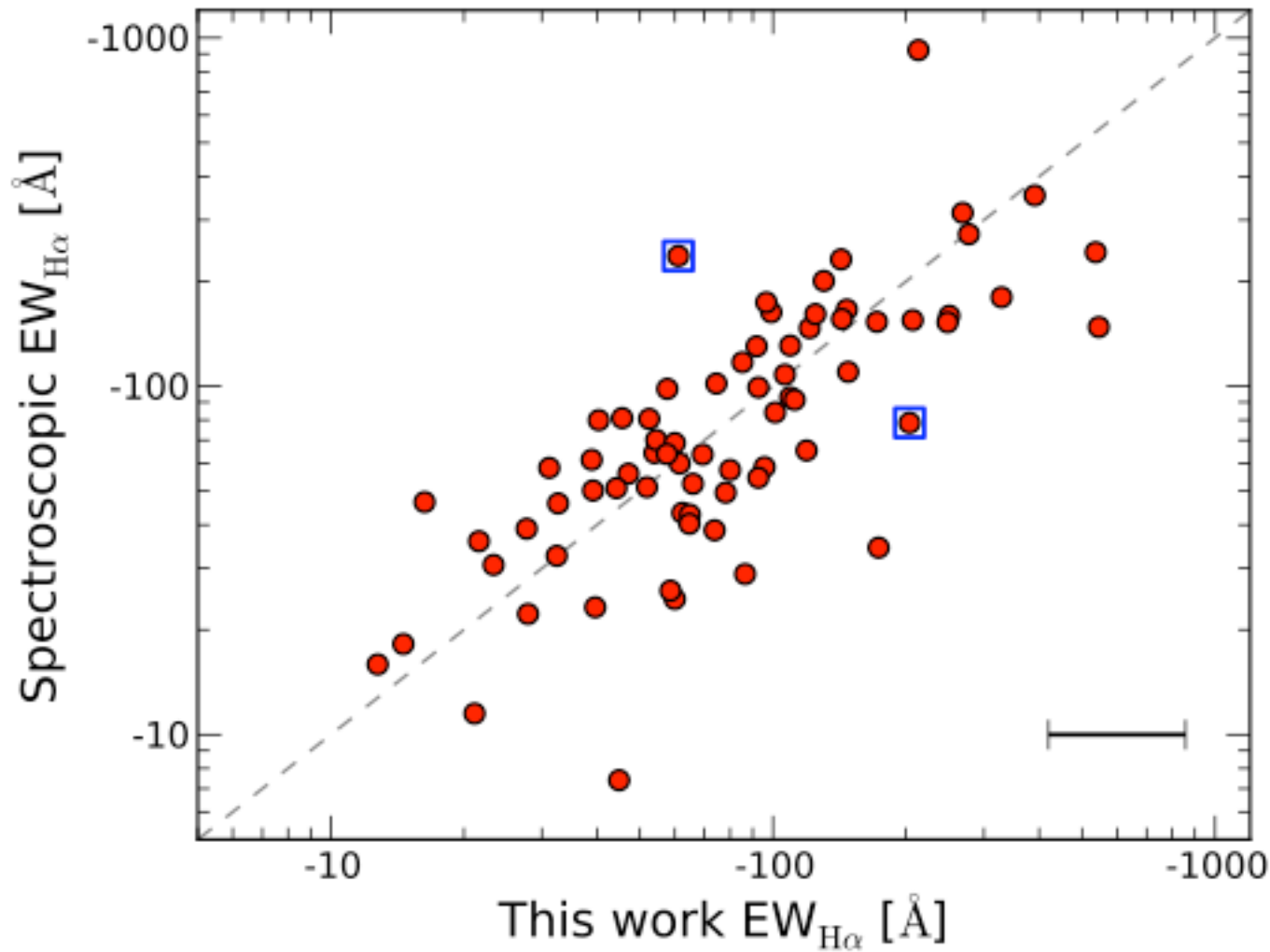
- Infrared
- Larger samples (Surveys)
- Monitoring
- Fainter (larger distances, extra-galactic, lower metallicity)

1) It works in the NIR !



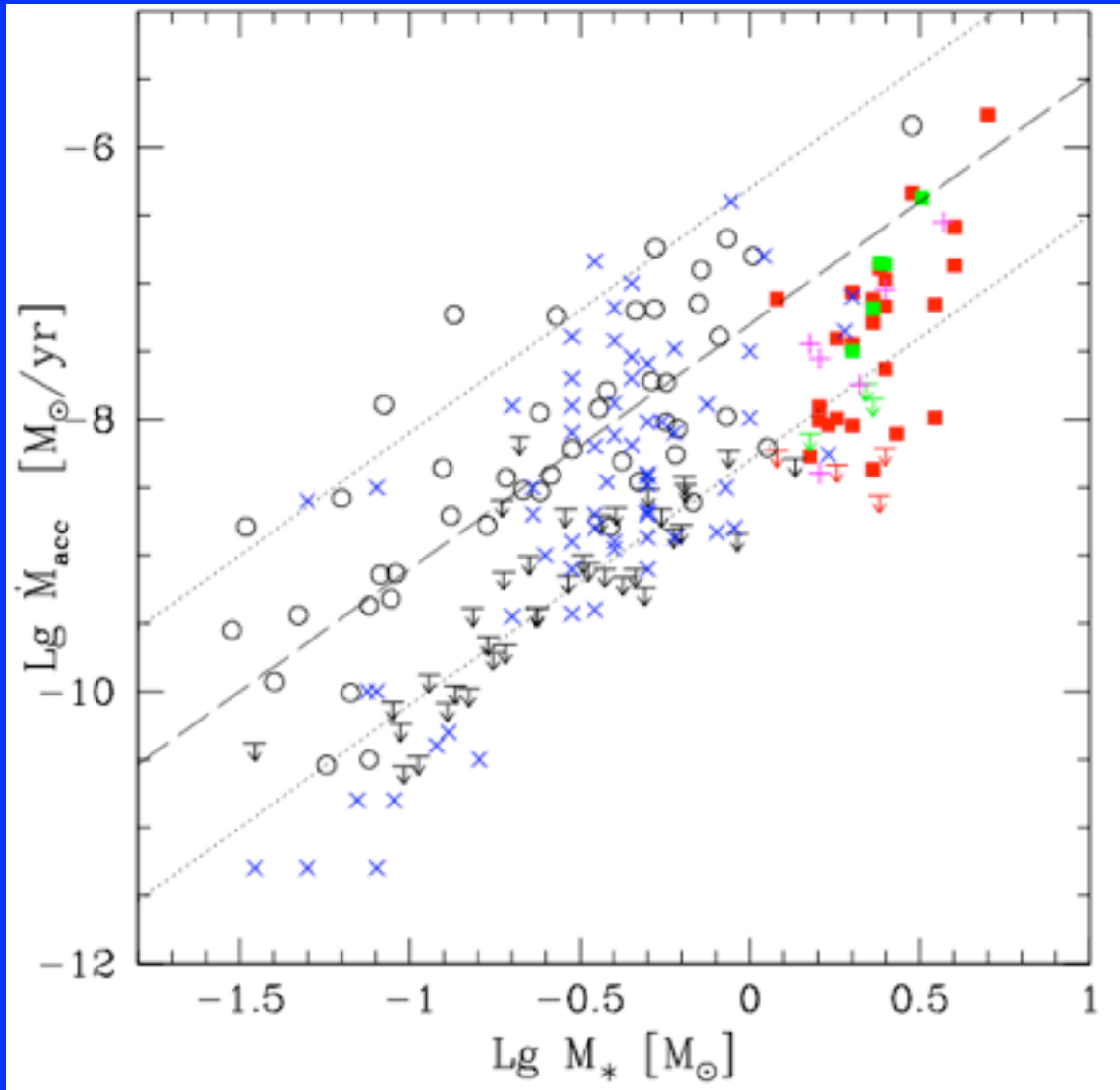
(Oudmajer et al. 2005)

2) dM/dt from IPHAS/VPHAS photometry vs. spectra



(Barentsen, Vink,
et al. 2013)

dM/dt - Mass Relation



(Garcia Lopez et al. 2006)
slope 2

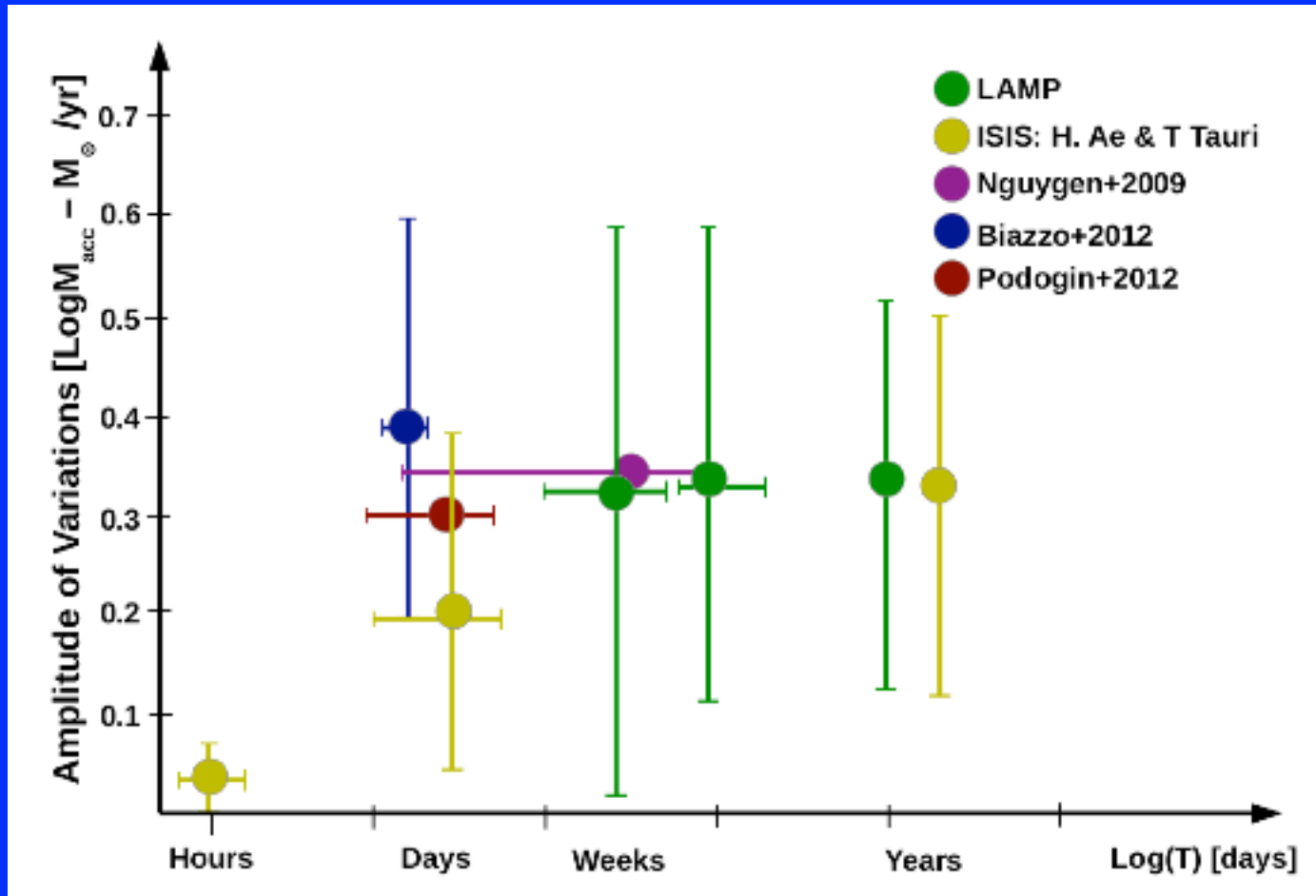
IPHAS:

slope 1 - 3

(Barentsen et al. 2011+2013)

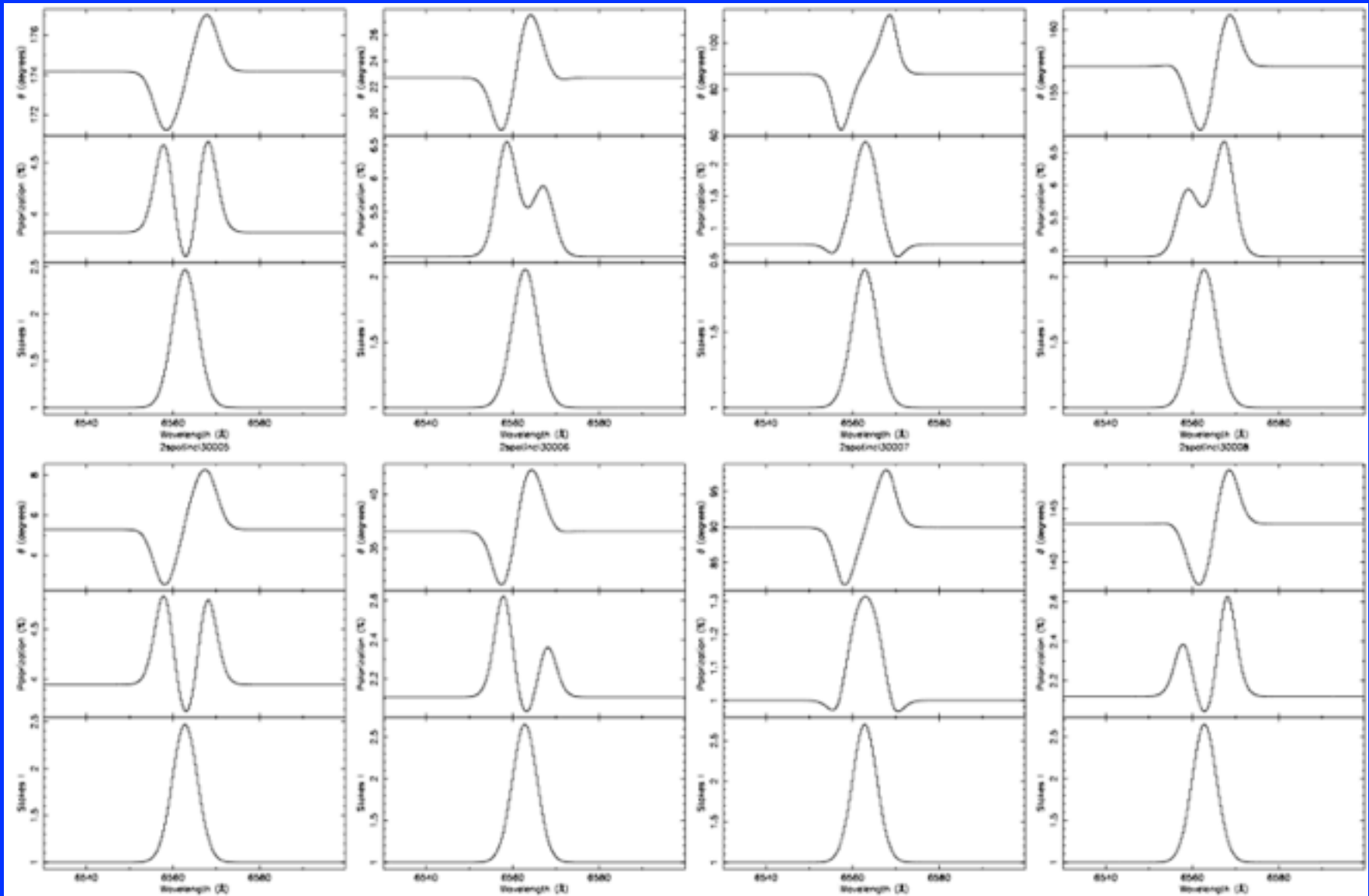
VPHAS+

Spectroscopic Monitoring

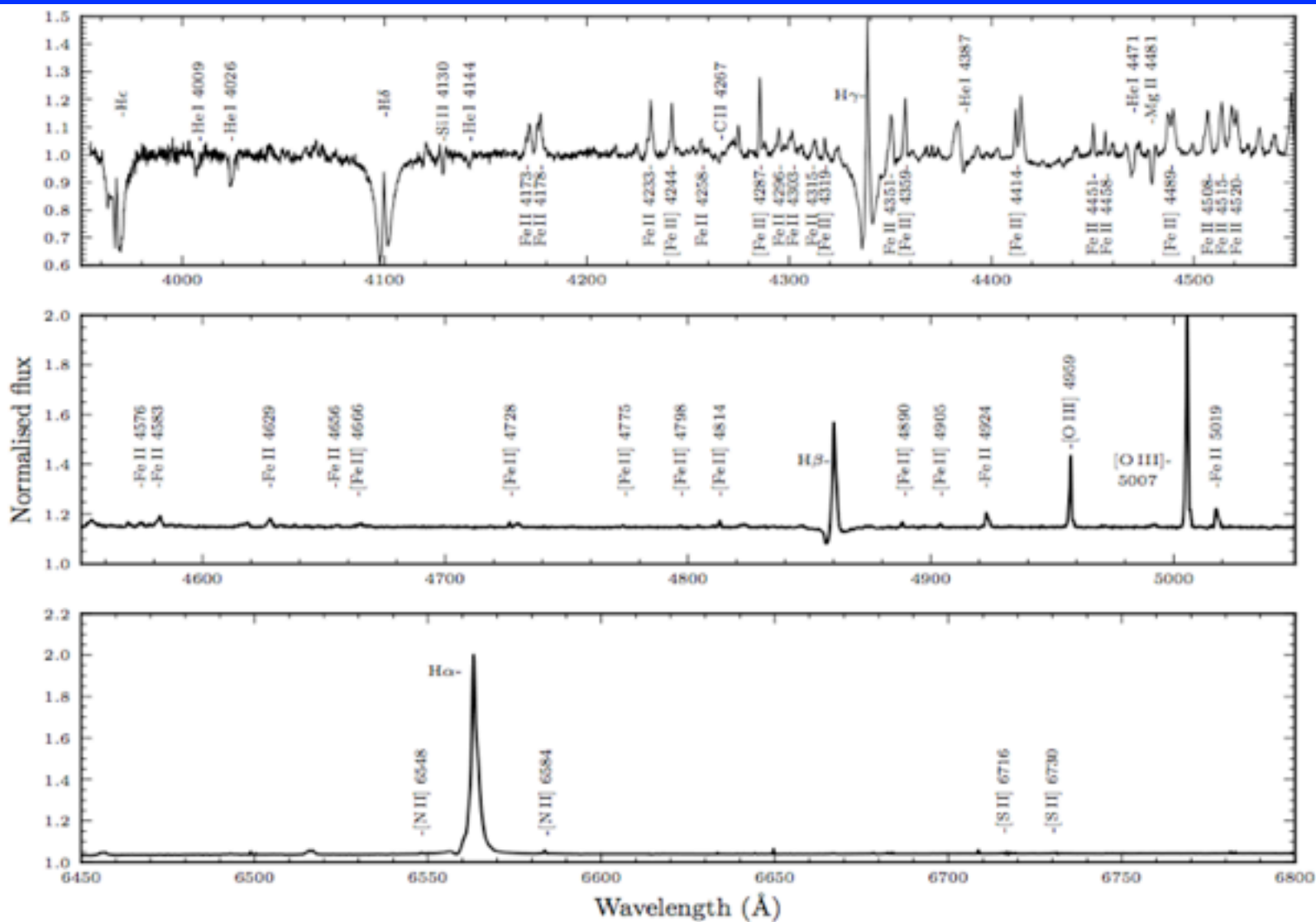


(Costigan et al. 2014 - astro-ph 1403.4088)

3) Spectropolarimetric Monitoring



4) VFTS 822: HB[e] in LMC



(Kalari et al. 2014)

Summary

- Herbig Ae/Be stars have small-scale disks
- Data consistent with disk fragmentation!

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- Herbig Ae/Be stars have small-scale disks
- Data consistent with disk fragmentation!

- Transition between Herbig Ae and HBe
- Rotational timescale key to dM/dt changes
- Require linear QU specpol monitoring!