B[e] Supergiants' circumstellar environment: disks or rings?

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A small introduction ...


GRANADA
CURE
VINK
KURFÜRST
KRTIČKA
SERIACOPI
MIROSHNICHENKO
MEILLAND
OUDMAIJER

more in
Kraus talk
tomorrow @ 8:50

B[e] SGs: observational properties

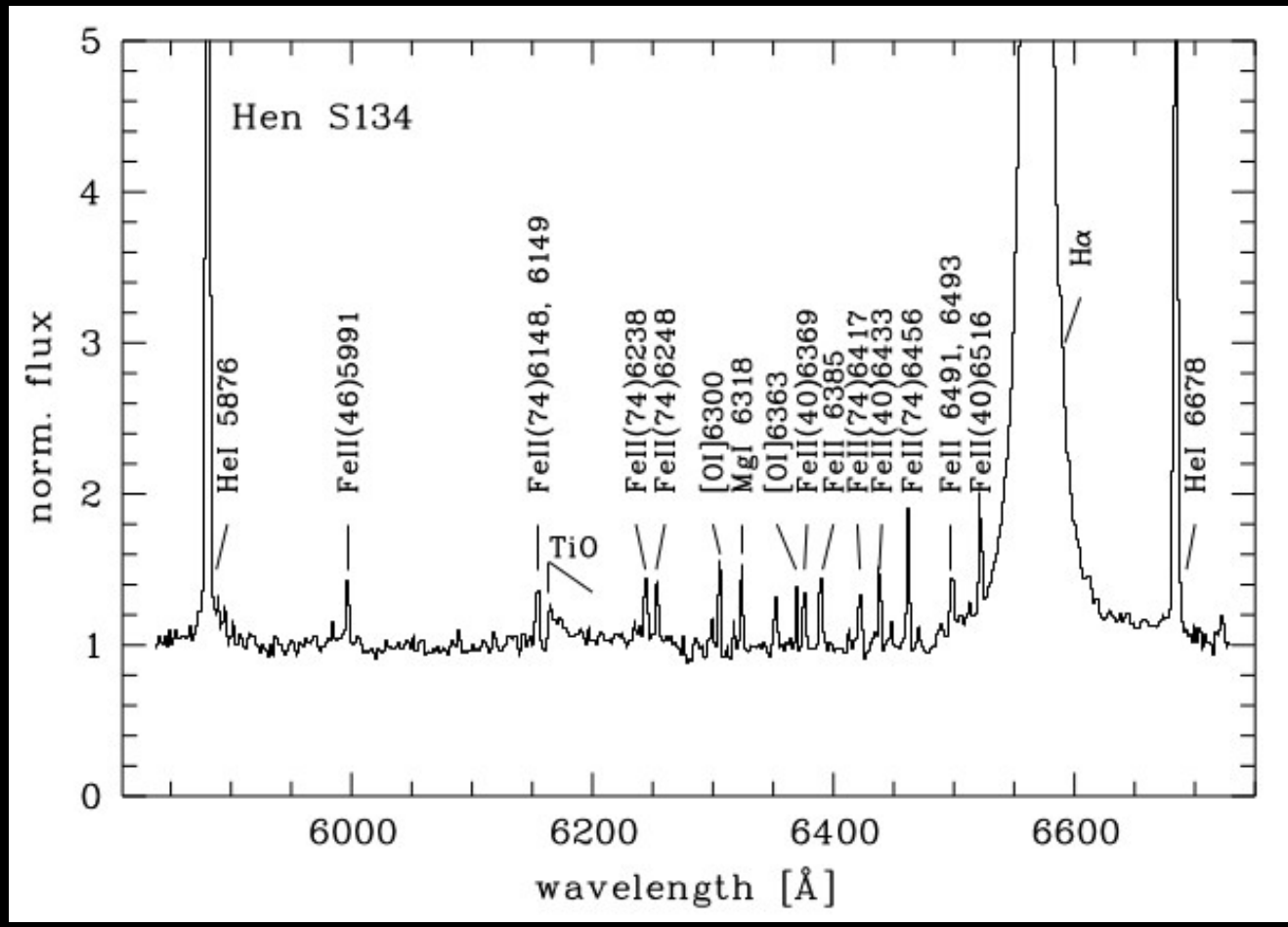
1. B[e] phenomenon

2. Strong Balmer lines,
+ usually P-Cygni profiles
($EQW_{H\alpha}$ ~ 10^2-10^3 Å)

3. Narrow, low-excitation FeII, [FeII], and [OI]

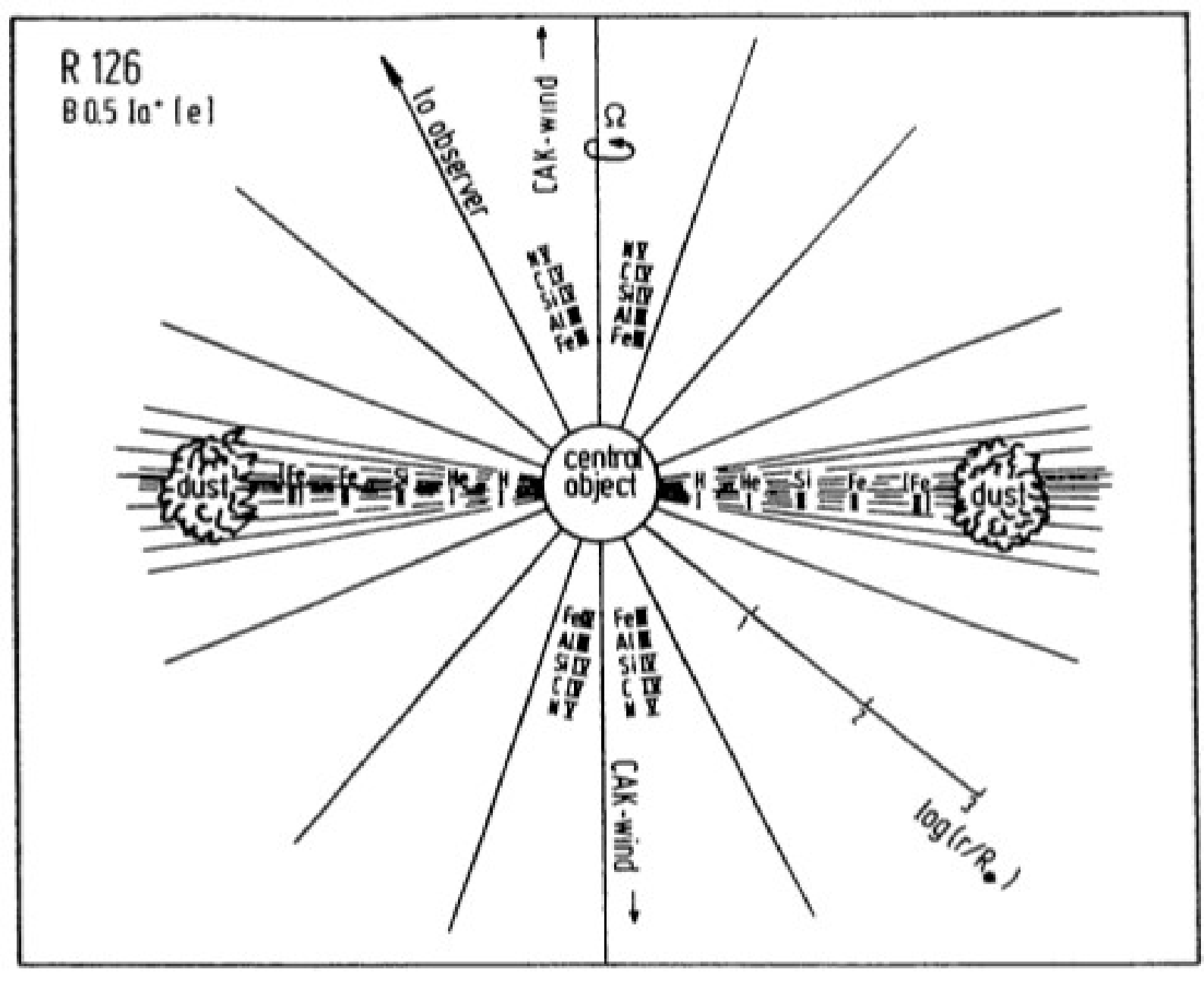
4. Stars → Supergiants
Log ($L_*/L_\odot$ > 6.0)

5. Chemically processed material → evolved evolutionary phase
(e.g. ^{13}CO enrichment, TiO)



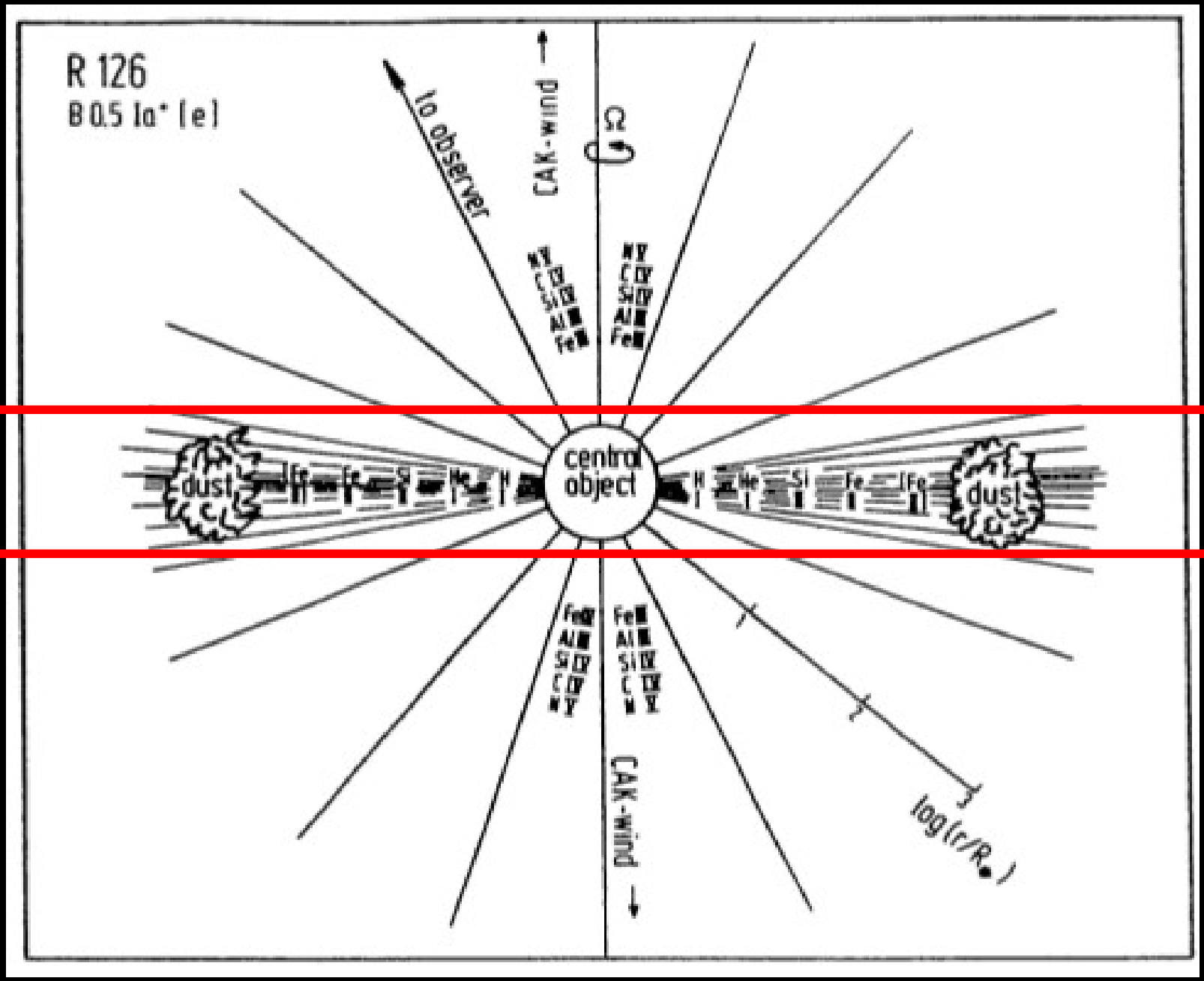
Lamers+ 1998

2-component wind model



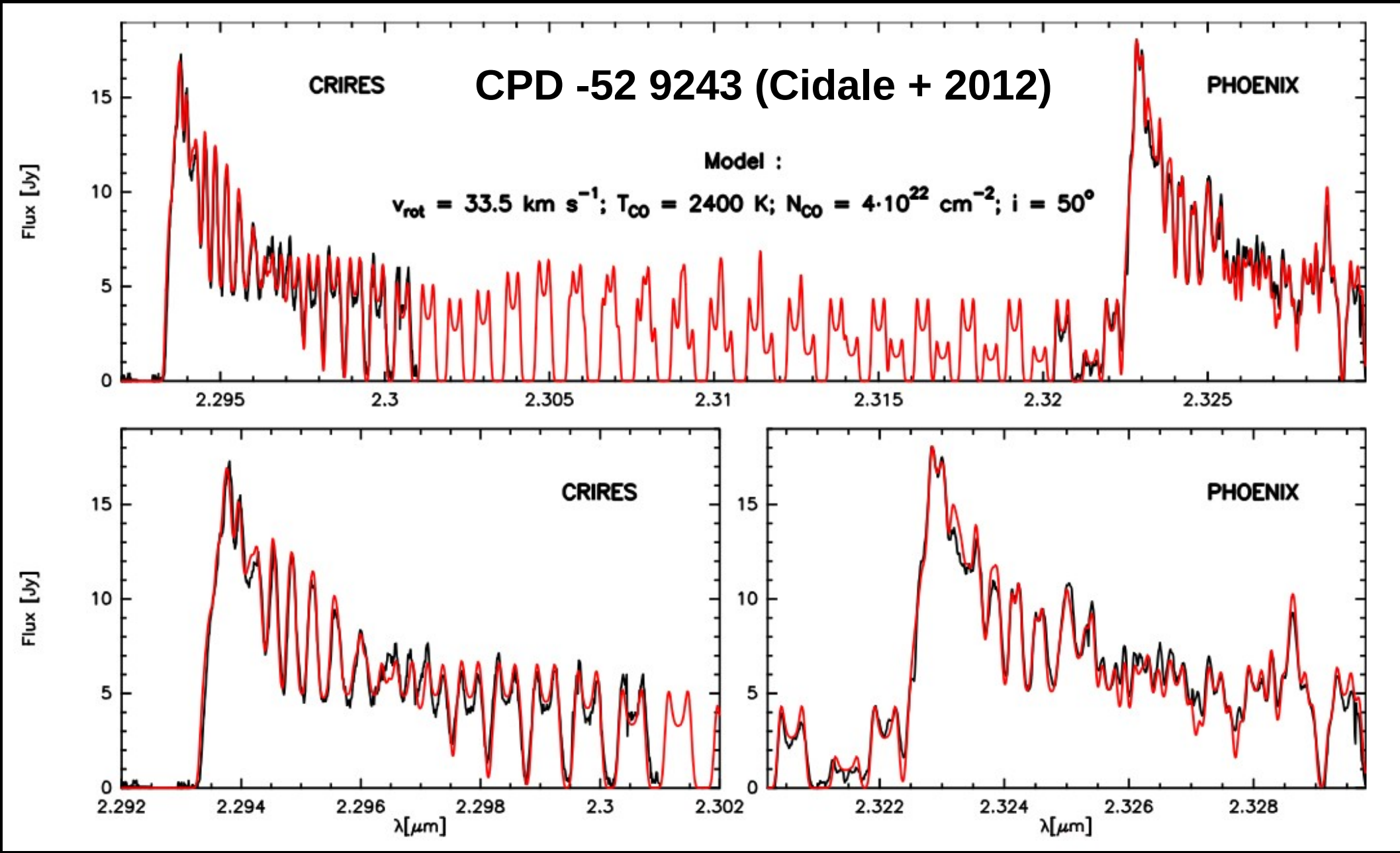
Zickgraf + 1985, 1992

2-component wind model



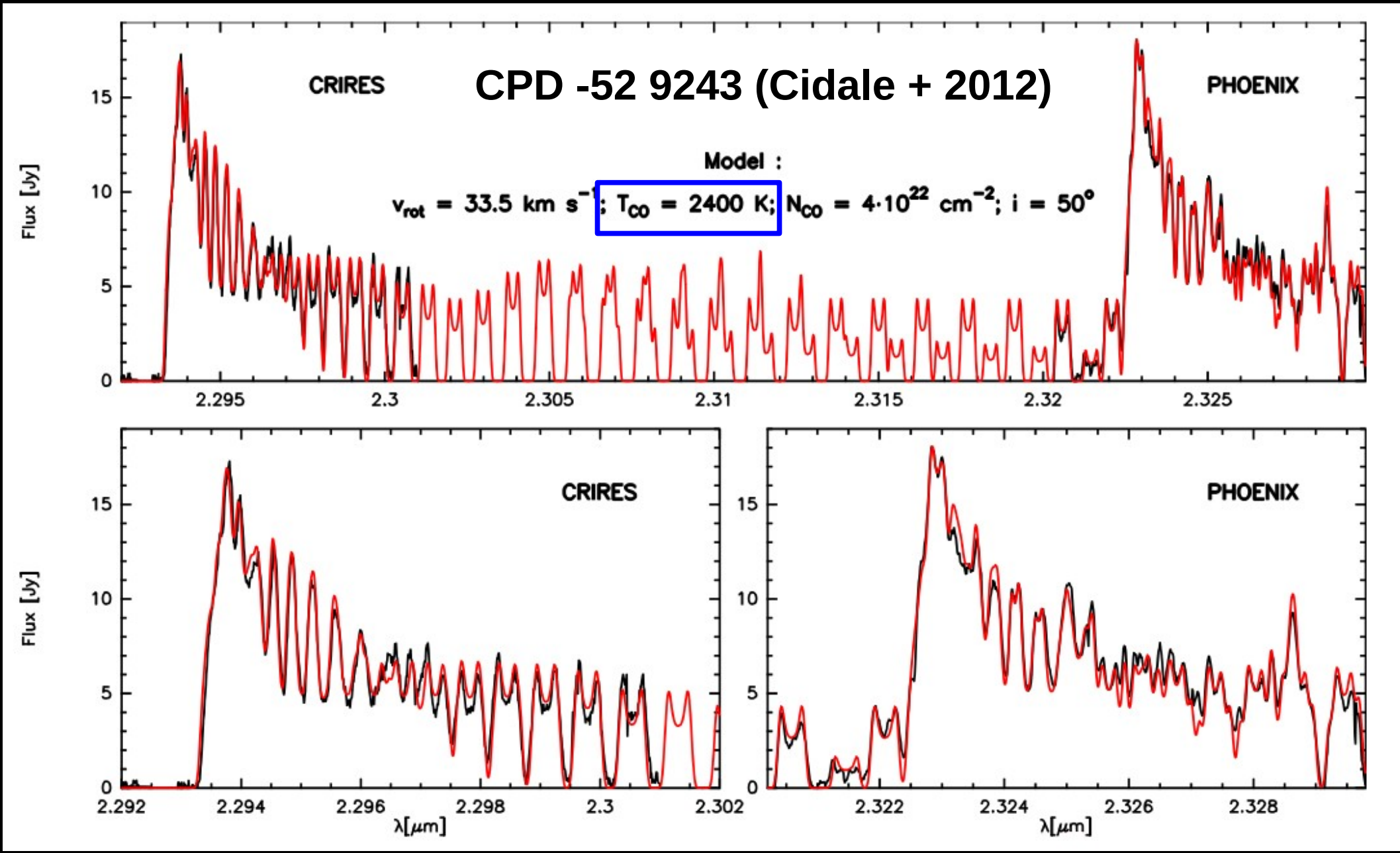
Zickgraf + 1985, 1992

Indications of detached disks



Cidale + 2012, Liermann +. 2010, Cidale + 2012, Oksala + 2013

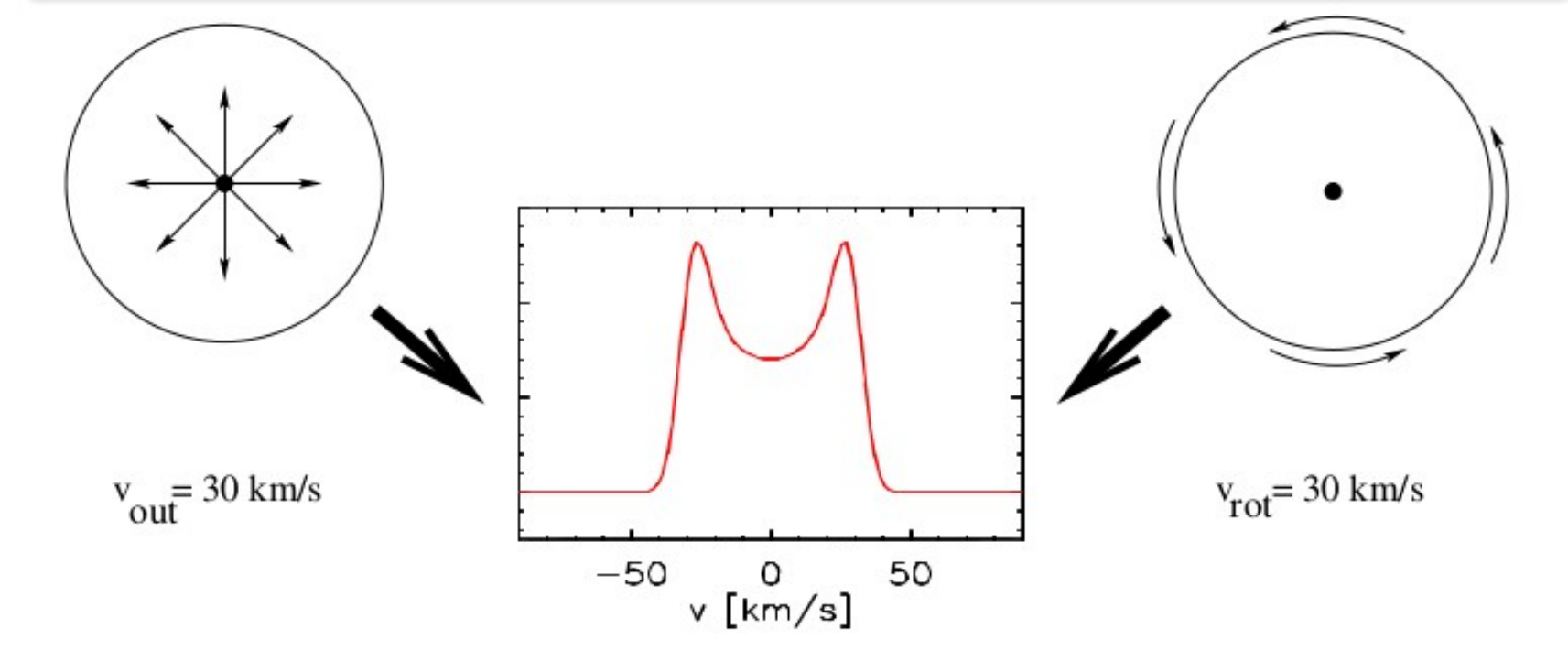
Indications of detached disks



Cidale + 2012, Liermann +. 2010, Cidale + 2012, Oksala + 2013

Outflowing disks or rotational rings ?

(after Kraus)

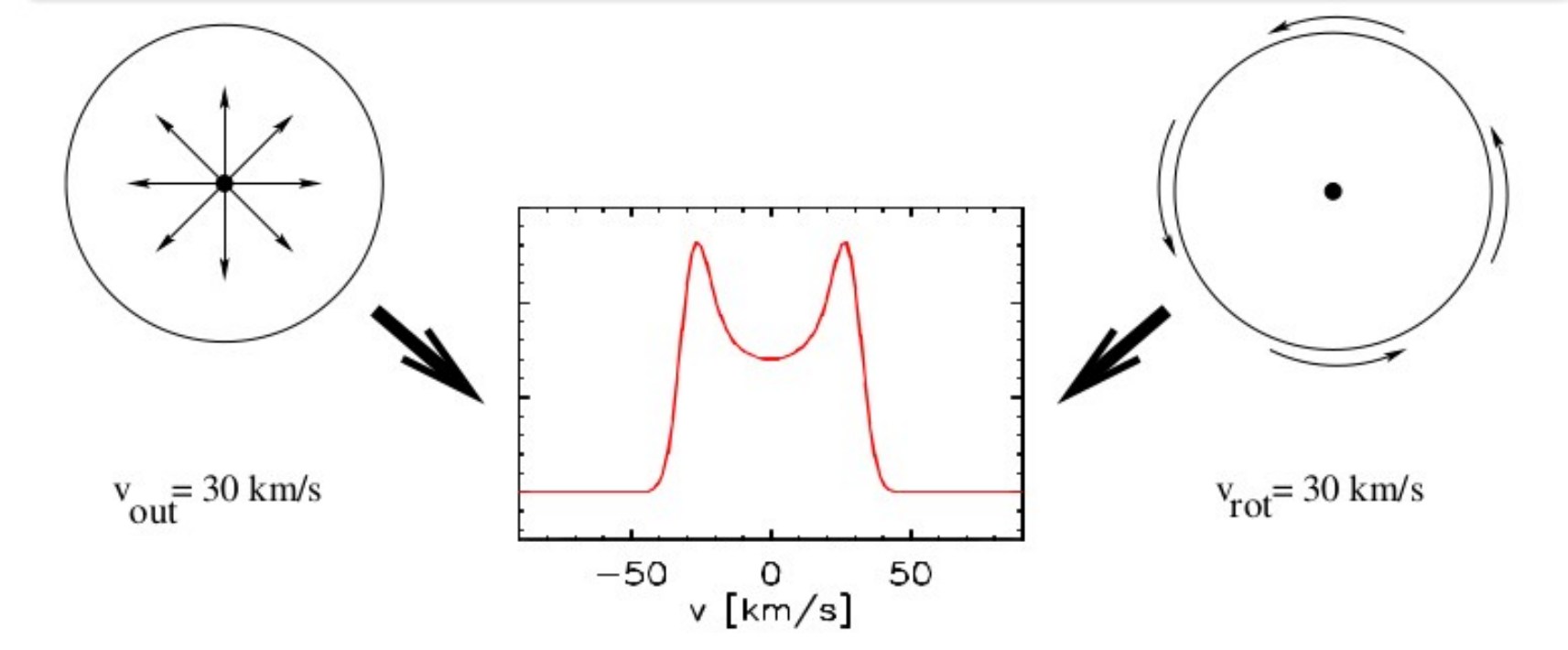


> expanding or rotating rings give the same line profiles

> a single line tracer is not enough to determine between the two

Outflowing disks or rotational rings ?

(after Kraus)

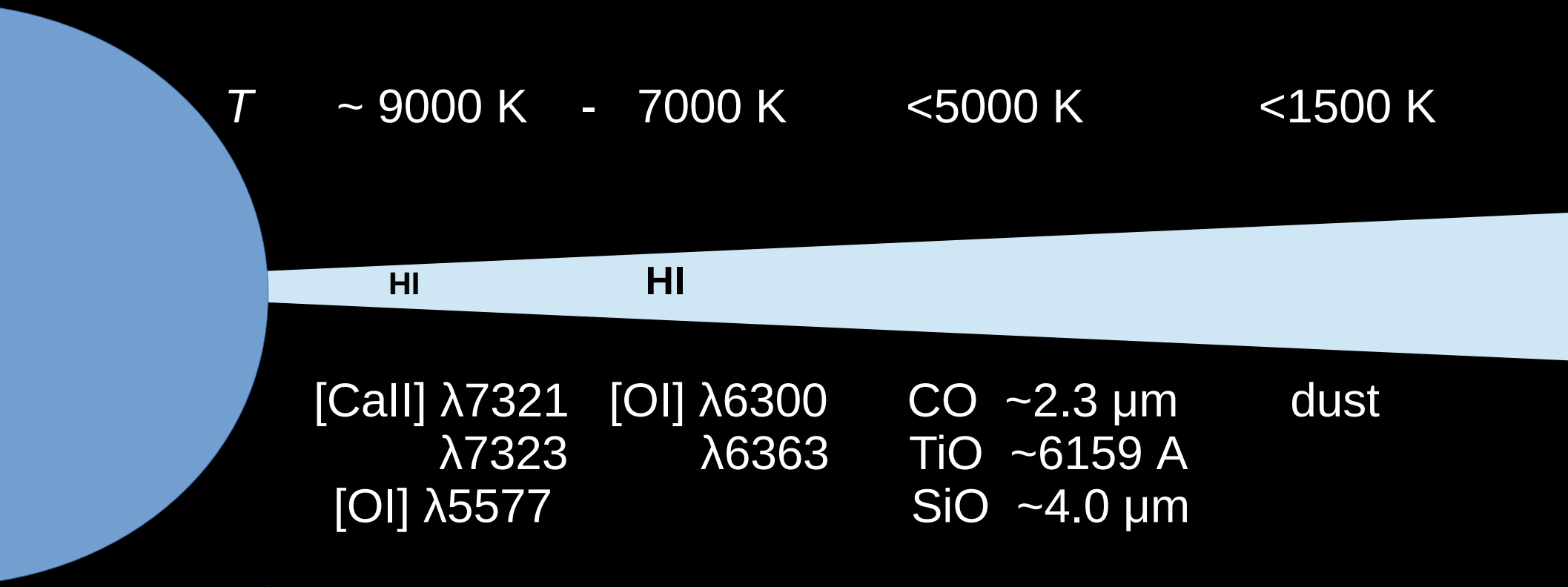


> expanding or rotating rings give the same line profiles

> a single line tracer is not enough to determine between the two

Are there more tracers ???

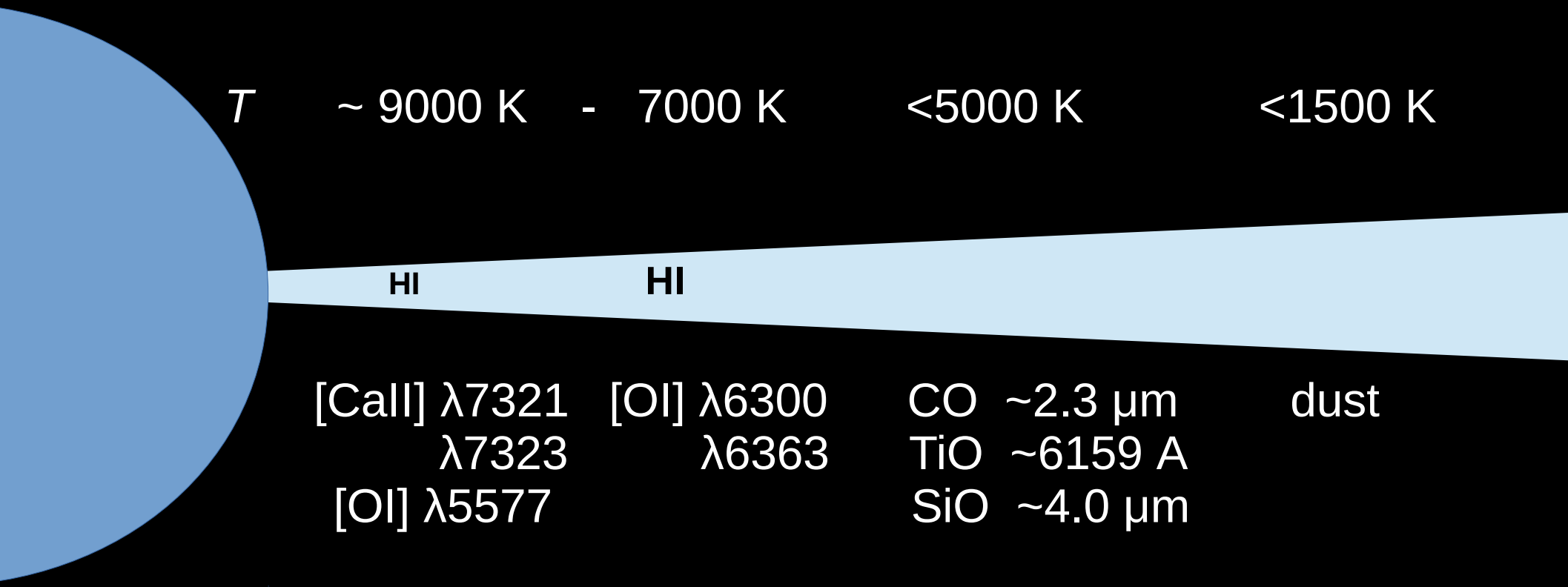
More disk tracers



[CaII] λ7321	[OI] λ6300	CO ~2.3 μm	dust
λ7323	λ6363	TiO ~6159 A	
[OI] λ5577		SiO ~4.0 μm	

Kraus+ 2007, 2010, Aret+ 2012

More disk tracers



Kraus+ 2007, 2010, Aret+ 2012

Optical emission lines ([OI],[CaII]) are optically thin
Probe the kinematics of their forming regions

Tracers of different *temperatures / densities)*
Probe different parts of the disk (structure)

Observing Campaign

Observations: FEROS @ 2.2m MPG/ESO
high-resolution echelle *R*~48k, ~3600-9200 Å
SINFONI @8.2m UT4/ESO
integral field spectrograph *R*~2k(J)-4k(K), 1.1-2.45μm
CRIRES @8.2m UT1/ESO
high-resolution echelle *R*~100k, 1-5.3μm
Phoenix @8m Gemini South
high-resolution slit, *R*~50k, 2.319-2.329μm

Time Span: **1999 – present**
better monitoring the last 3 years
Tycho Brahe program (CR, 2014, 2015x2, 2016x2)
+ ESO programs

Sample: Galaxy: 12
Large Magellanic Cloud = 11
Small Magellanic Cloud = 5

Kinematical Model

Broadening of the line profile due to:

1. Emission from narrow rotating ring of gas
   (constant de-projected velocity Vrot)

+

2. Gaussian component (Vg),
which is a combination of:
   a. FEROS spectral resolution (~5.5-6.5kms^{-1}),
   b. thermal velocity (~1-2 kms^{-1})
   c. some random internal motion (~few kms^{-1}),
      implying a wider ring

Free parameters: velocities + flux

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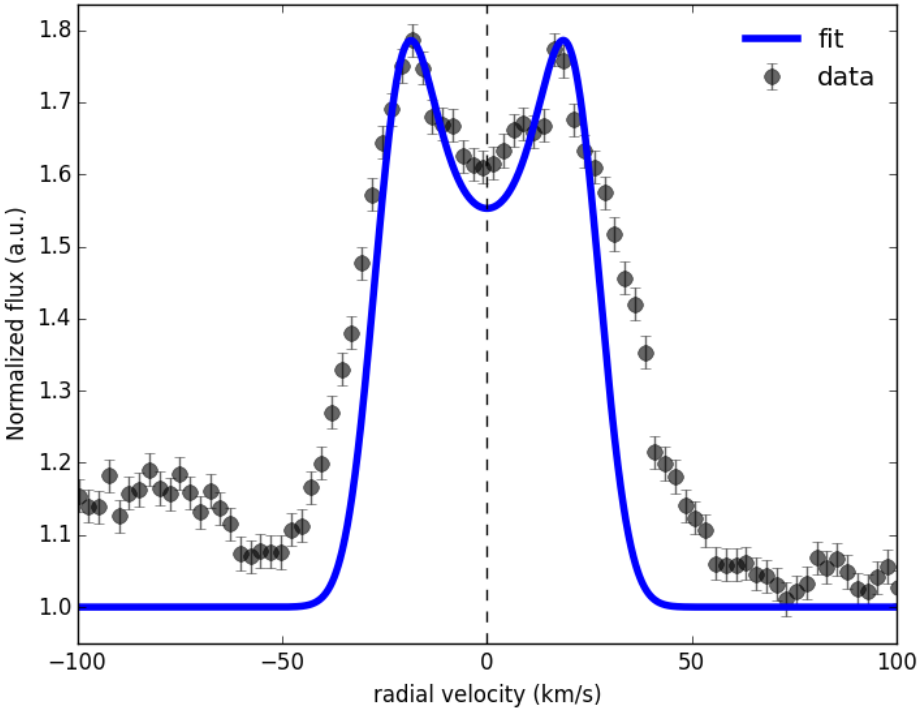
keep this for Aret talk ! tomorrow @ 10:15

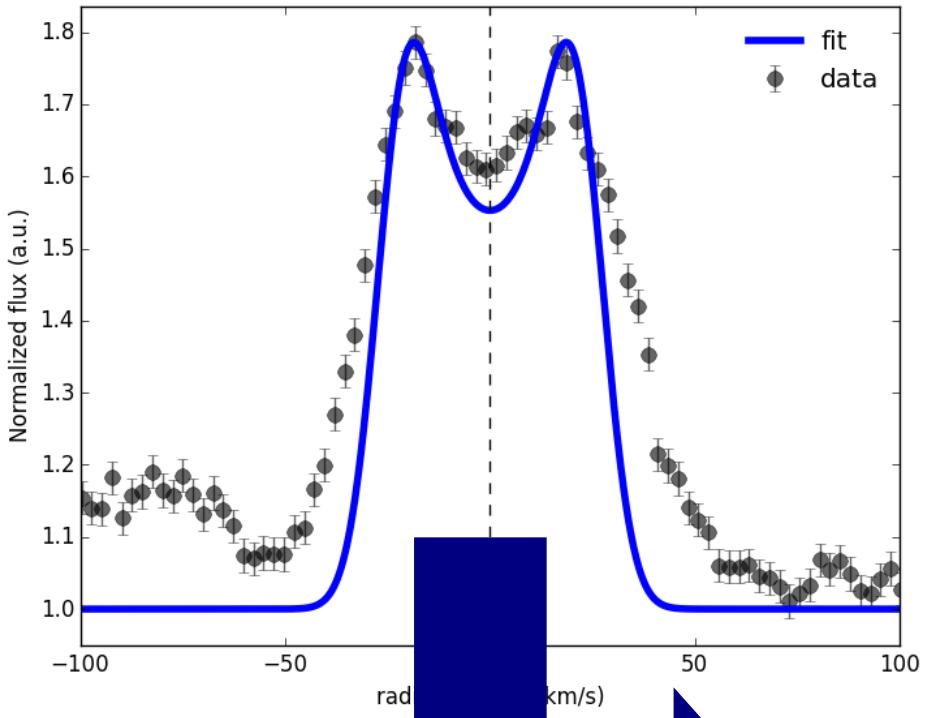
Kinematical Model



example: CPD -52 9243
[CaII] λ7291, Mar 2000

Assuming same region with CO
Vrot = 33.5±2 Vg = 8±1 kms^{-1}

Kinematical Model



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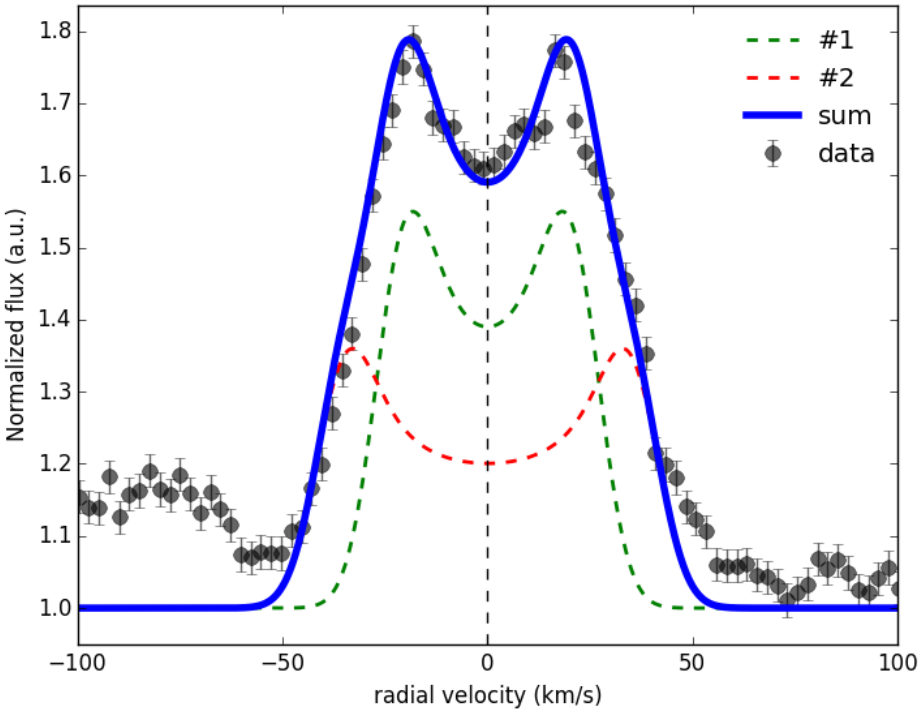
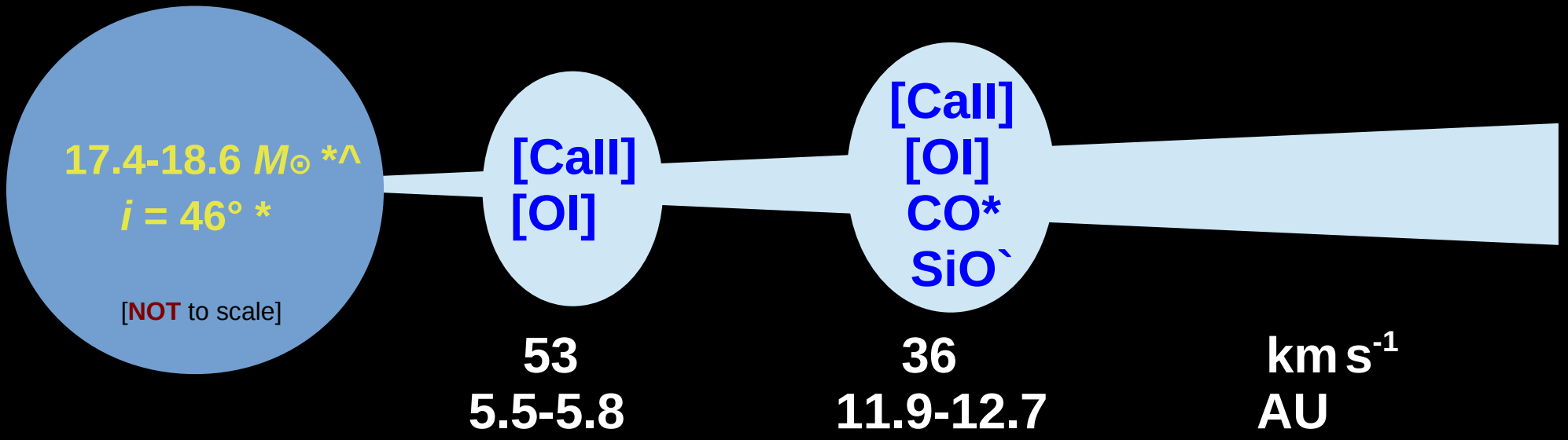
2 rings



Vrot = 36±1 Vg = 9±1 kms^{-1}

Vrot = 52±1 Vg = 9±1 kms^{-1}

CPD -52 9243



* *Cidale+ 2012,*
^ *Swings 1981,*
` *Kraus+ 2015*

typical ring-width ~5 kms^{-1}

> 2 distinct rings
> Gas present closer than CO ring.

NOTE !
No [OI] λ5577 detected, only [OI] λλ6300/6363 for all objects

CPD -52 9243

17.4-18.6 $M_\odot$ *^
i = 46° *

[NOT to scale]

[CaII]
[OI]

[CaII]
[OI]
CO*
SiO`

53
5.5-5.8

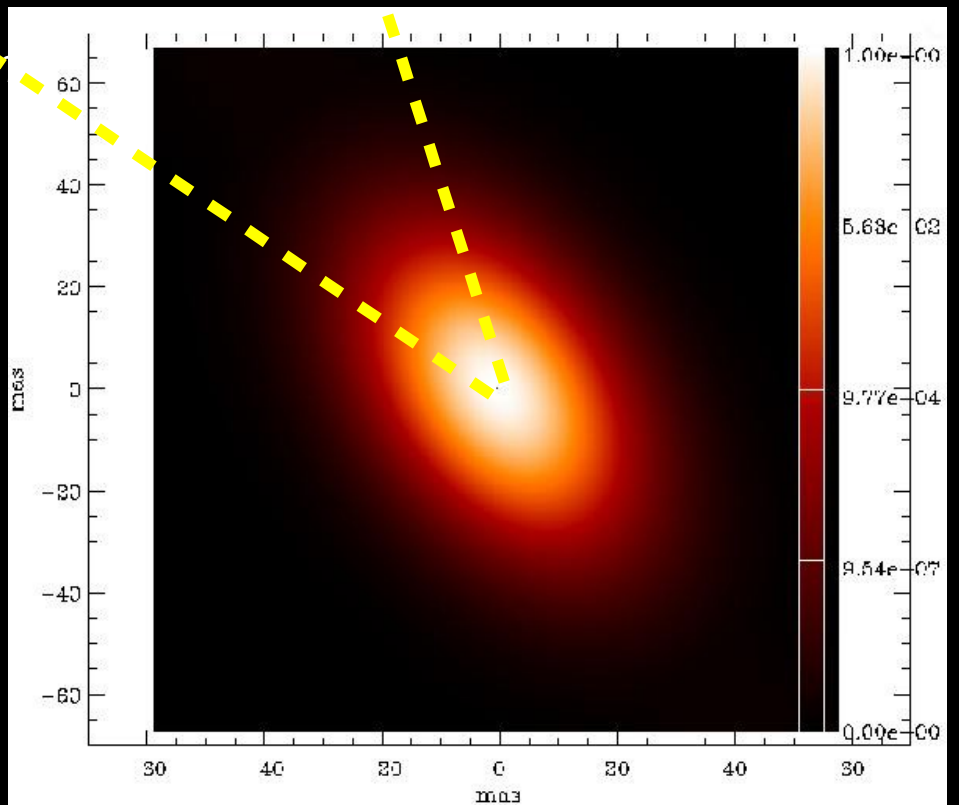
36
11.9-12.7

km s^{-1}
AU

* *Cidale+ 2012,*
^ *Swings 1981,*
` *Kraus+ 2015*

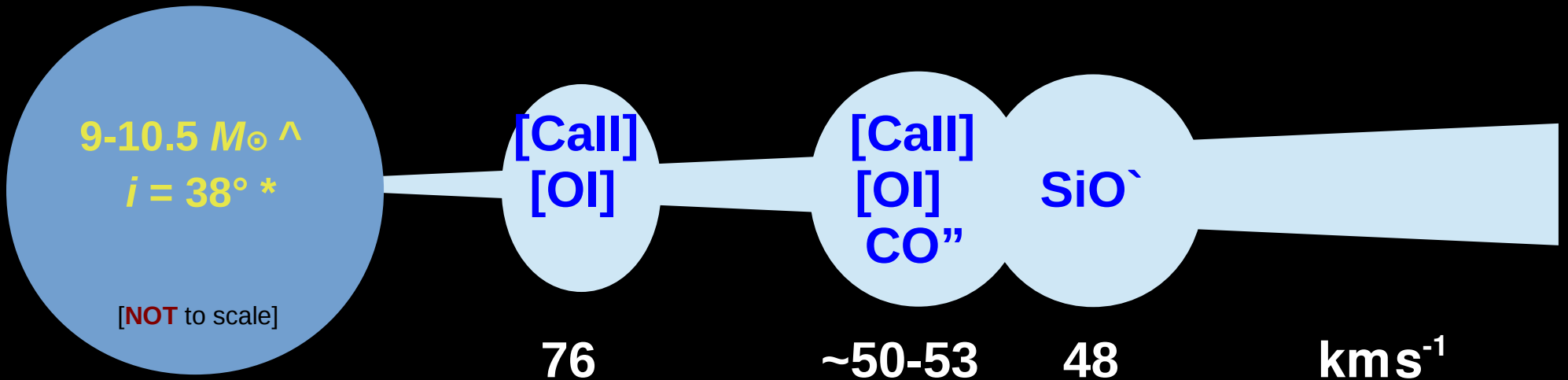
typical ring-width ~5 km

> 2 distinct rings
> Gas present closer than CO ring.
> Dust further out (>24.8 AU)
> Binary ?



Cidale + 2012

HD 62623 (3 Pup)



76 ~50-53 48 kms^{-1}

1.4-1.6 2.8-3.2/3.3-3.7 3.5-4.0 AU

^ *Aret+ 2016,*
* *Millour+ 2011,*
` *Kraus+ 2015,*
“ *Muratore+ 2012*

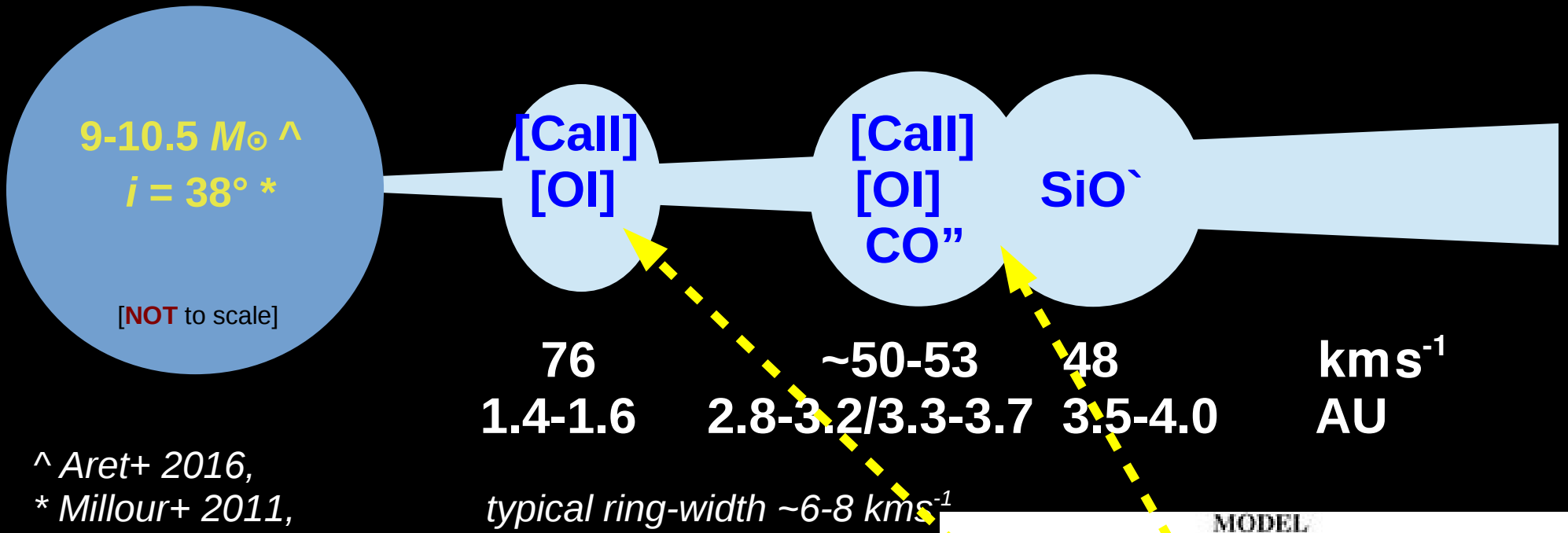
typical ring-width ~6-8 kms^{-1}

Meilland talk

> Possible two/three distinct rings

see also Aret talk tomorrow @ 10:15

HD 62623 (3 Pup)



^ *Aret+ 2016,*
* *Millour+ 2011,*
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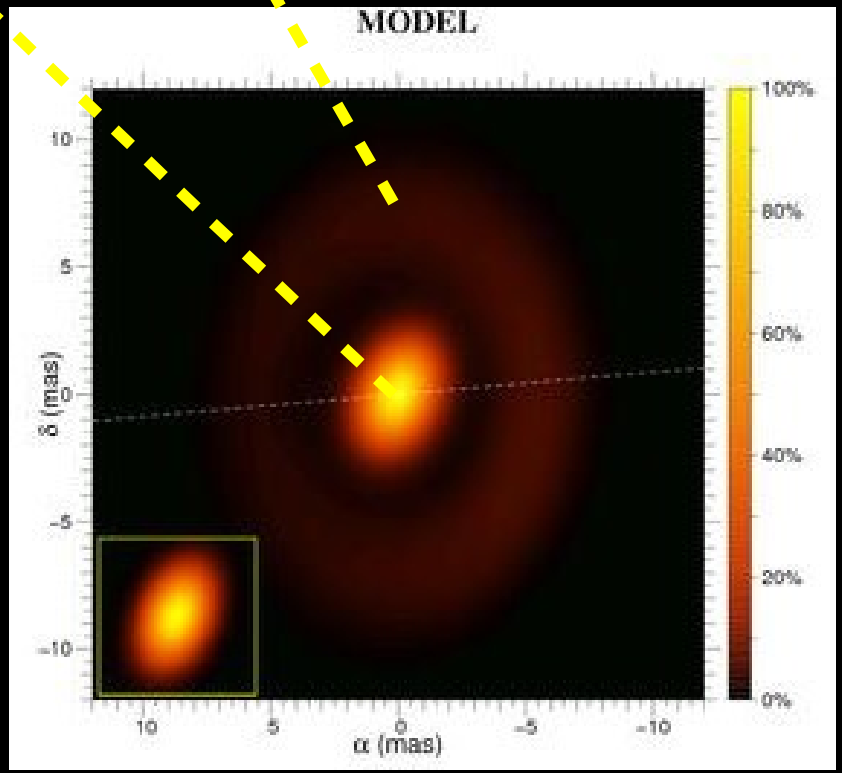
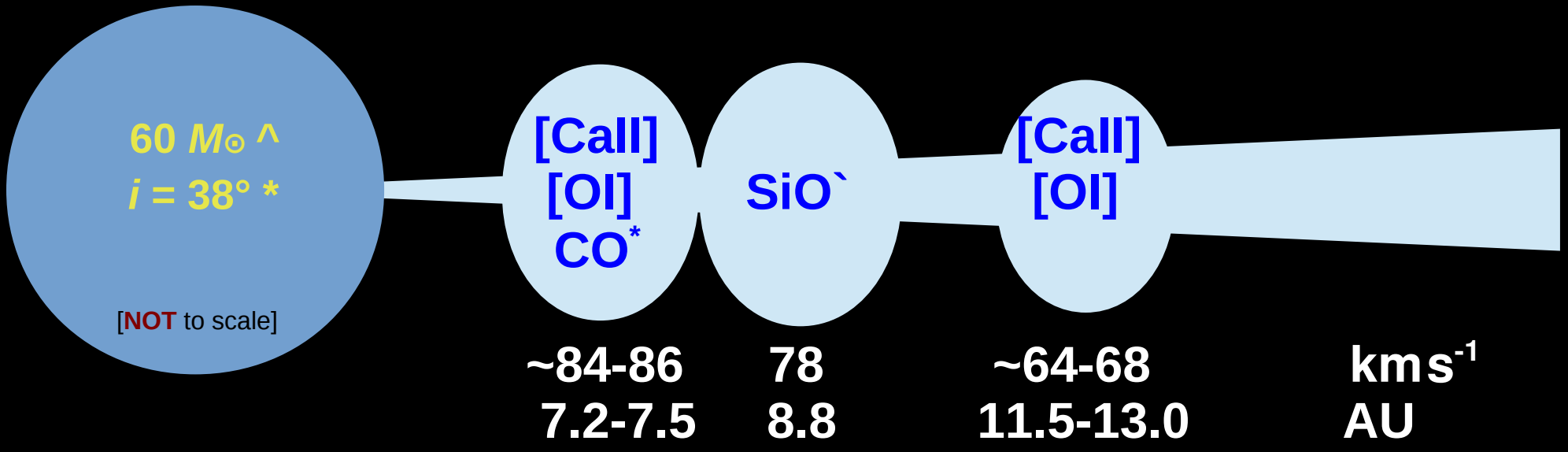
typical ring-width ~6-8 kms^{-1}

> Possible two/three distinct rings
> Binary ?



Millour + 2011

HD 327083

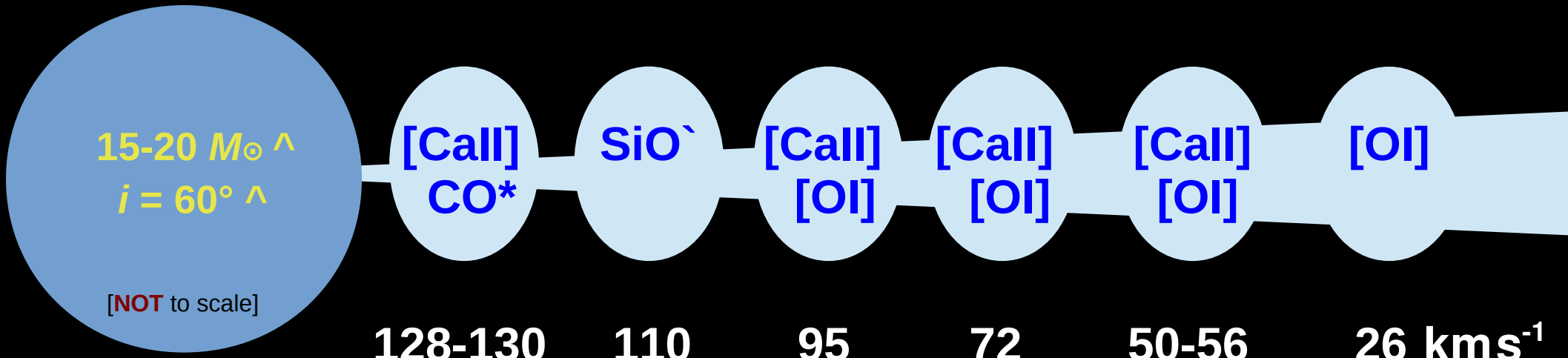


^ *Machado & Araújo 2003*
* *Marchiano+ in prep.,*
* *Millour+ 2011,*
` *Kraus+ 2015*

typical ring-width ~4 kms^{-1}

> Possible two/three distinct rings
> Rings are circumbinary
> No gas closer than CO ring.
> Binary (Wheelwright + 2012)
Highly eccentric, *P*orb ~ 120 d (Marchiano + in prep.)

CPD -57 2874



128-130	110	95	72	50-56	26 kms^{-1}
~0.8-1.1	1.1-1.5	1.5-2.0	2.6-3.4	~5.0-6.5	19.7-26.3 AU

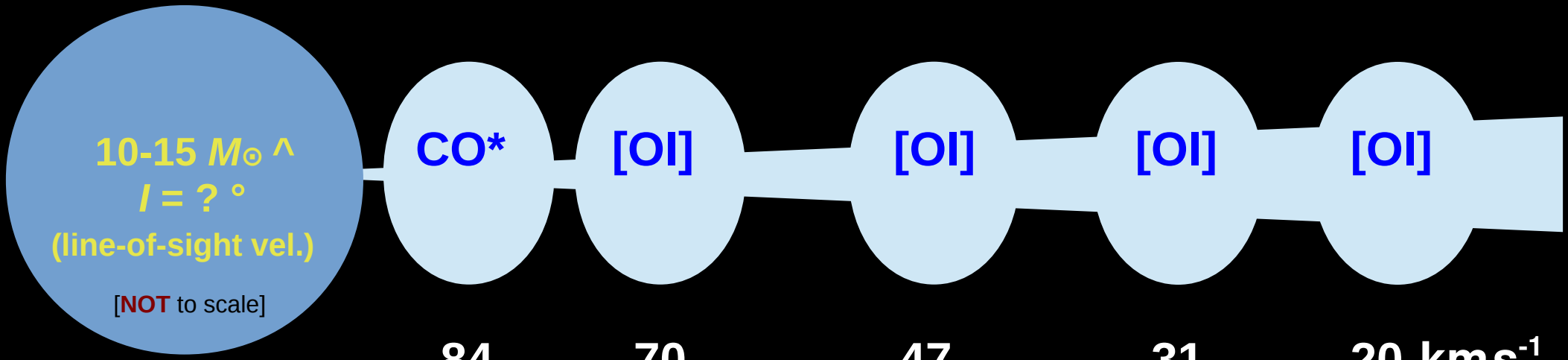
^ *Domiciano de Souza+ 2011*
* *Muratore+ 2012,*
` *Kraus+ 2015*

typical ring-width ~4-9 kms^{-1}

> Multiple rings → disk?
> No gas closer than CO ring

> Highly mixed/alternate emitting regions further than CO

MWC 137



84	70	47	31	20 kms^{-1}
1.2-1.8	1.8-2.7	4.0-6.0	9.2-13.9	22.1-33.3 AU

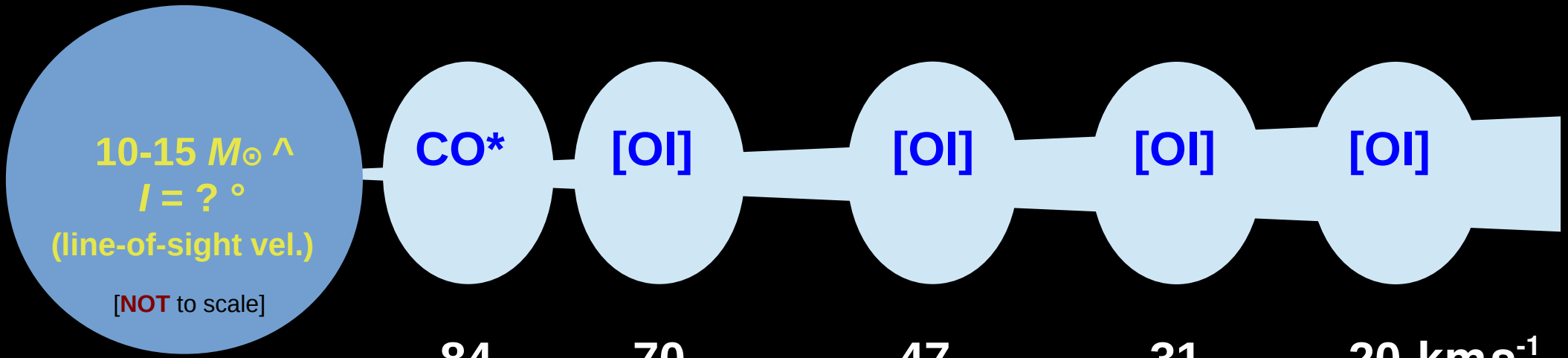
^ *Mehner+ 2016*
* *Muratore+ 2015*

typical ring-width ~3-7 kms^{-1},

> No [CaII] emission
> No atomic gas in CO ring / no molecular emission further out?

> Mixed/alternate emitting regions further than CO

MWC 137



^ *Mehner+ 2016*
* *Muratore+ 2015*

typical ring-width ~3-7 kms^{-1},

> N
> N g / no mole out?

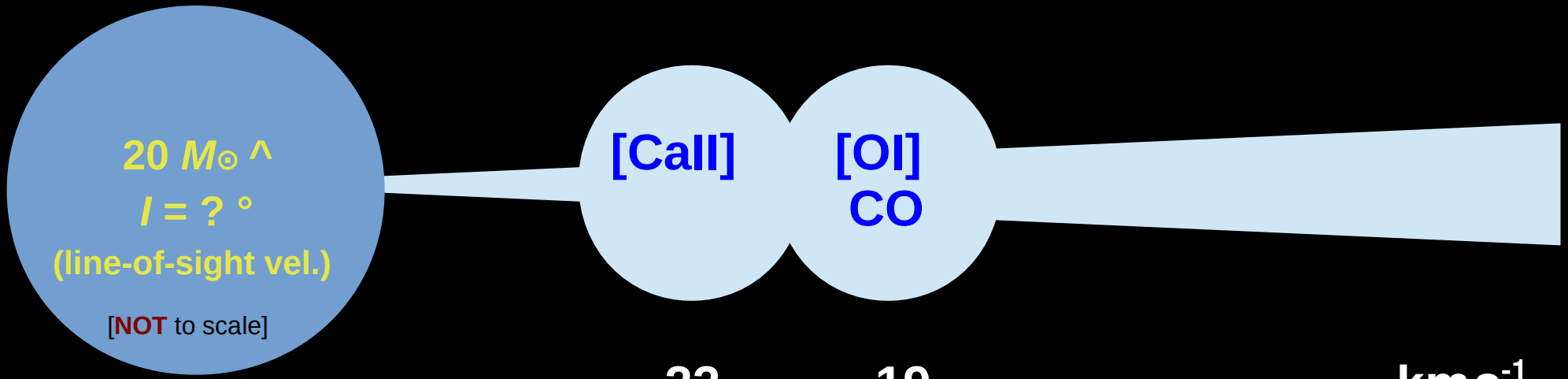
Mehner talk
Tomorrow @ 14:00

Kraus
Poster 16

> M emitting regions further

> More complex environment with jets and large-scale structures

Hen 3-298



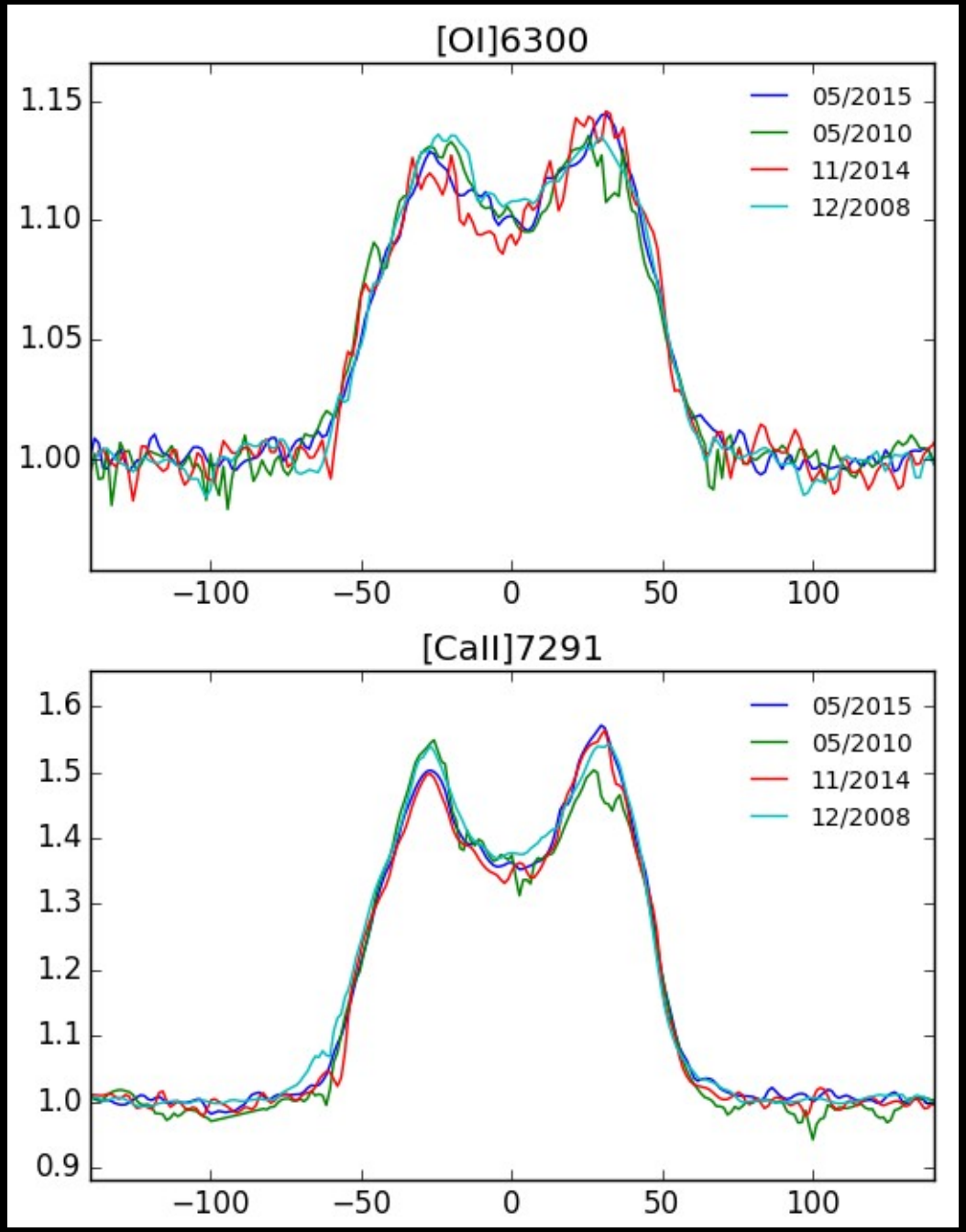
^ *Oksala+ 2013*

typical ring-width ~4-10 kms^{-1},

> Two rings with rather wide rings → possible one

> Binary ? (Miroshnichenko + 2005)

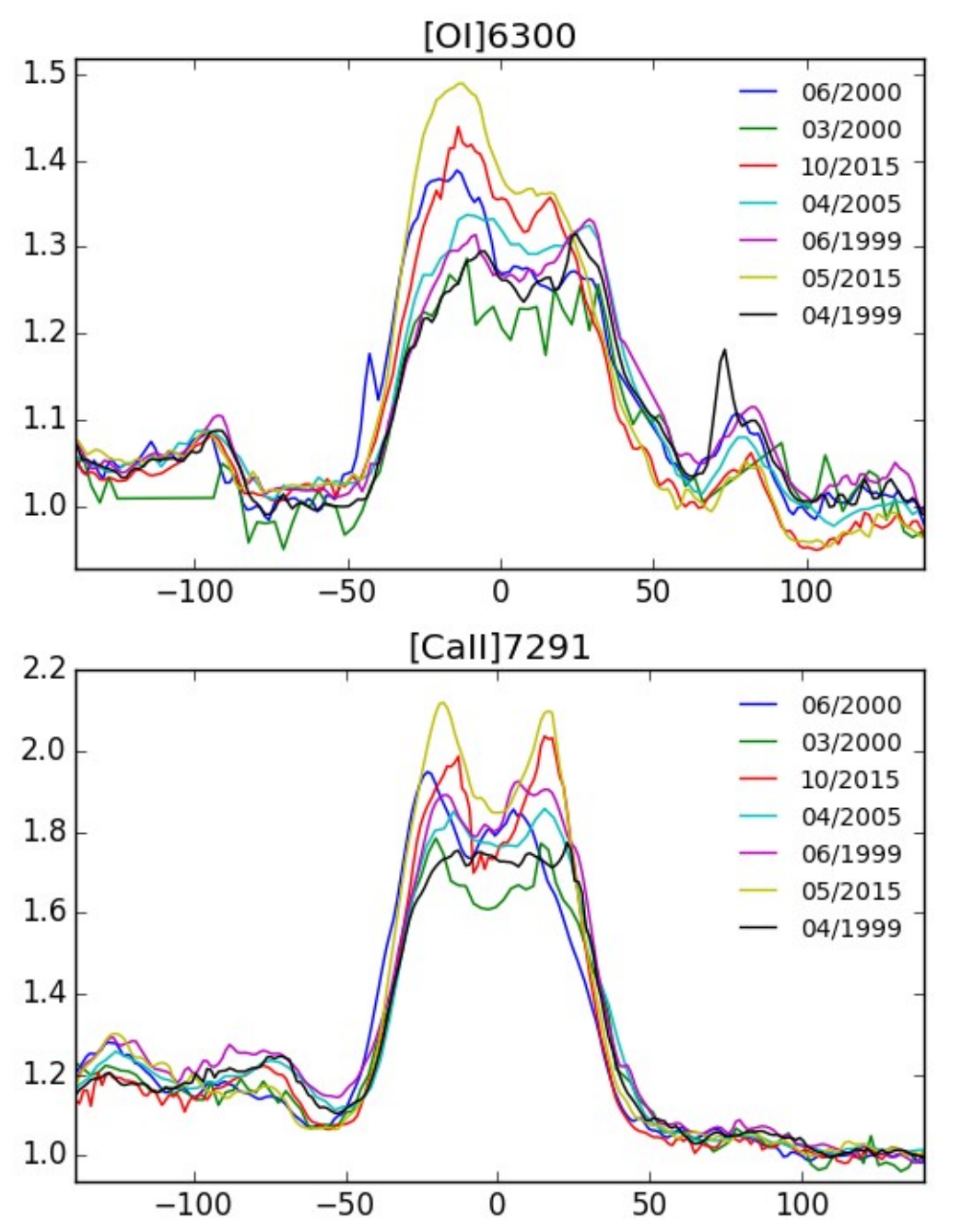
Non-variable structures ?



HD 62623

Stable over 8 years

Non-variable structures ?

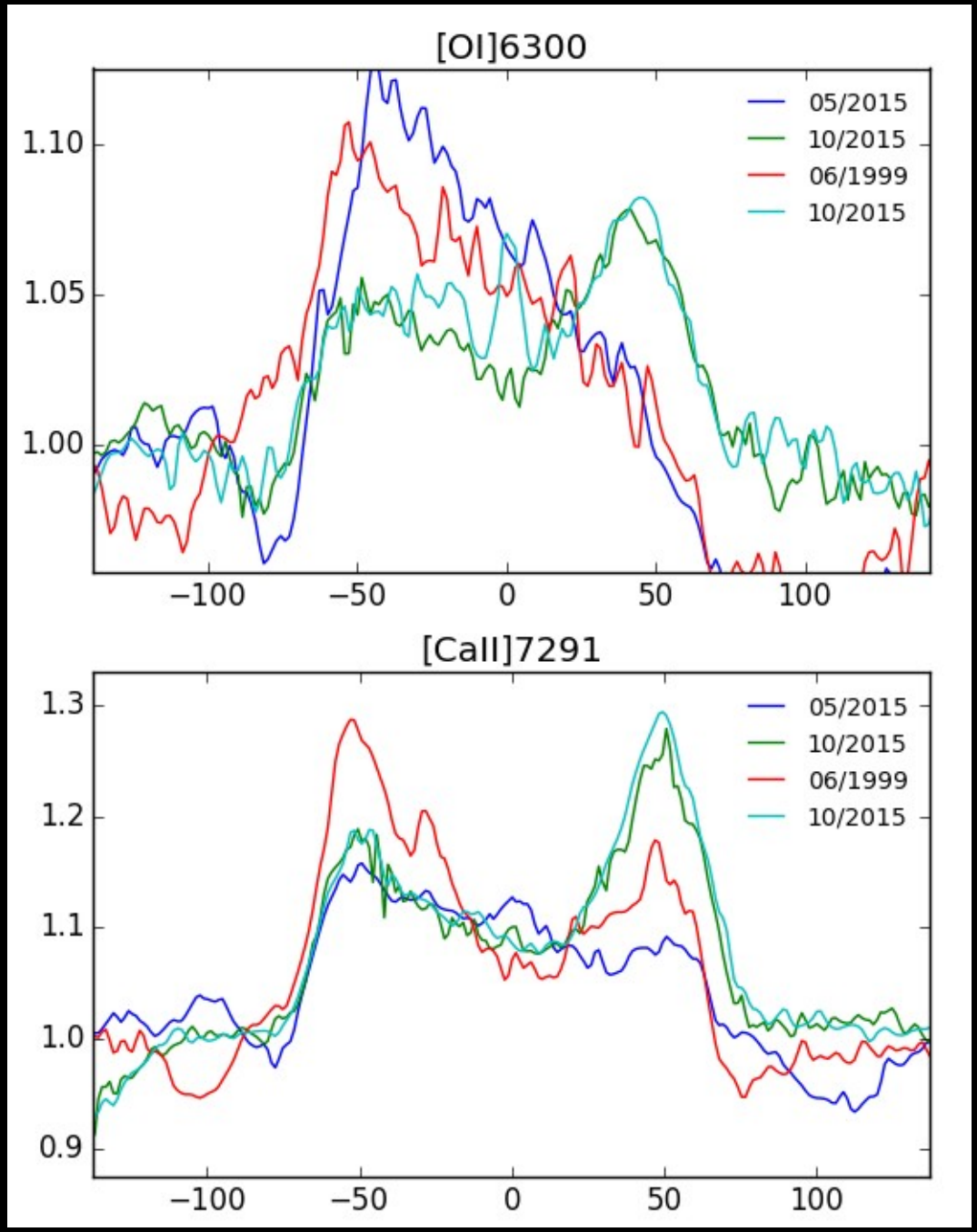


CPD -52 9243

Same kinematics over 16 years

Changes in profiles and intensity

Non-variable structures ?



HD 327083

Same kinematics over 16 years

Changes in profiles only due to binarity

Conclusions

⟶ Using emission features ([OI], [CaII] λ7291, CO, SiO) we can
> probe regions of different temperature and density
> get information about the kinematics and the structure of the CSM

⟶ B[e] SGs' circumstellar environment:
very complex structures but stable (over observed time)
> often no gas closer to star than CO ring
> series of single and/or multiple equatorial rings
> alternate mixing of rings (densities and temperatures)
=> probable result of previous mass-loss events
Maravelias et al. 2016, in prep.

⟶ *More to come...*
Spectroscopic campaign for Galactic and Magellanic B[e] SGs
> acquire more observations at a homogeneous approach
> monitor activity
– variability optical/IR ?
– connection to mass-loss history ?