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Observations of winds from AGB stars

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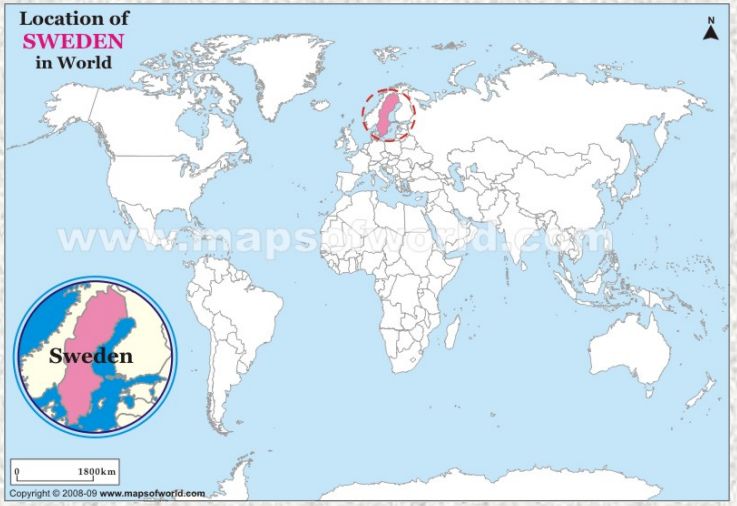
Ambition:

- Give an overview of the current status from my point of view



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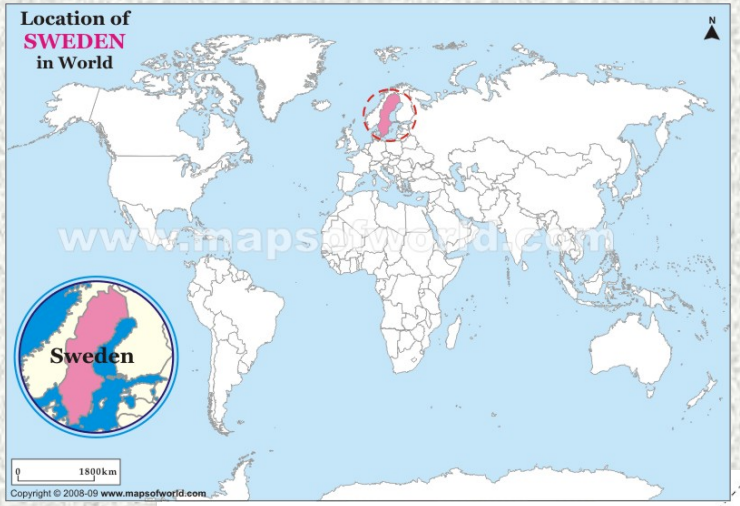
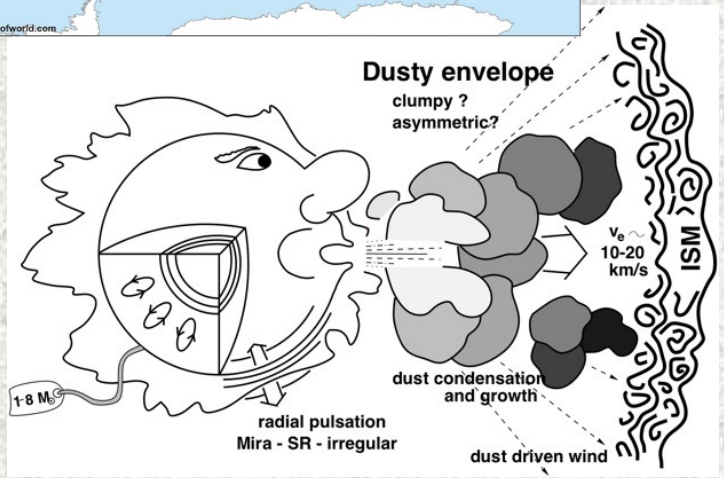
Ambition:

- Give an overview of the current status from my point of view
- Focus on AGB winds - not chemistry, not all observations, not RSG





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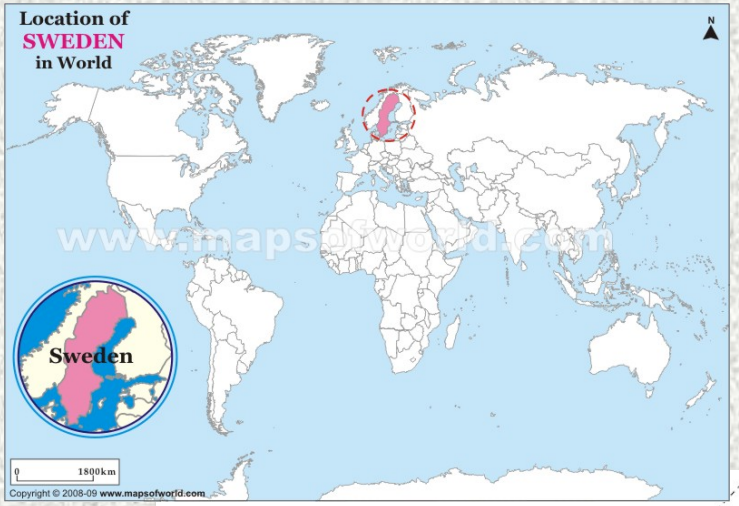
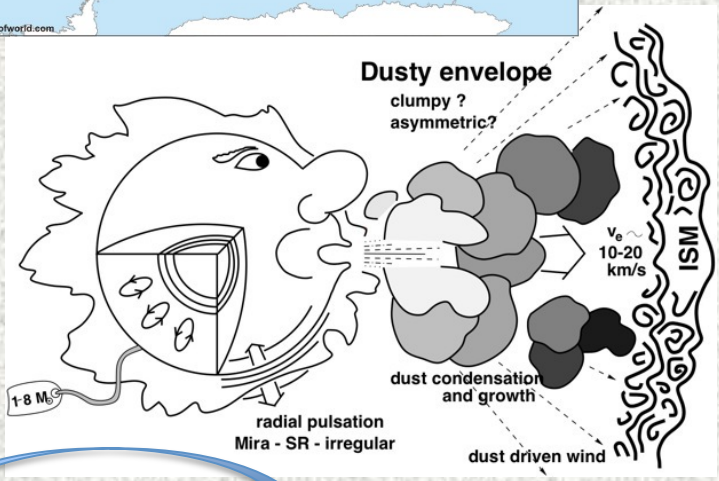
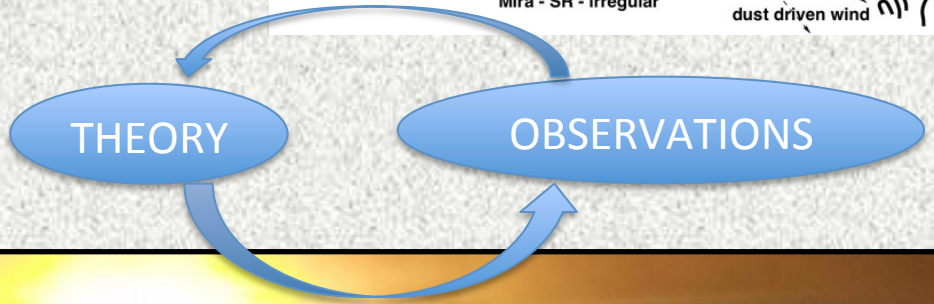
Ambition:

- Give an overview of the current status from my point of view
- Focus on AGB winds - not chemistry, not all observations, not RSG
- Convince you of the importance of a broad investigation







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Breaking point for Galactic AGBs!

Obs: Unresolved → Imaging at milliarcsecond resolution

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Breaking point for Galactic AGBs!

Obs: Unresolved → Imaging at milliarcsecond resolution

Mod: 1D → 3D models with detailed physics and radiative transfer

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Outline

- A little bit of history
- Wind observations and models
- Resolved images

...

- Magnetic fields?

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How do we know that AGB stars lose mass?

- Indirect arguments, e.g., WD in clusters
- Circumstellar (CS) lines
- IR excess

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$$v_e = \sqrt{\frac{2GM}{r}}$$

α Her

CS M-type lines in companion spectra

Deutsch 1956, ...and later Reimers 1975

IR surveys late 60ies showed IR excess => Presence of large amounts of CS dust

e.g., 2.2 μm IRC-survey (Neugebauer & Leighton 1969)
...and later IRAS, ISO

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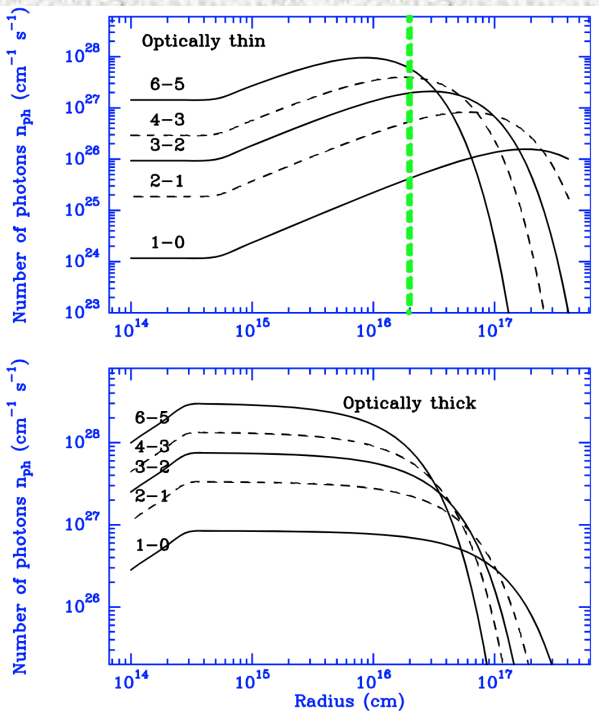
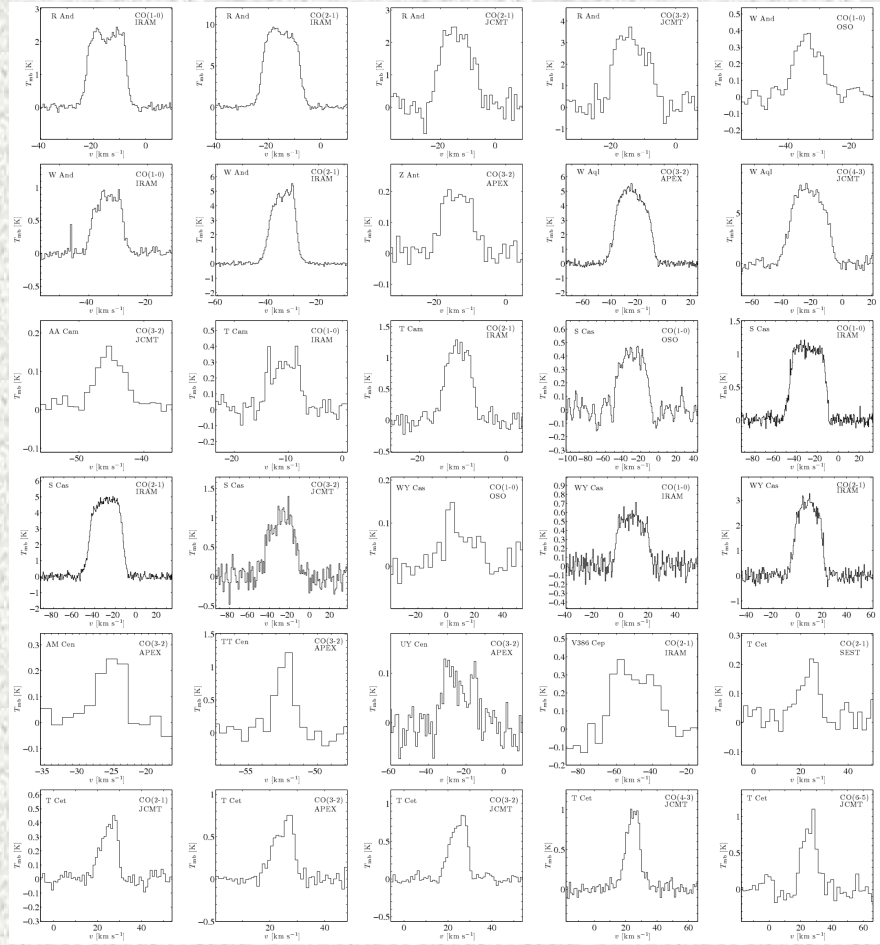
Radio lines





Teyssier et al. 2006
Ramstedt et al. 2009

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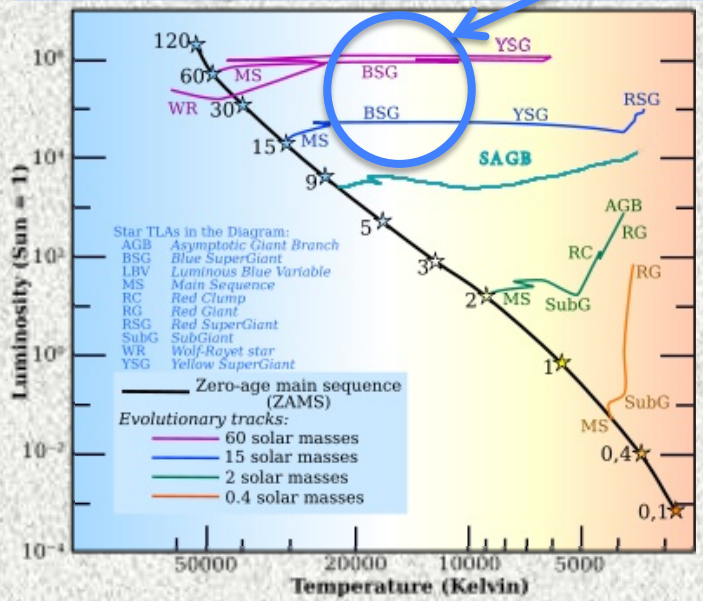
Driving mechanism(s)?

(B)SG★

T_{eff}~10000+ K => No dust (in the right place)
Strong UV emission

L~30000+ L_{sun} => Line driven wind => v_{exp}> 500 km/s, dM/dt~10^{-6} M_{sun}/yr



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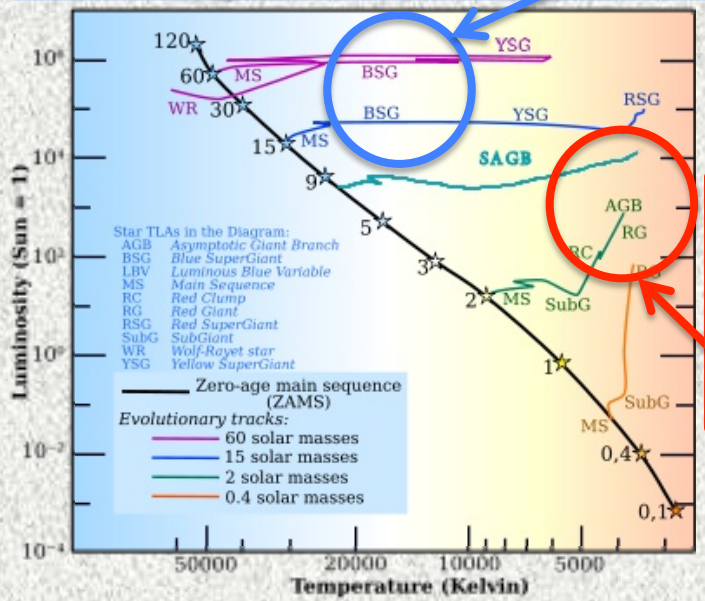

AGB★

T_{eff}~3000 K => Dust! (in the right place)
IR emission

L~5000 L_{sun} => Dust driven wind =>
v_{exp}~10 km/s, dM/dt~10^{-7} M_{sun}/yr

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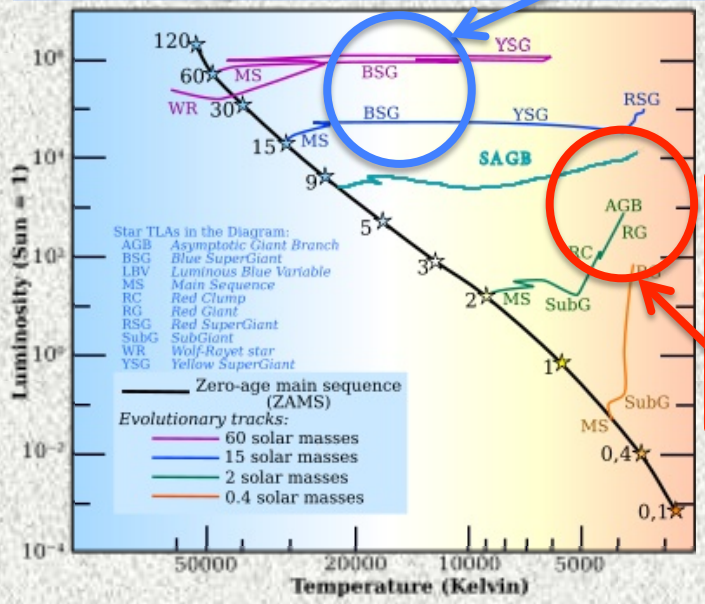

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Radiation pressure ~ L/M
Dust formation

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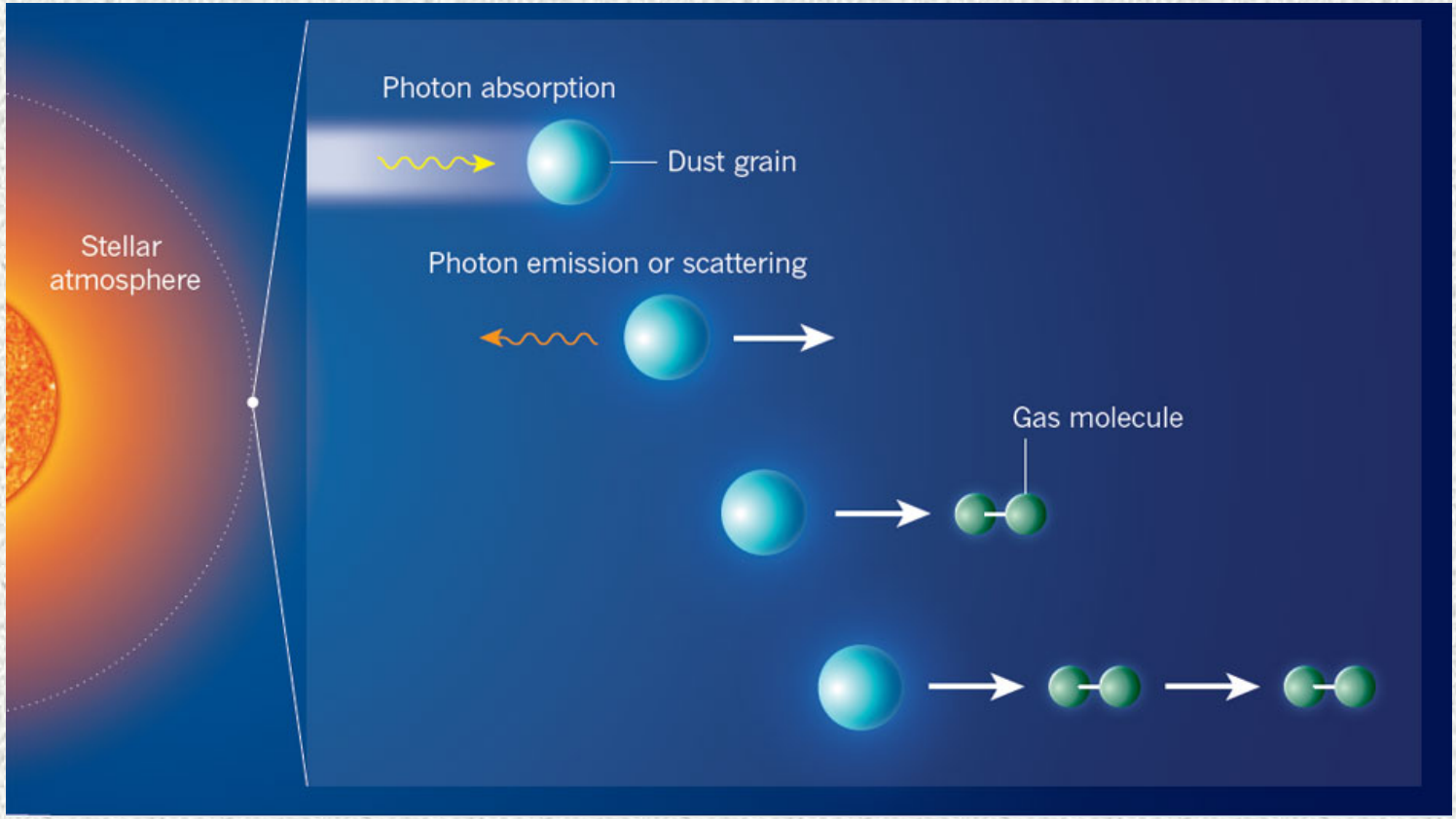
Höfner et al. 2016
Eriksson et al. 2014

1D models "DARWIN"



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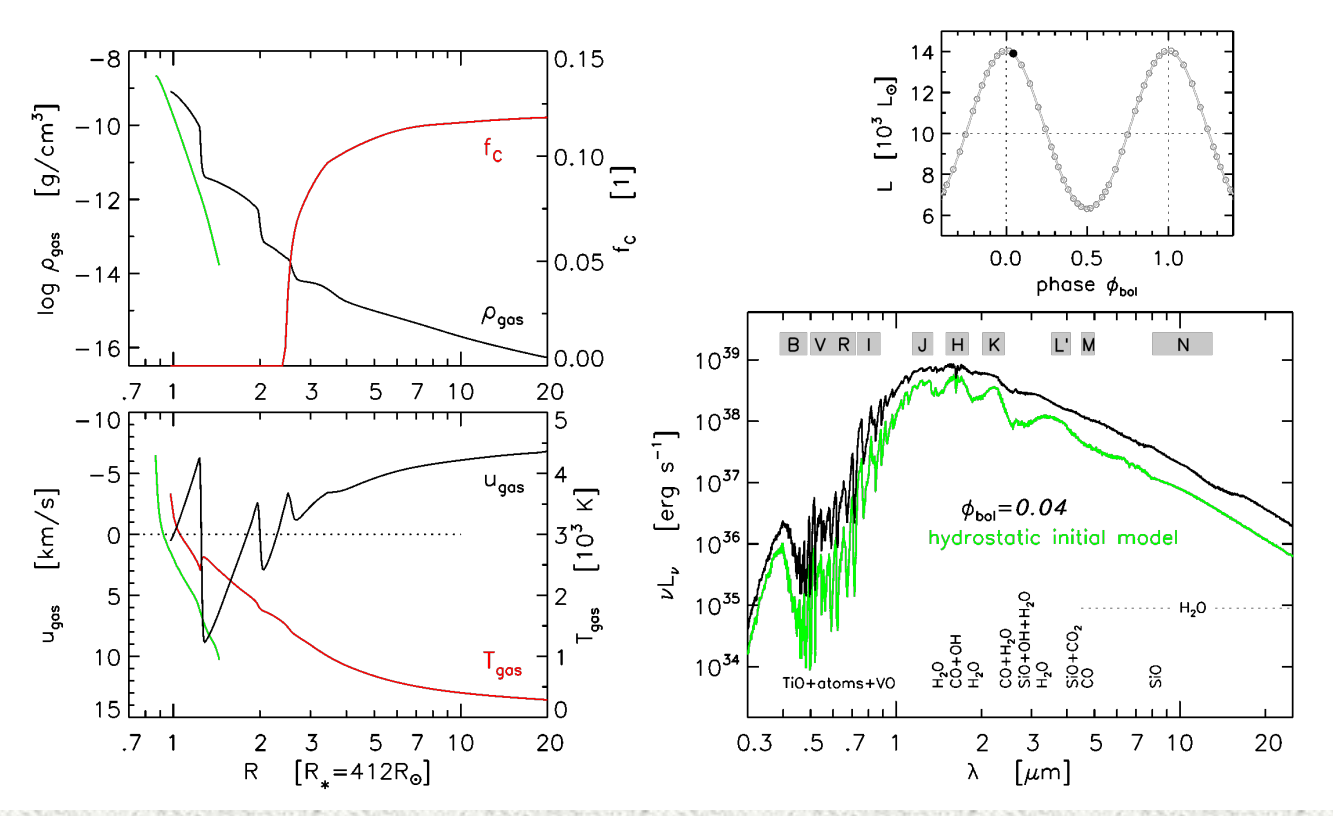
Bladh et al. 2015

Reproduce colors and spectra



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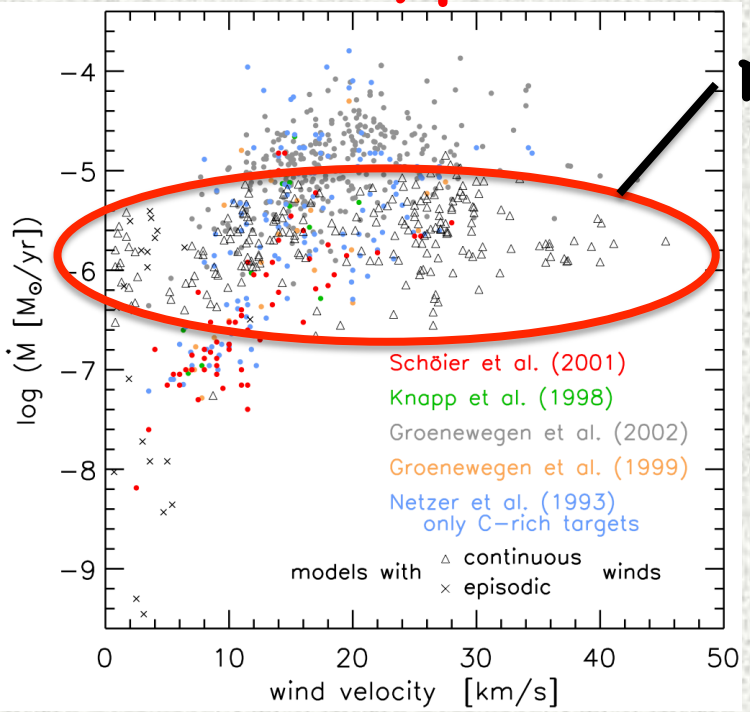
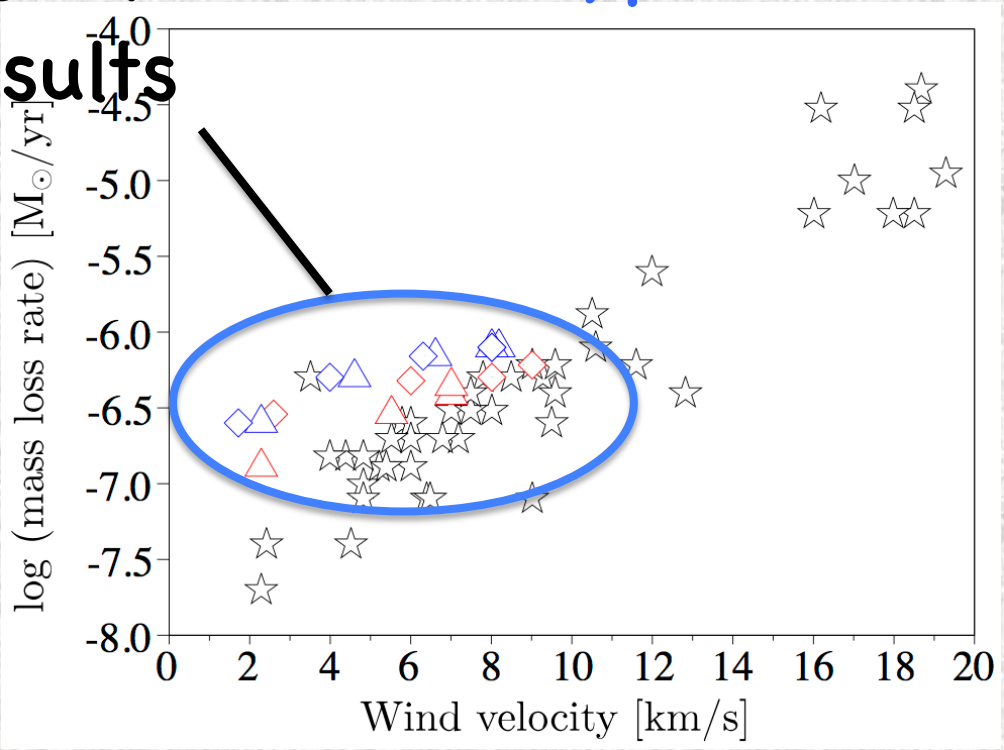
Höfner et al. 2016
Eriksson et al. 2014

Wind properties

C-type model results M-type





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Wind properties - Observations

$$\rho_{\mathrm{wind}} = \frac{\dot{m}_{\mathrm{wind}}(t)}{4\pi r^2(t)\, v_{\mathrm{wind}}(t)}$$

Two methods!

IR photometry+spectra
Dust radiative transfer

CO line emission
observations
CO rad. transfer

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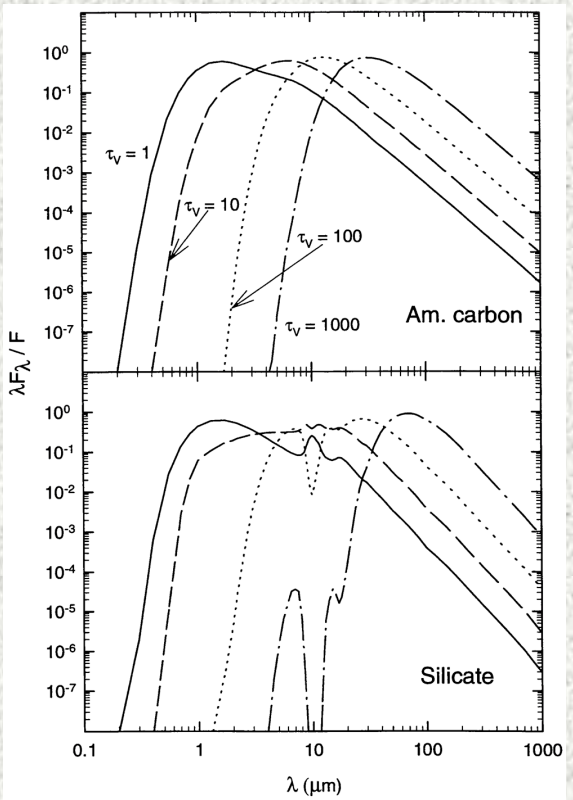
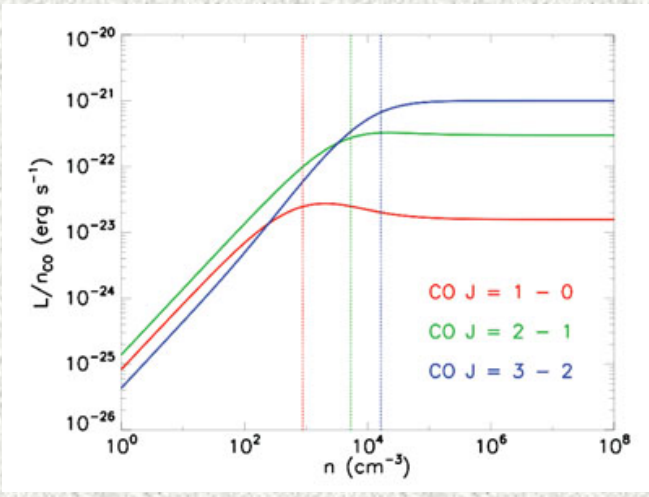
Wind properties - Observations



Two methods!



$$\rho_{\text{wind}} = \frac{\dot{m}_{\text{wind}}(t)}{4\pi r^2(t)\, v_{\text{wind}}(t)}$$

Ivezic & Elitzur 1997; Krumholz 2011

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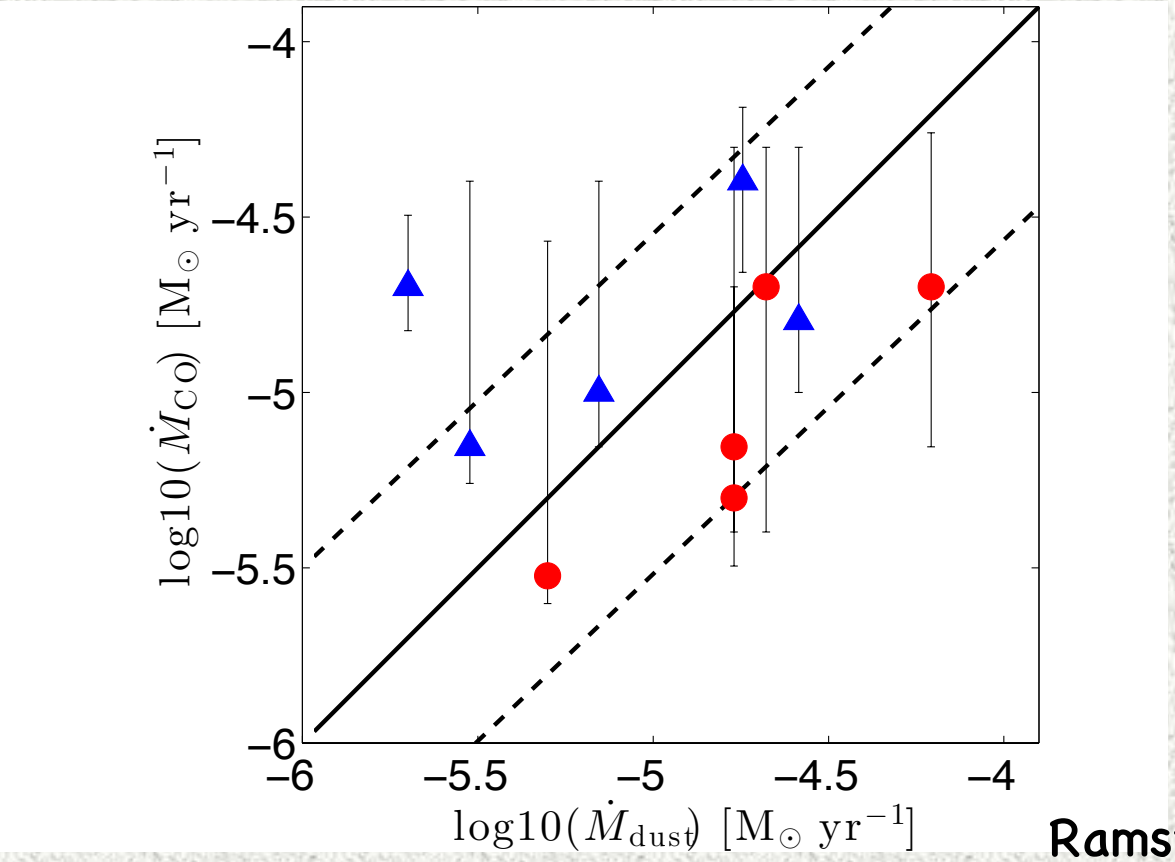
Comparison between two methods



Ramstedt et al. 2008

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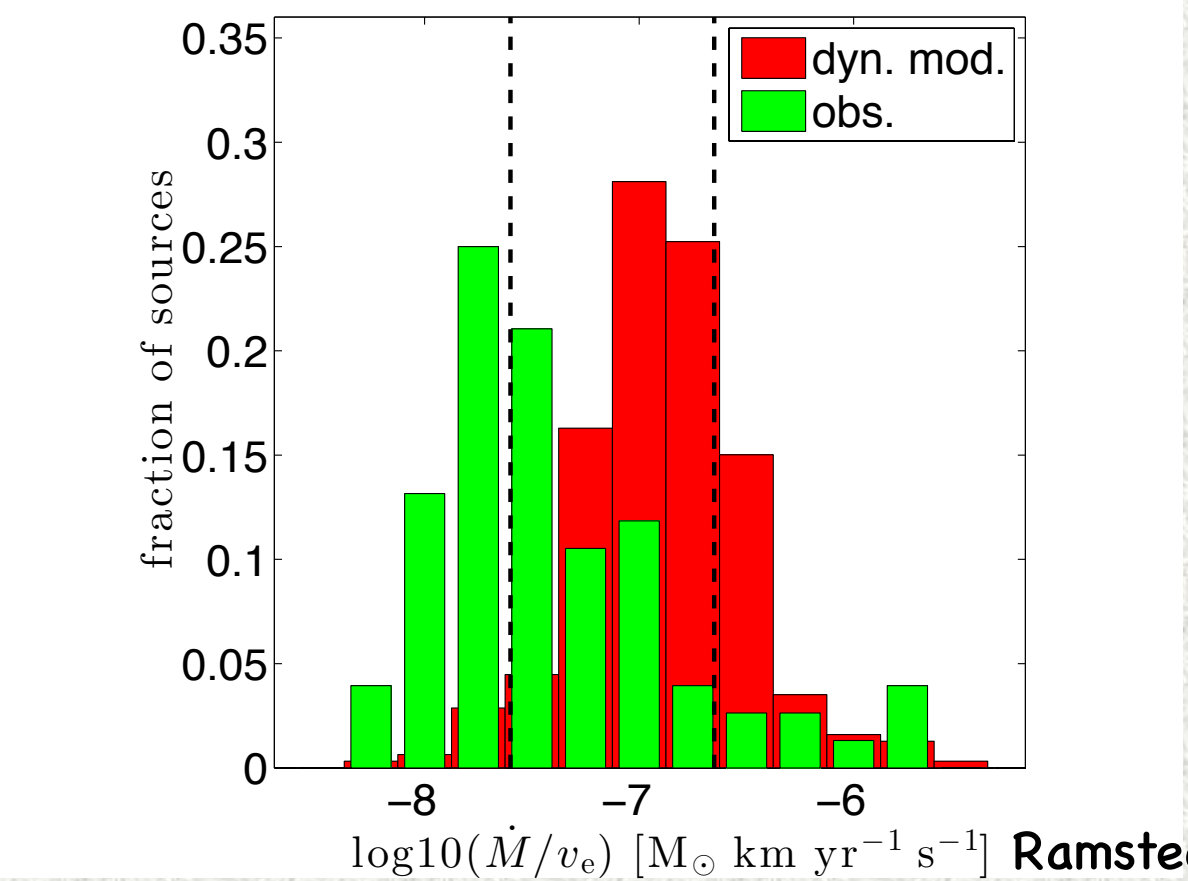
Comparison to models



Ramstedt et al. in prep.

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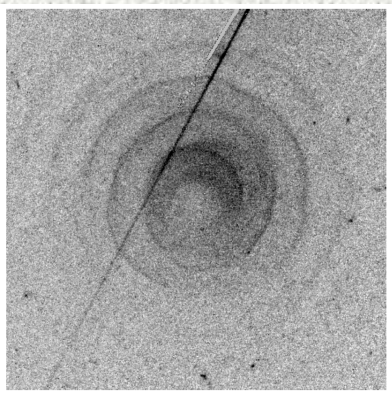
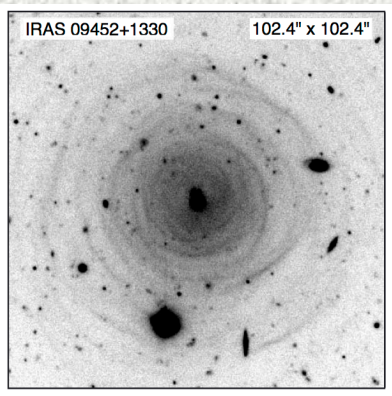
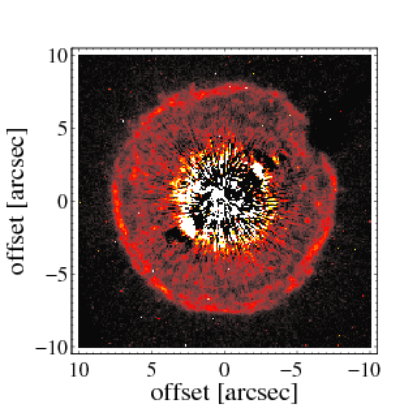
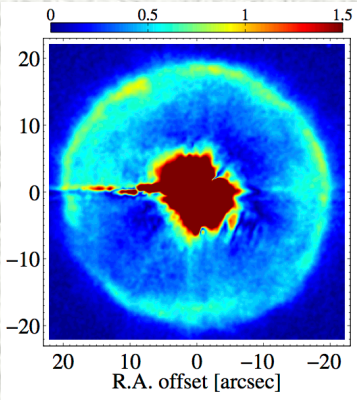
CS Images - Dust scattering

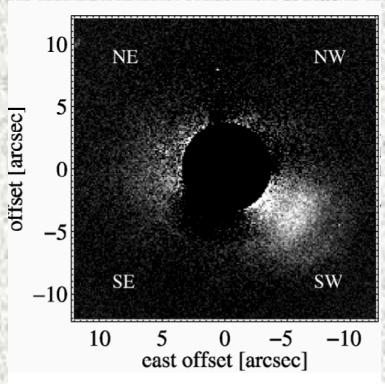




Mauron & Huggins 2006
Mauron et al. 2013
Olofsson et al. 2010
Maercker et al. 2014
Ramstedt et al. 2011







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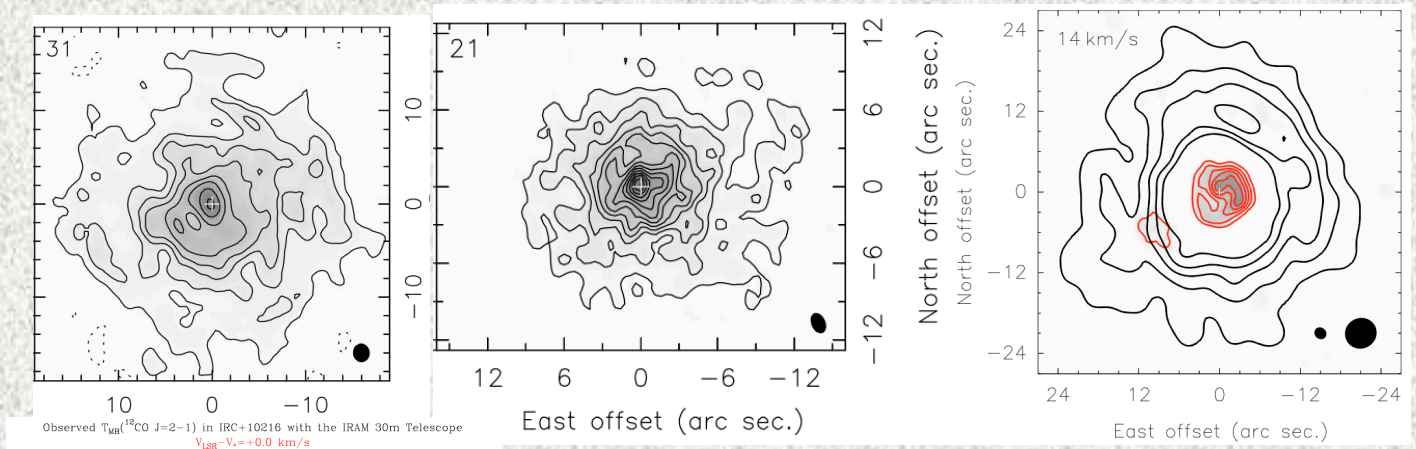
Circumstellar Images - IRAM



Castro-Carrizo et al. 2010
Cernicharo et al. 2016

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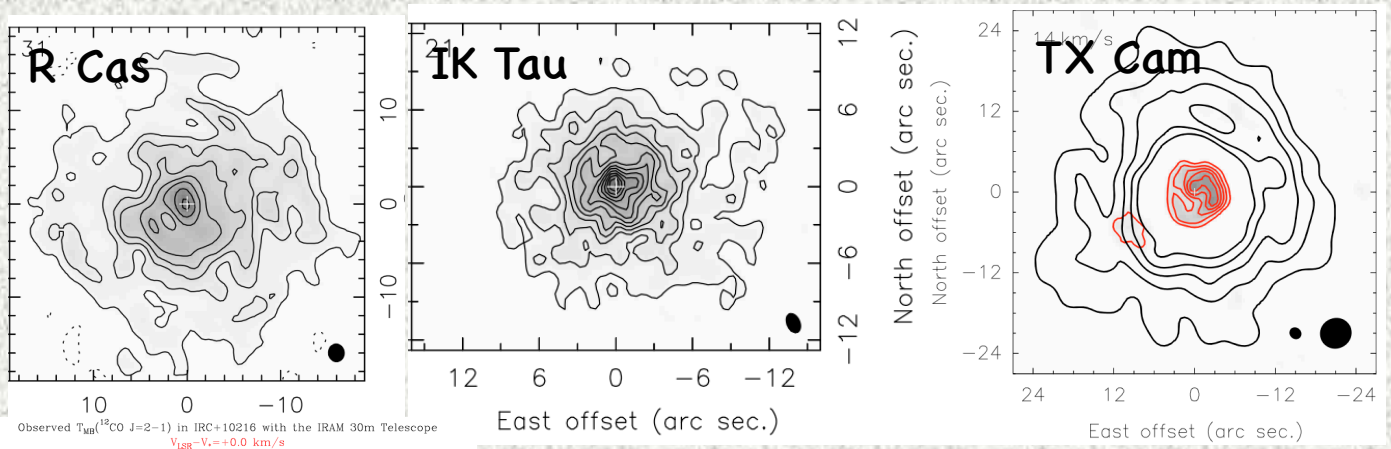

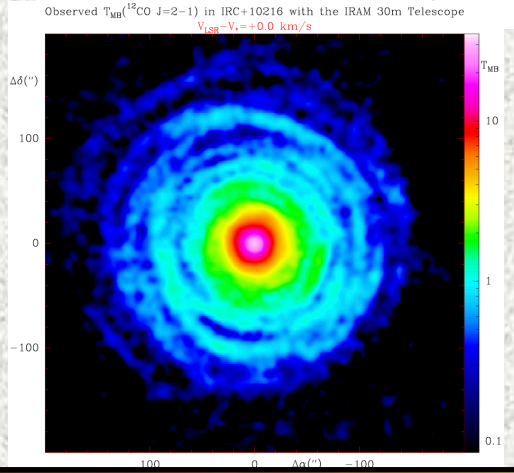

Castro-Carrizo et al. 2010
Cernicharo et al. 2016

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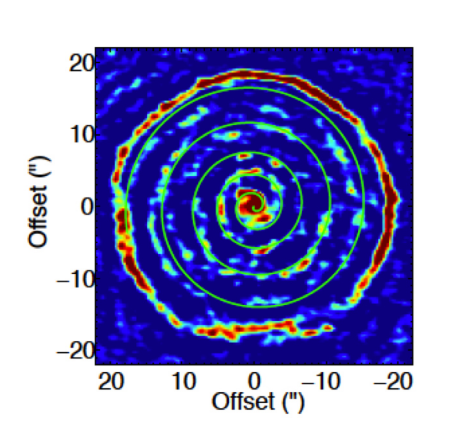
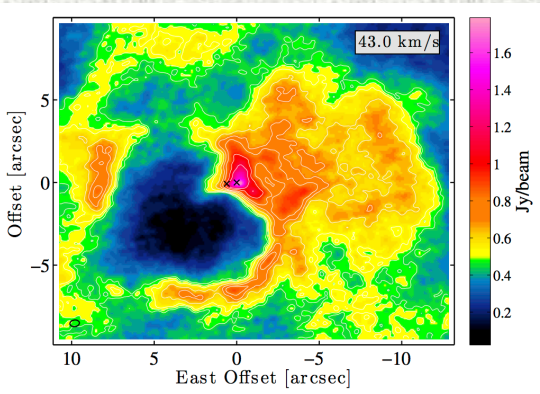
Maercker et al. 2012, in prep.
Ramstedt et al. 2014; Planesas et al. 2016

Circumstellar Images - ALMA





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Maercker et al. 2012, in prep.
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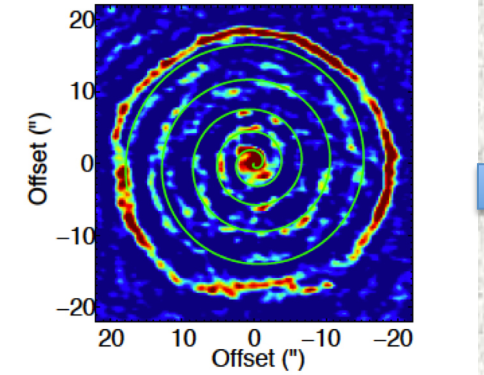
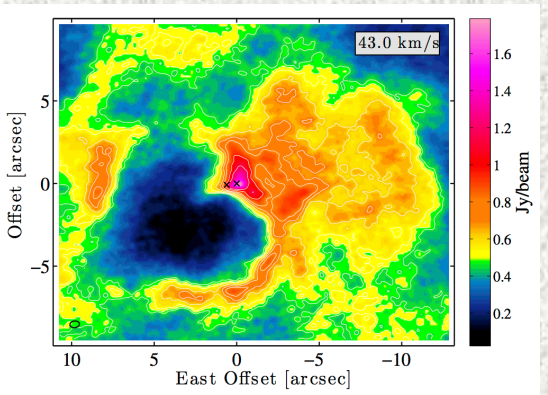
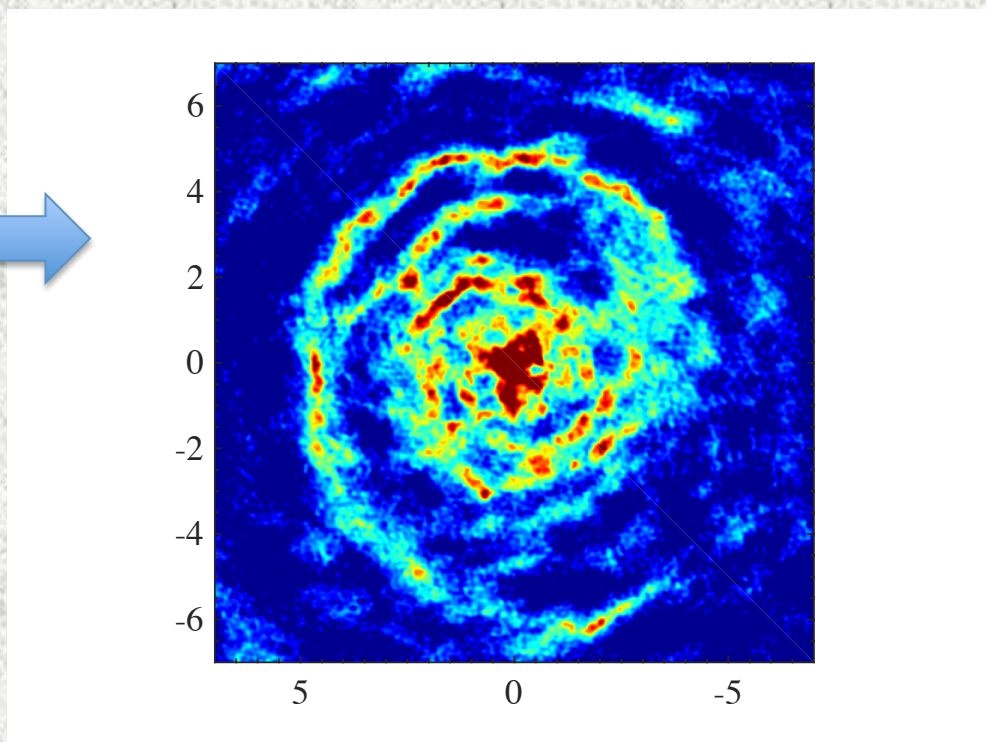
Circumstellar Images - ALMA







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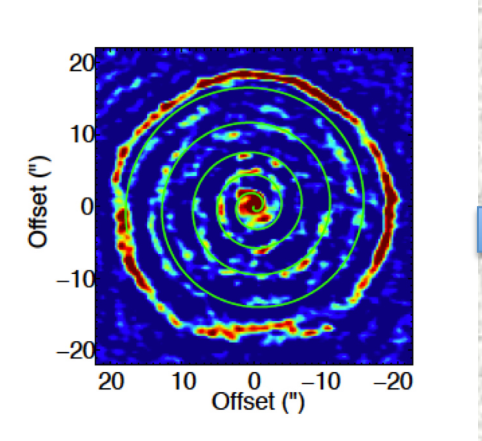
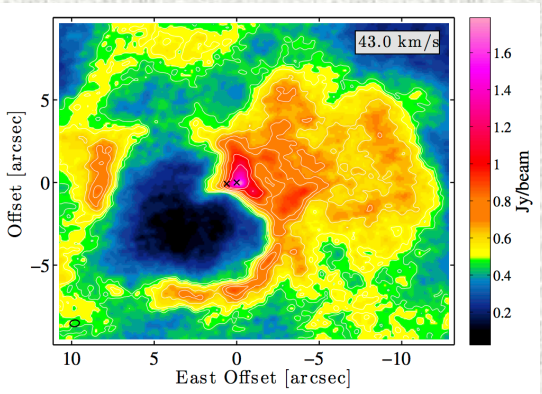
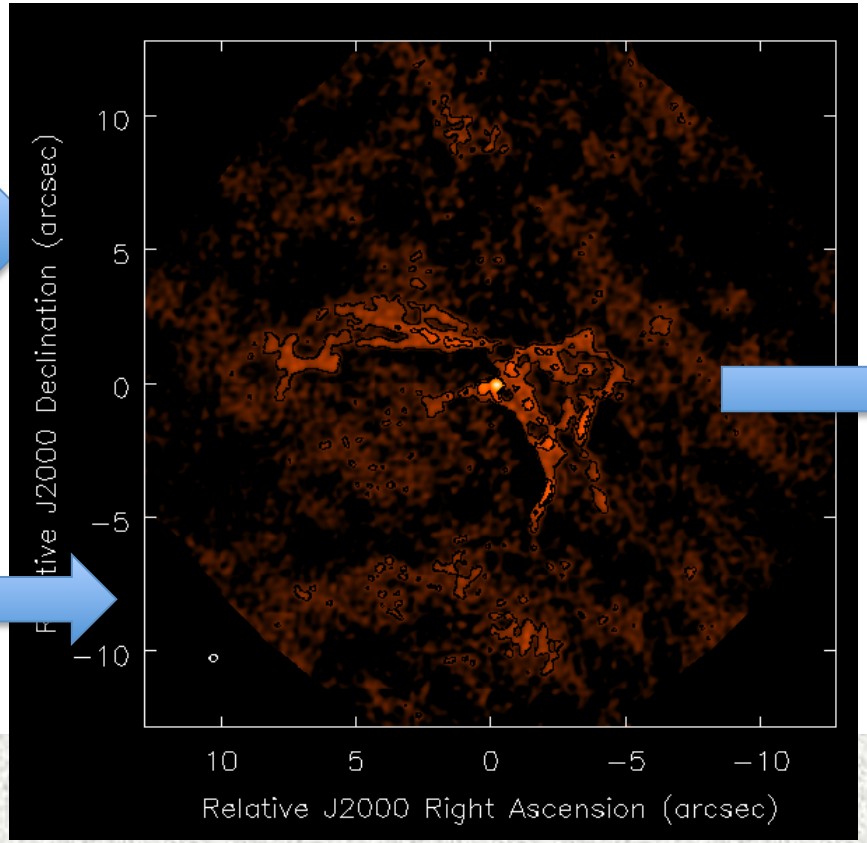
Maercker et al. 2012, in prep.
Ramstedt et al. 2014; Planesas et al. 2016
Talk by Decin!

Circumstellar Images - ALMA







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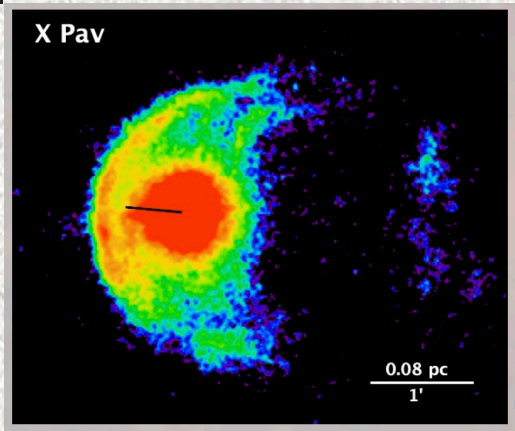
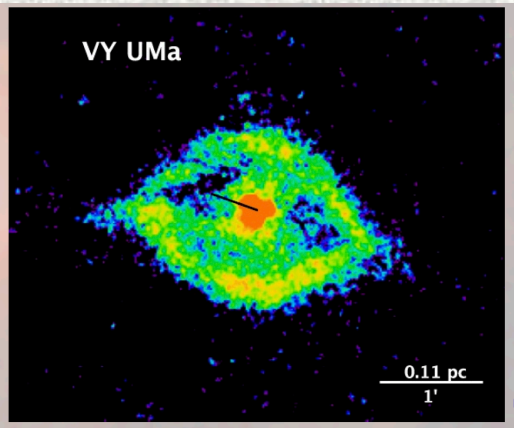
Cox et al. 2012; Ottensamer 2013

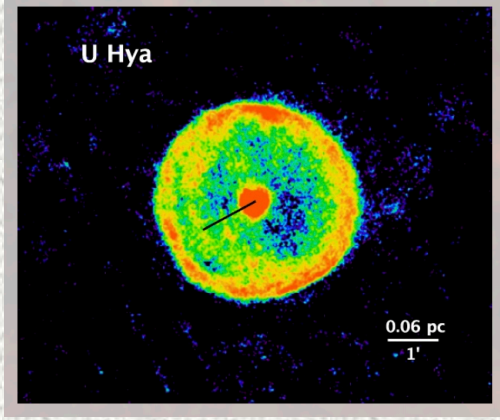
CS Large-scale Images - PACS



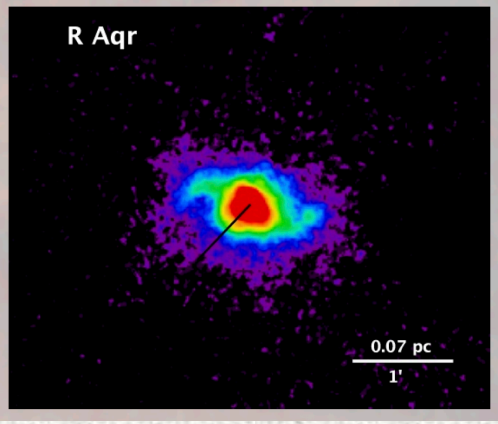
"fermata"



"eyes"



"rings"



"irregular"

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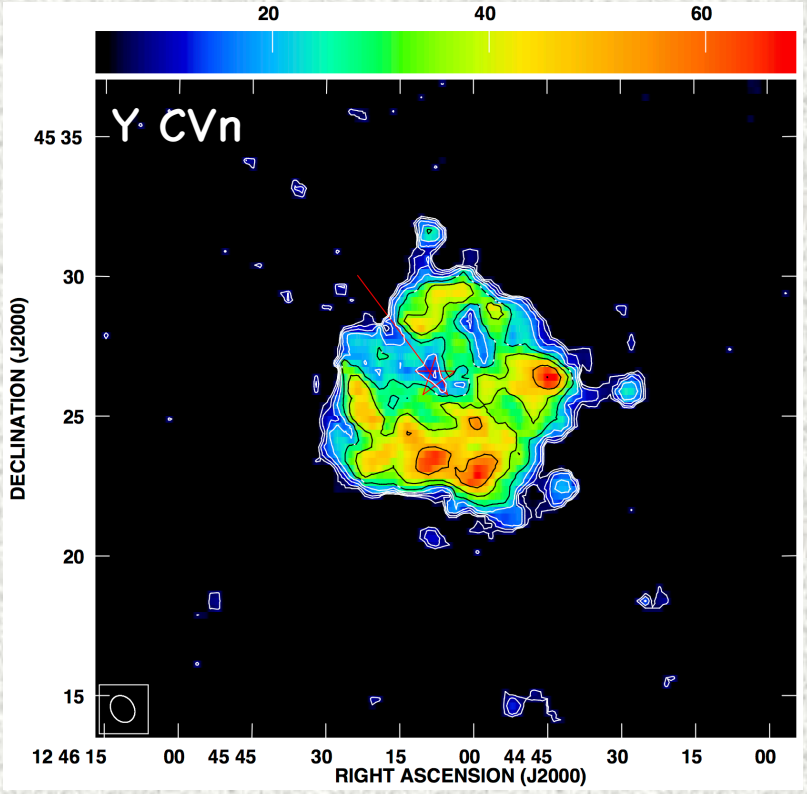
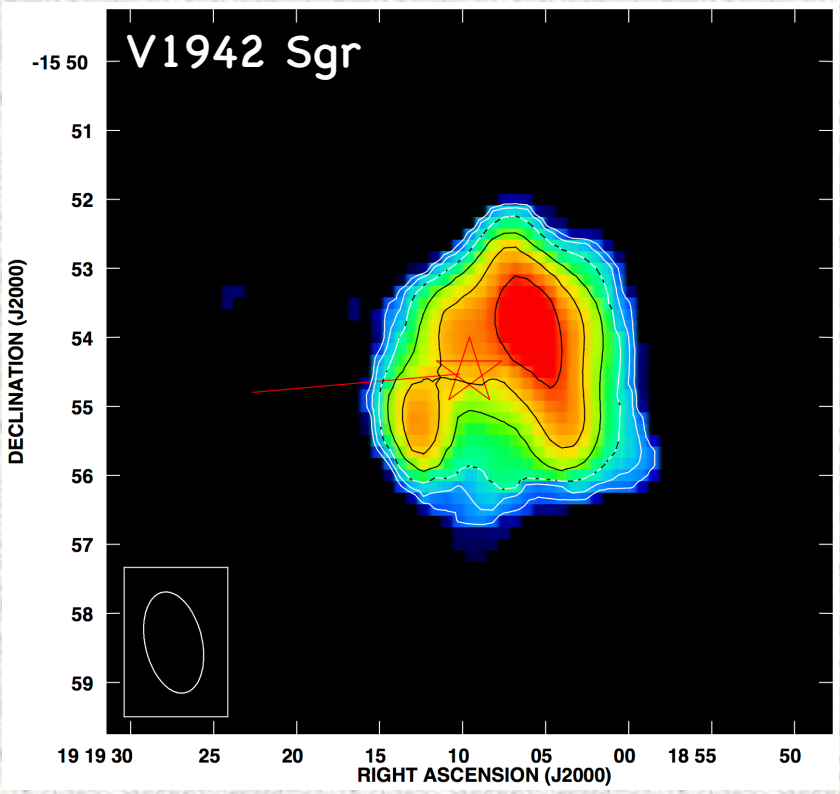
Matthews et al. 2013
Several papers by Libert et al.
Talk by Le Bertre!

CS Large-scale Images - HI





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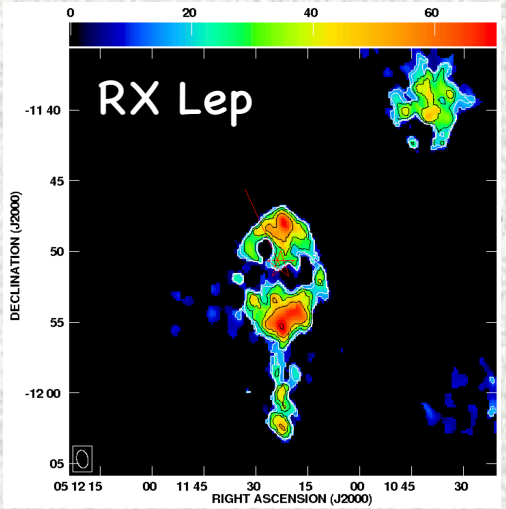
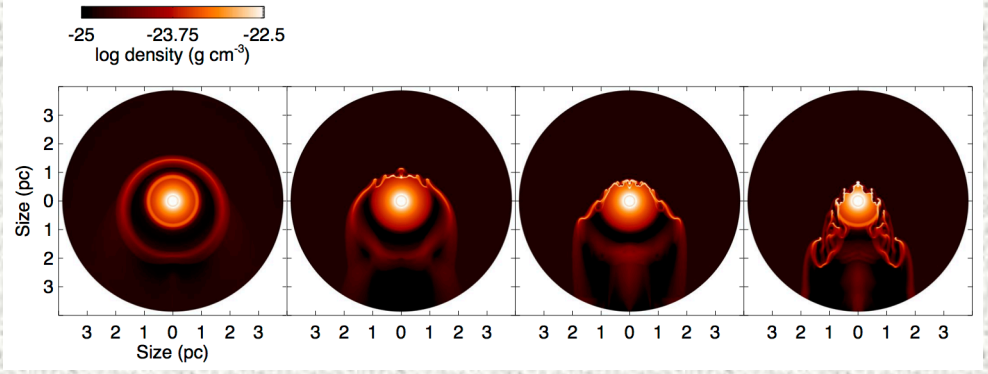
Comparing to models - CS Images

www.eso.org

www.eso.org





Maercker et al. 2012; Mohamed et al. 2012
Matthews et al. 2013;Villaver et al. 2012
See Mohamed's talk!

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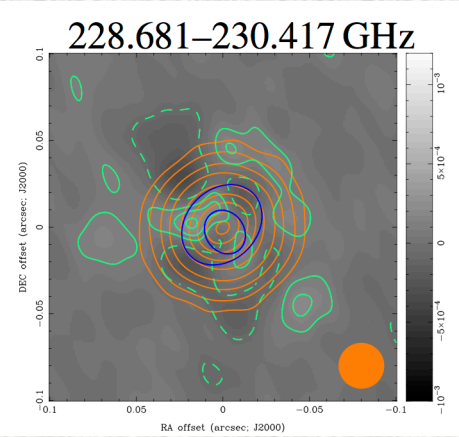
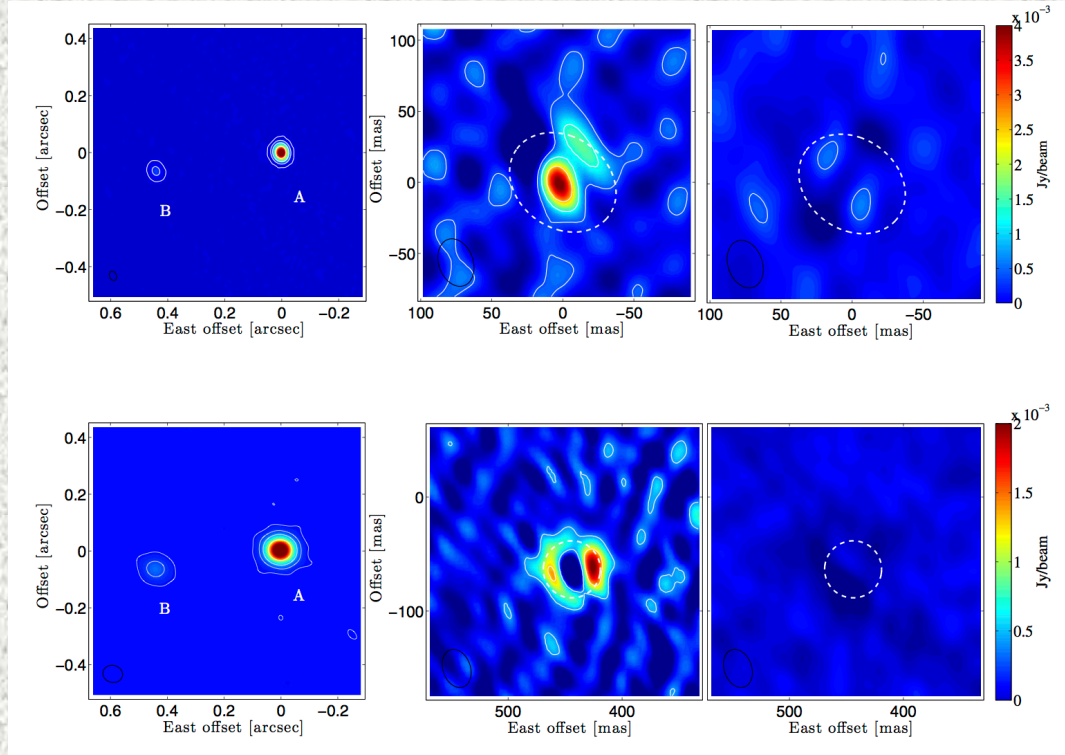
Stellar Images - ALMA





Wong et al. 2016
Vlemmings et al. 2015
See Wong's talk!

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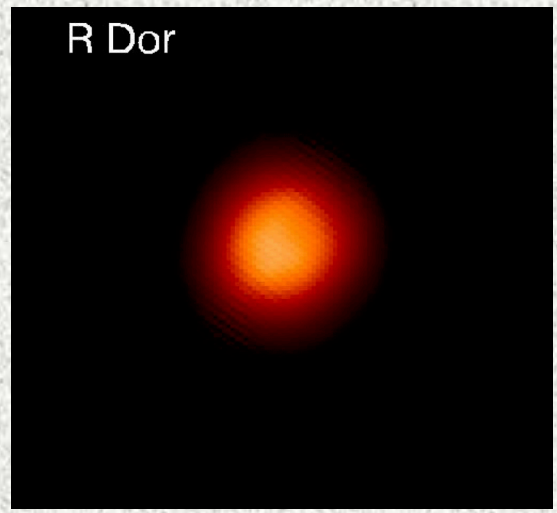
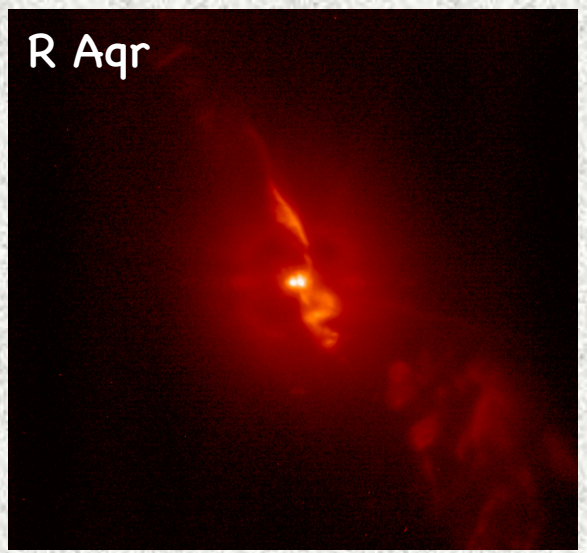
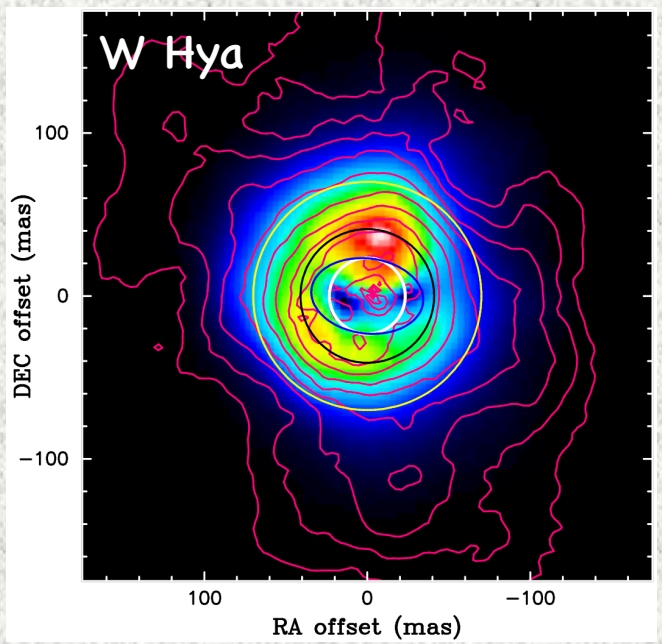
Stellar Images - VLT/Sphere







Khouri et al. 2016
Lagadec 2016
Ohnaka et al. 2016

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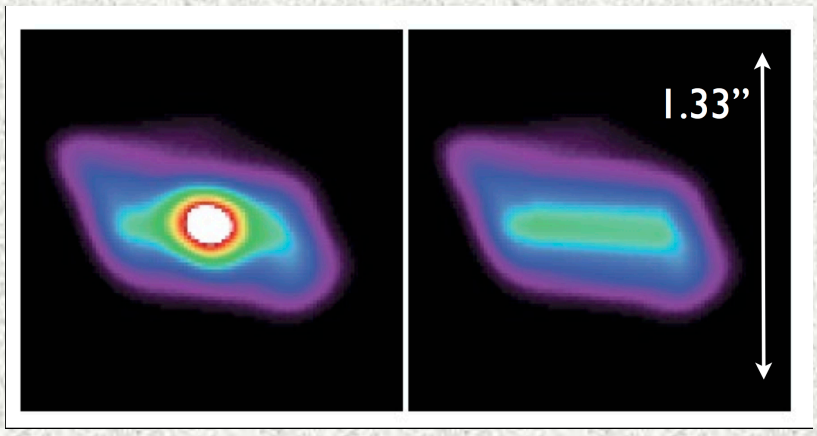
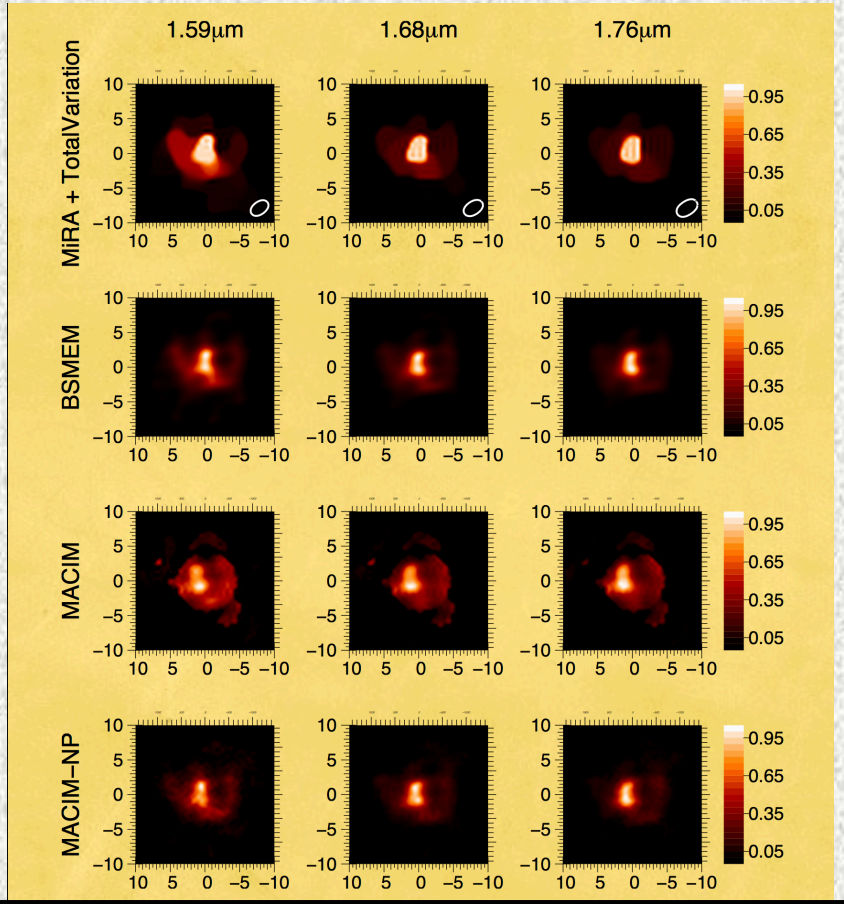
Stellar Images - VLT/NACO, VLTI/Pionier



Kervella et al. 2014
Lykou et al. 2014
Paladini et al. in prep.
See Haubois talk!



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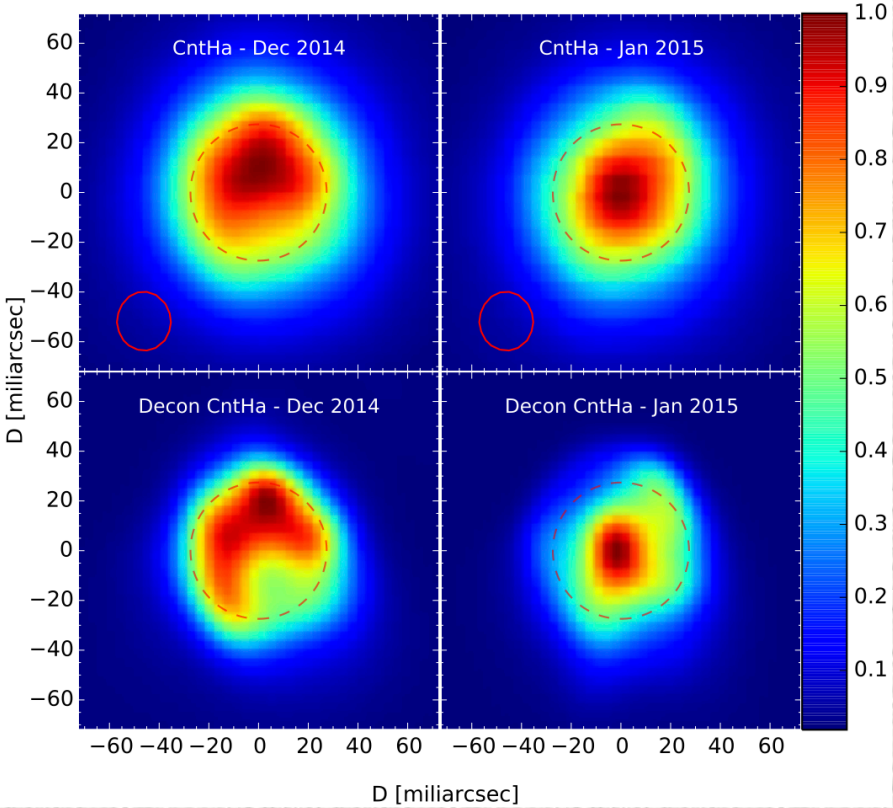
Khouri et al. 2016
Freytag et al. in prep.

Comparing to models



See S. Liljegren's talk!

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Future lies in monotoring!

Gonidakis et al. 2013
See Imai's talk!

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Concluding remarks

Breaking point for AGB stars

Extreme resolution + 3D models

Need to take advantage of this and work in collaborations

Multiwavelength + Theory

Discuss important scientific questions

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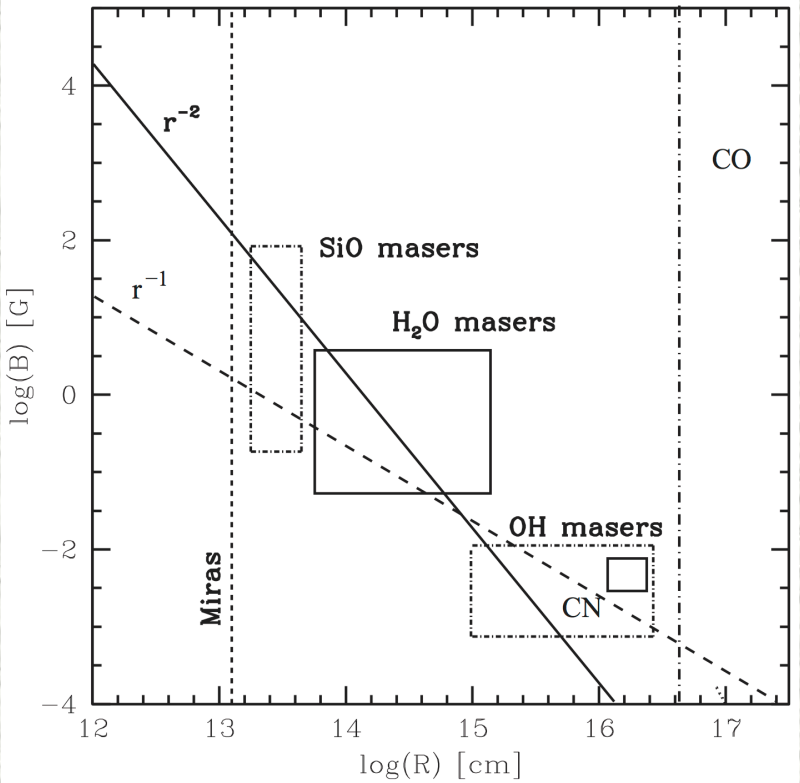
Vlemmings et al. +

Magnetic field observations



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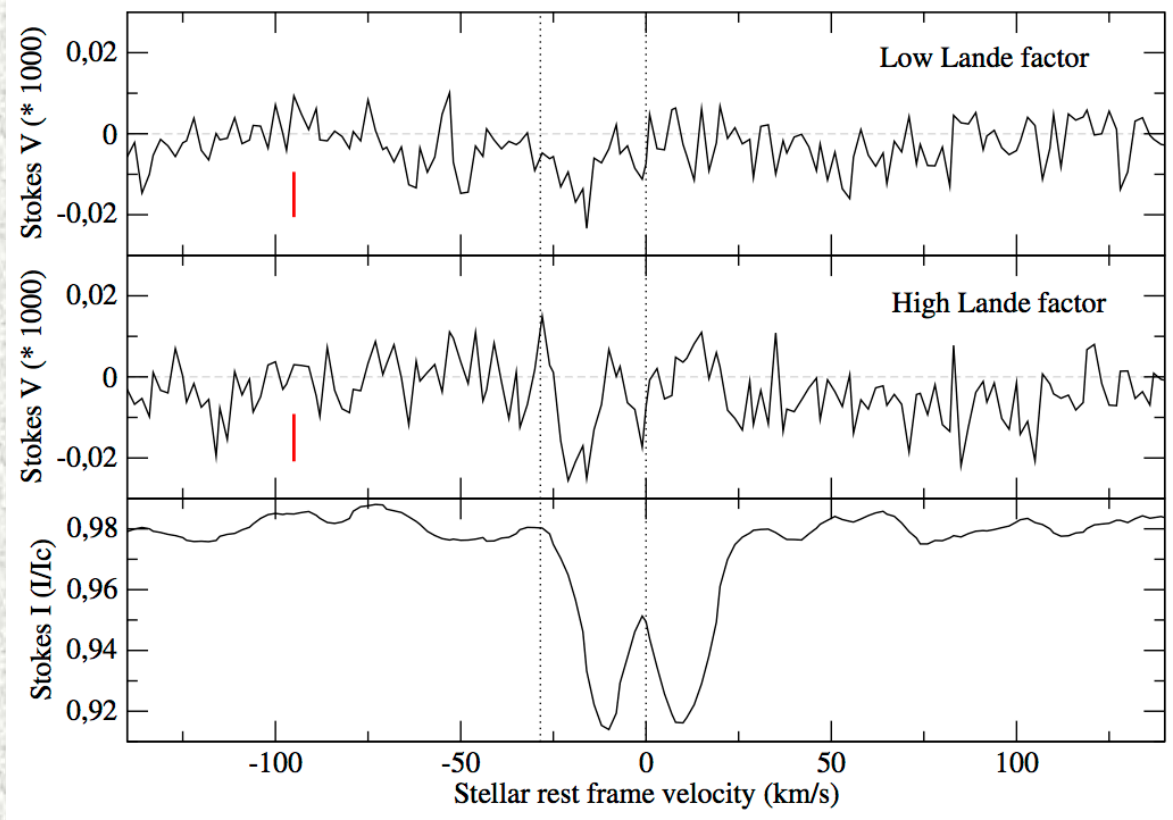
Lebre et al. 2014

Magnetic field observations



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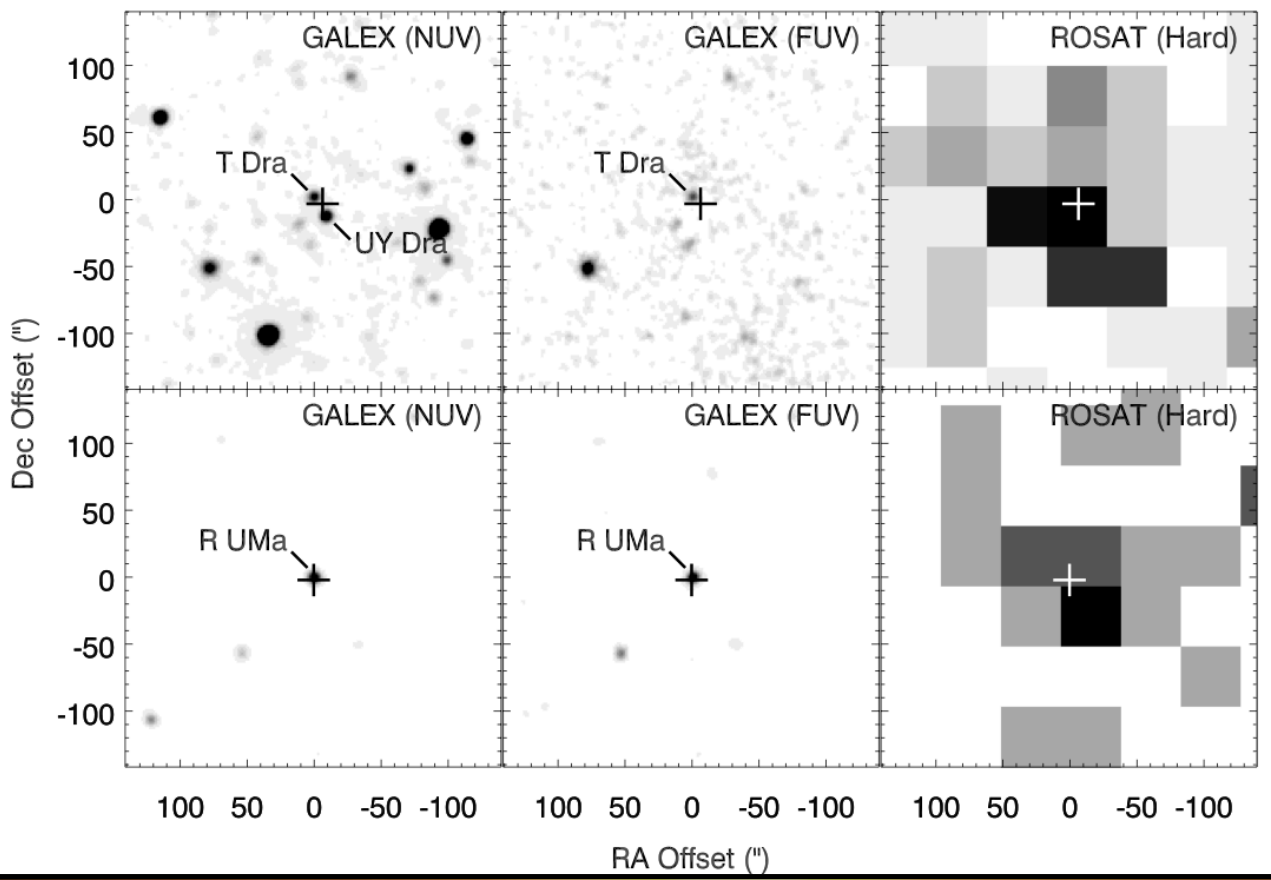
Ramstedt et al. 2012

Magnetic field observations



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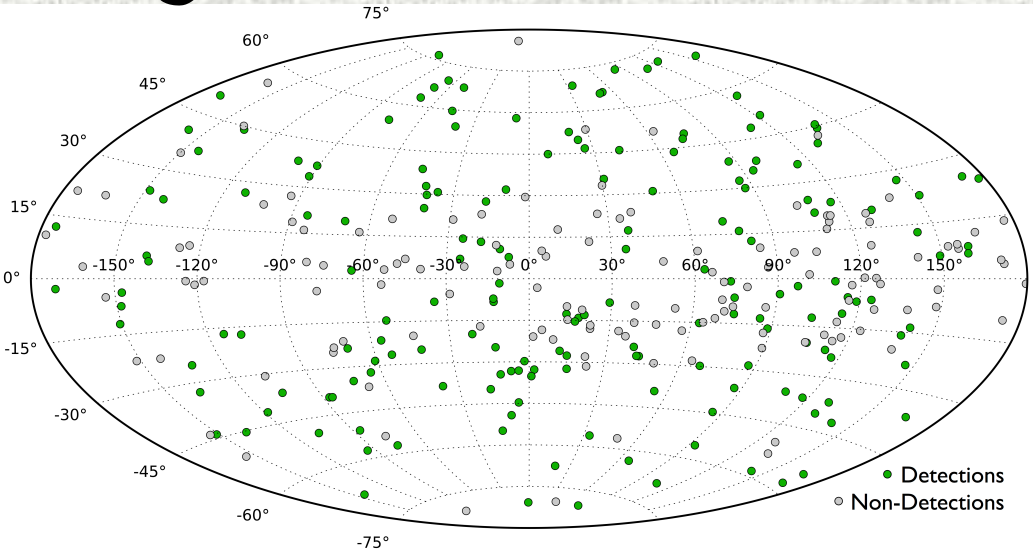
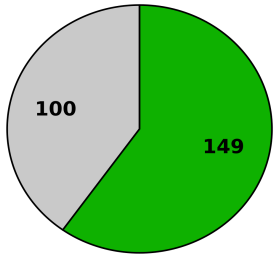
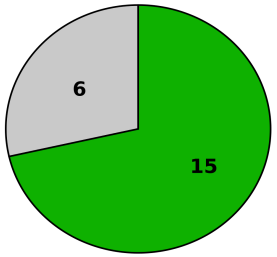
Montez et al. in prep.

Magnetic field observations





O-types (C/O < 1)



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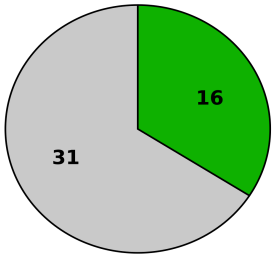

C-types (C/O > 1)

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