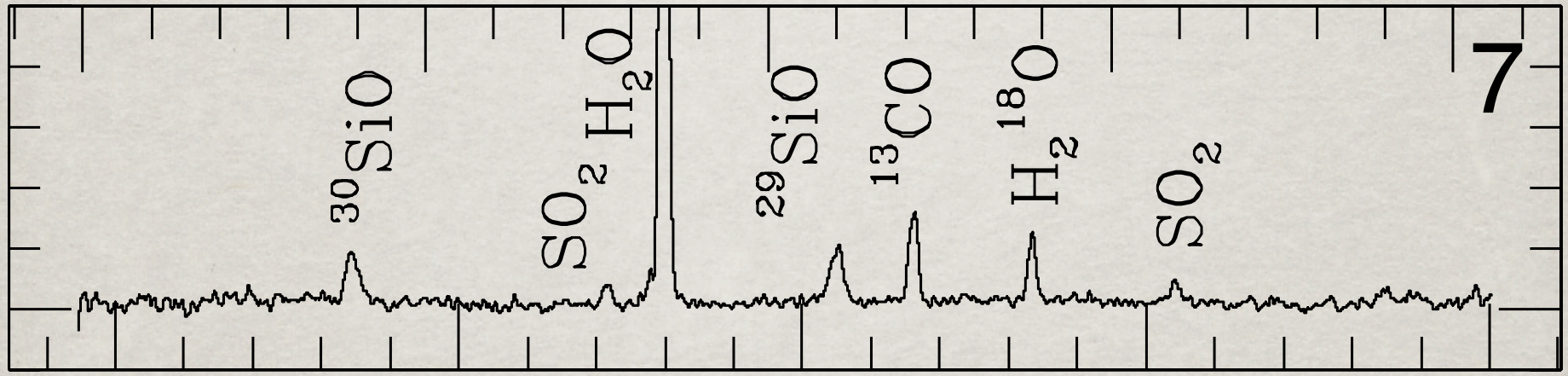
A HIFI molecular inventory of oxygen-rich AGB stars



Matthias Maercker

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Justtanont, K., Olofsson, H., Bergman, P.
and the HIFISTARS team

Asymptotic Giant Branch stars

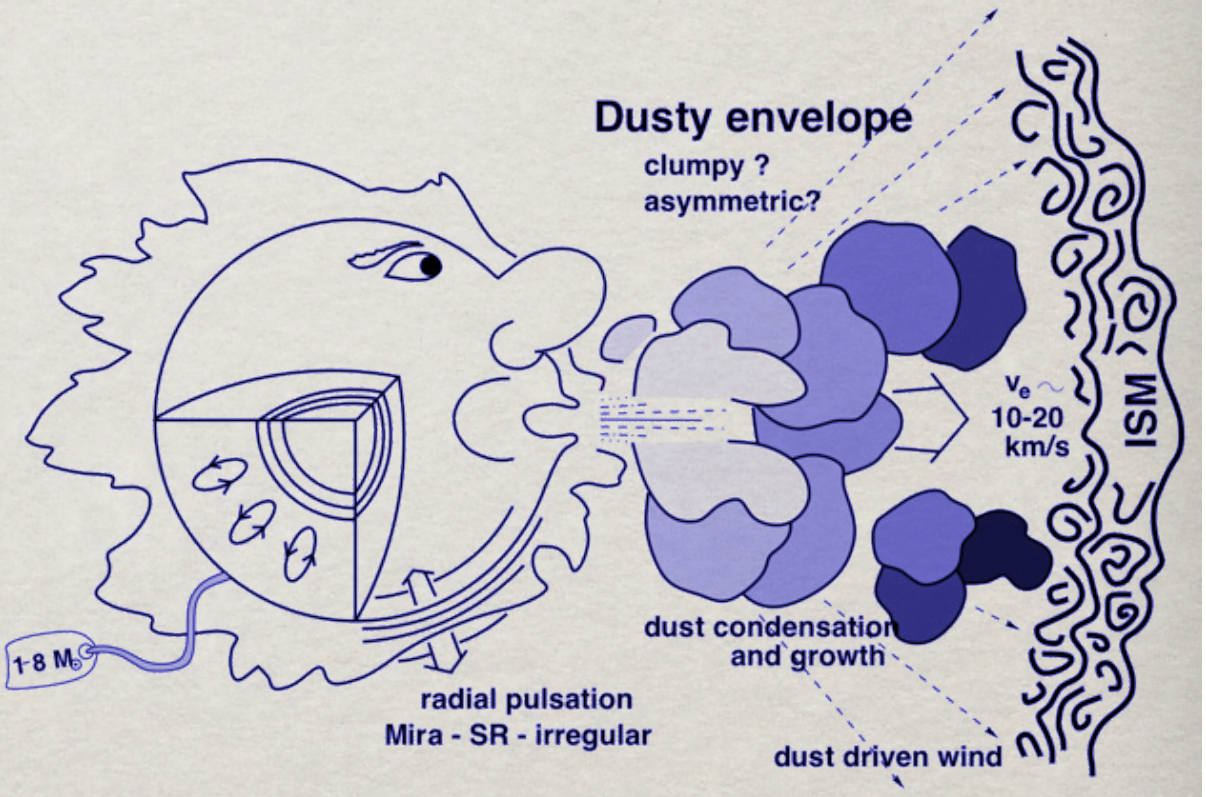
Stars between **0.8-8 $M_\odot$**

- ➡ dormant C/O-core
- ➡ He-burning shell
- ➡ H-burning shell
- ➡ convective envelope
- ➡ pulsating atmosphere

Mass-loss rates of **10^{-7}-10^{-4} $M_\odot yr^{-1}$**

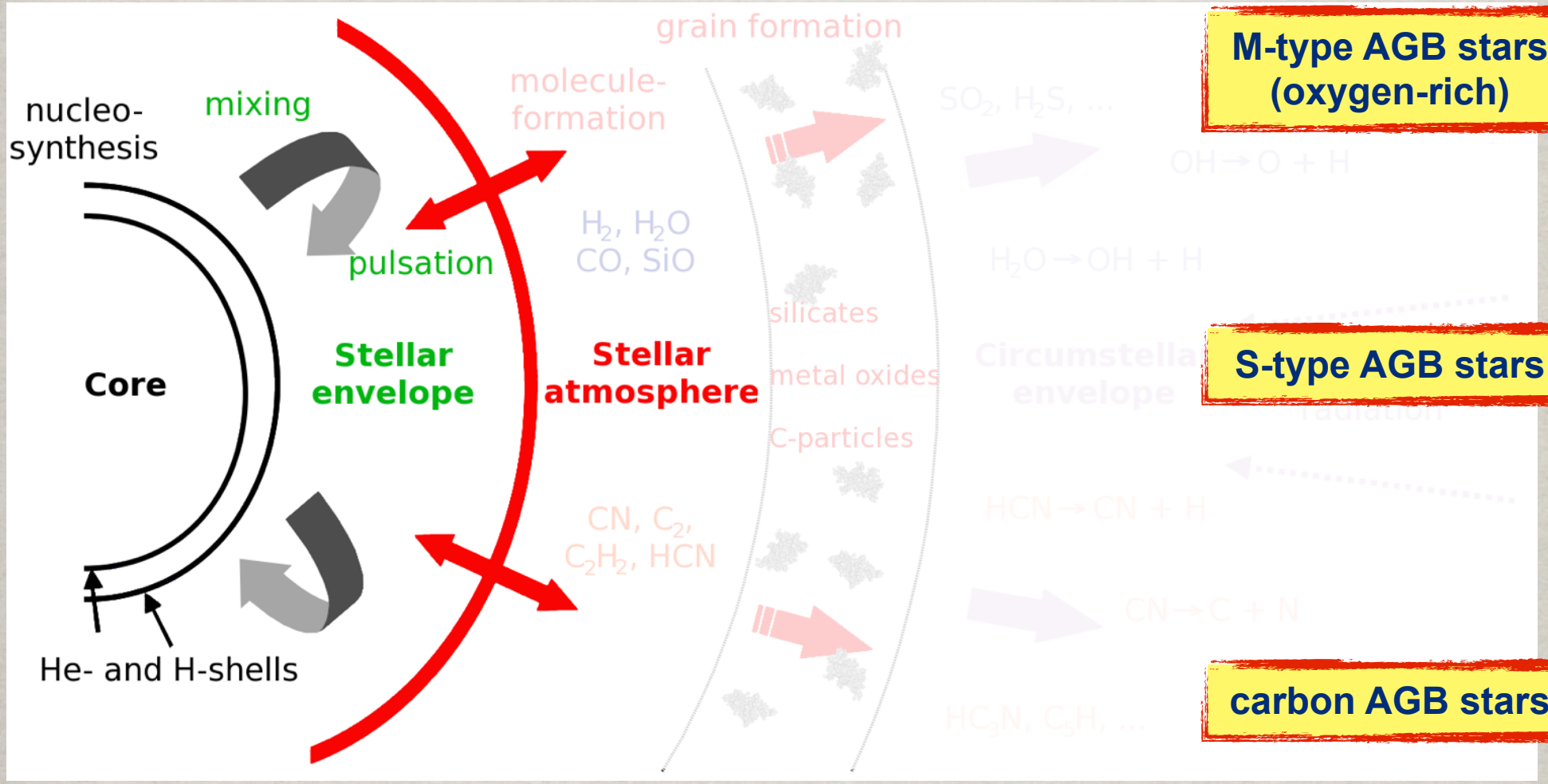
Expansion velocities of **10-20 km/s**

build-up of large, **circumstellar envelope** (CSE)



effective producers of
new elements and dust

AGB Circumstellar envelopes



What do we still want to know (in more detail)?

The chemistry of evolved stars

- ➡ nucleosynthesis inside the star
- ➡ mixing and dredge-up
- ➡ atmosphere chemistry, molecule formation
- ➡ dust formation and circumstellar chemistry

The dynamics of evolved stars

- ➡ wind velocities
- ➡ acceleration zone
- ➡ mass-loss mechanism

✓ chemistry in astronomy

✓ stellar yields

✓ chemical evolution of the ISM

✓ ingredients for new stars and planets

HIFI observations of M-type AGB stars

High sensitivity, high spectral-resolution observations between 500 - 1900 GHz

HIFISTARS guaranteed time key program
P.I.: V. Bujarrabal

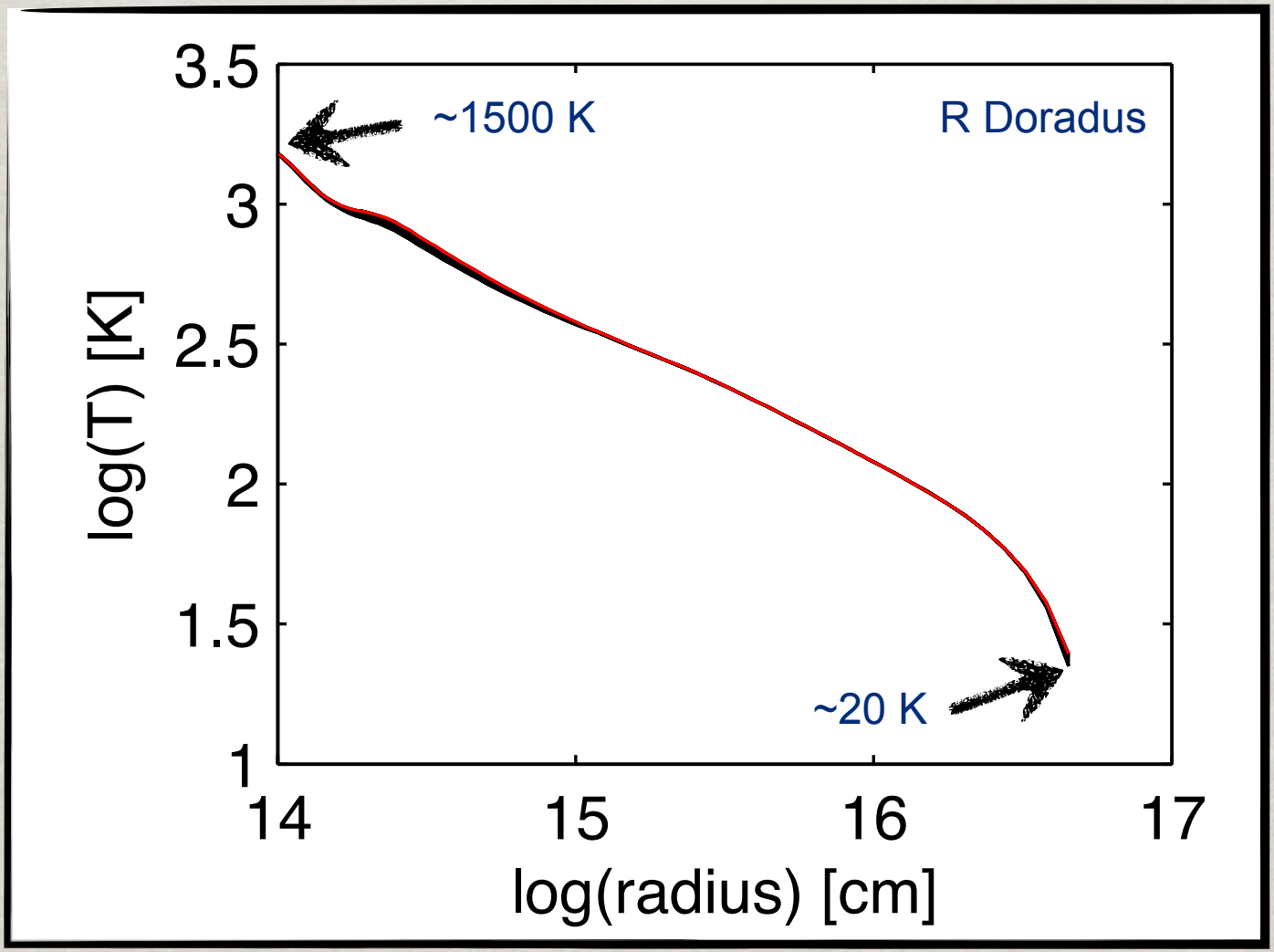
Source	#set	D pc	Mdot 10^{-6} $M_\odot yr^{-1}$
OH26.5+0.6	8	1370	260
AFGL 5379	8	580	200
IRC+10011	15	740	19
TX Cam	9	380	6.5
IK Tau	15	260	4.5
o Cet	9	107	0.25
R Dor	9	59	0.2
W Hya	16	77	0.08
R Cas	9	106	0.04

molecule	E_{up} K	isotopologues with
H_2O	2400 - 50	^{17}O, ^{18}O
CO	750 - 100	^{13}C, ^{18}O
HCN	400 - 100	^{13}C
SiO	2300 - 200	^{29}Si, ^{30}Si
SO	500 - 200	
SO_2	600 - 250	
SiS	2800	
OH	180	
NH_3	30	

M-type sources presented in Justtanont et al. 2012

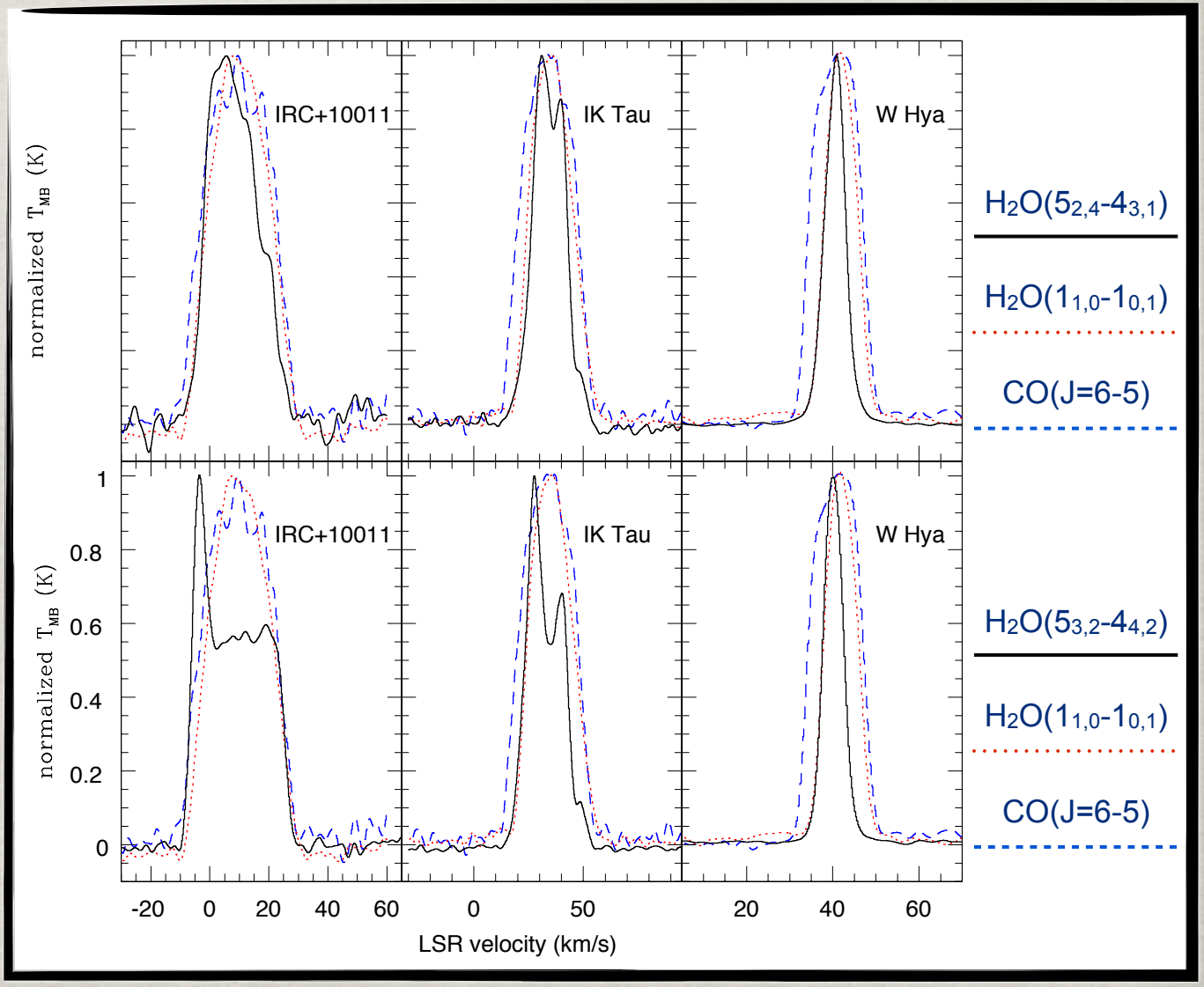
Where does the emission come from?

Upper-state energy of a transition a rough tracer of the emission region



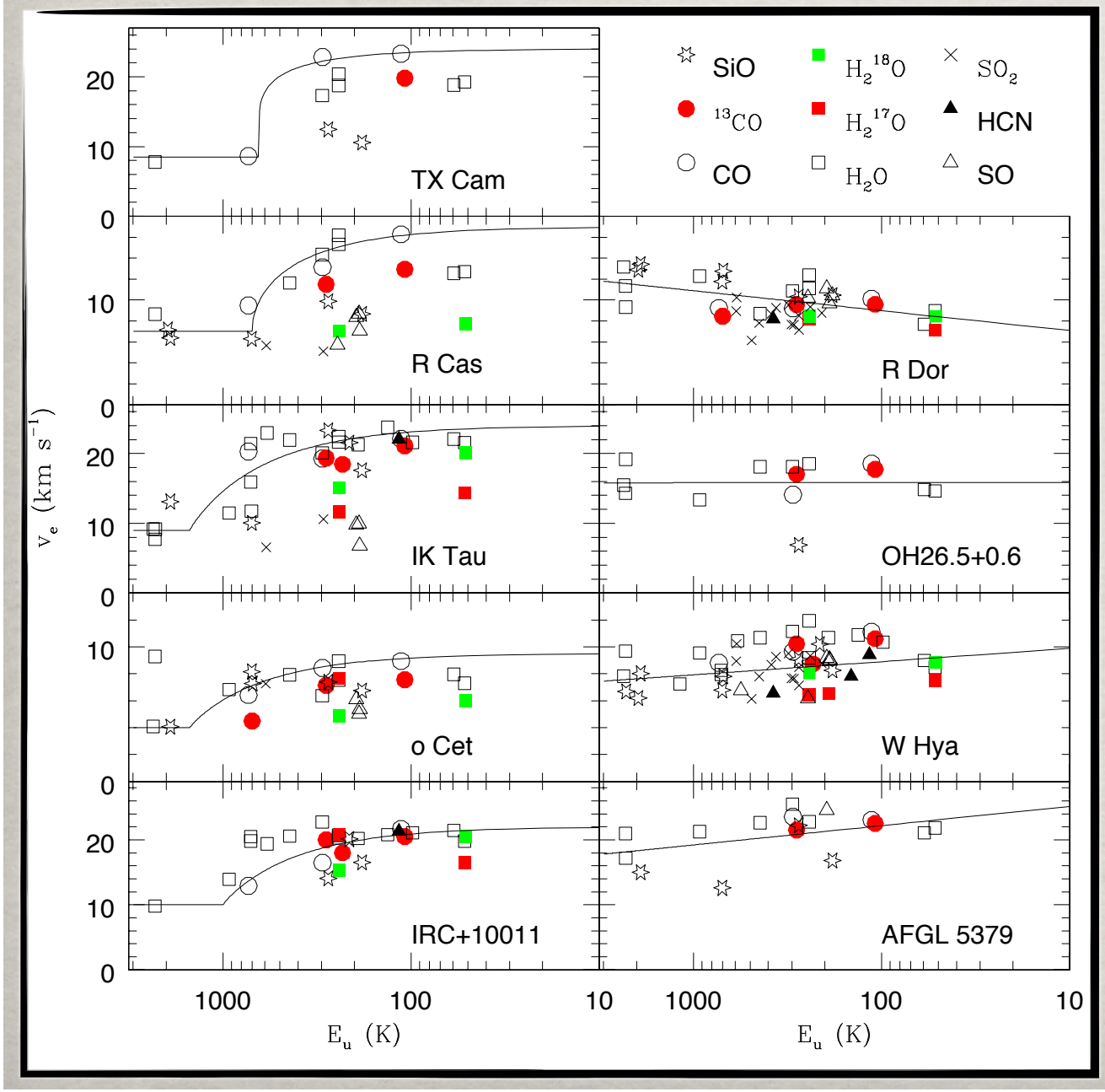
What do the lines tell us?

- The presence of that molecule!
  - chemical processes
- expansion velocities
- line profiles
  - excitation conditions
  - masers,
  - etc...



Justtanont et al. 2012

Expansion velocity profile



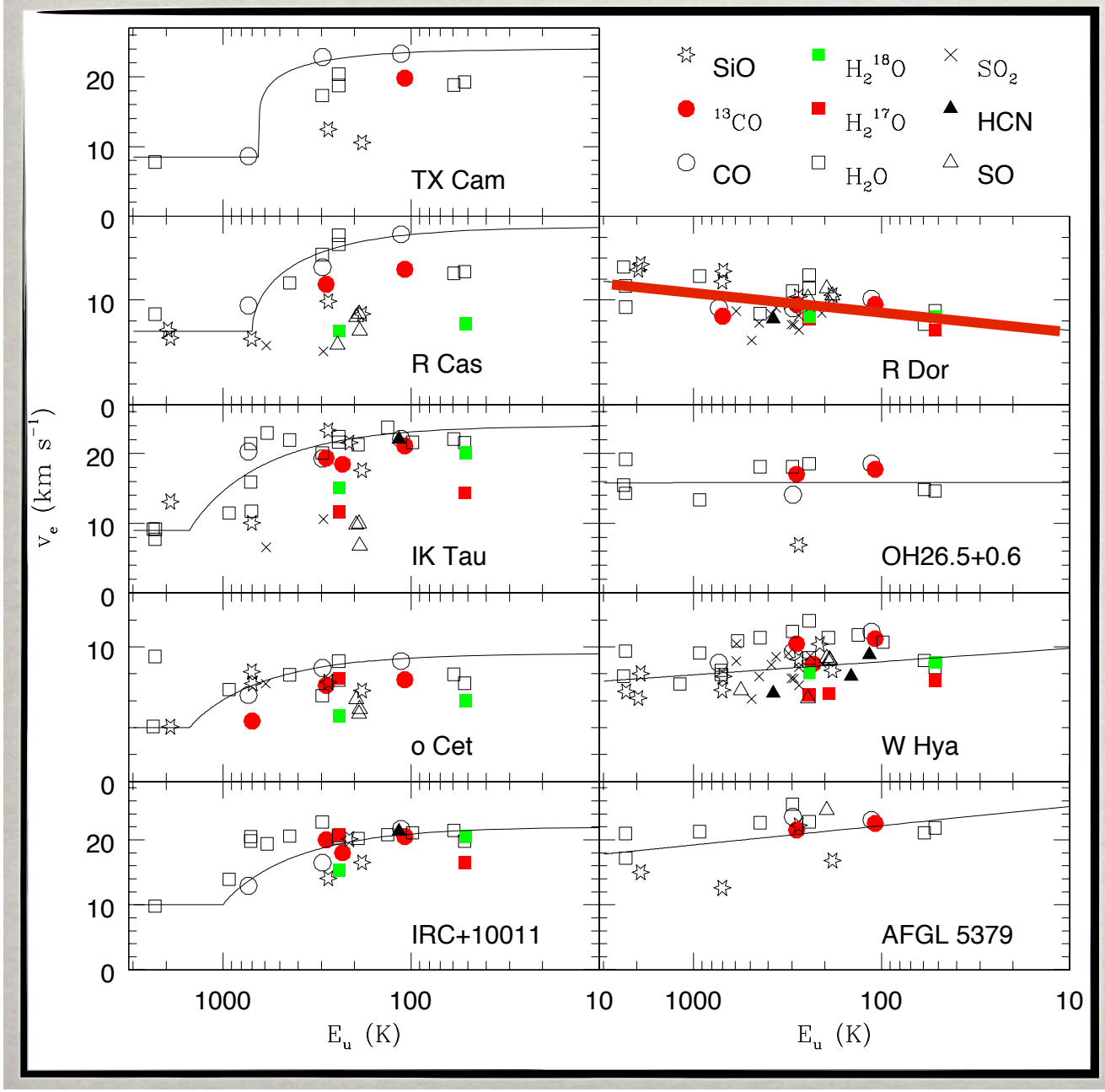
- ✓ wind acceleration
- ✓ many lines in many sources
- ✓ mass-loss in M-type stars:

  ➡ how is the wind initiated and accelerated?

  Woitke 2006
  Höfner 2008

Justtanont et al. 2012

Expansion velocity profile



for proper

parameter vs. R

dependence

full radiative transfer

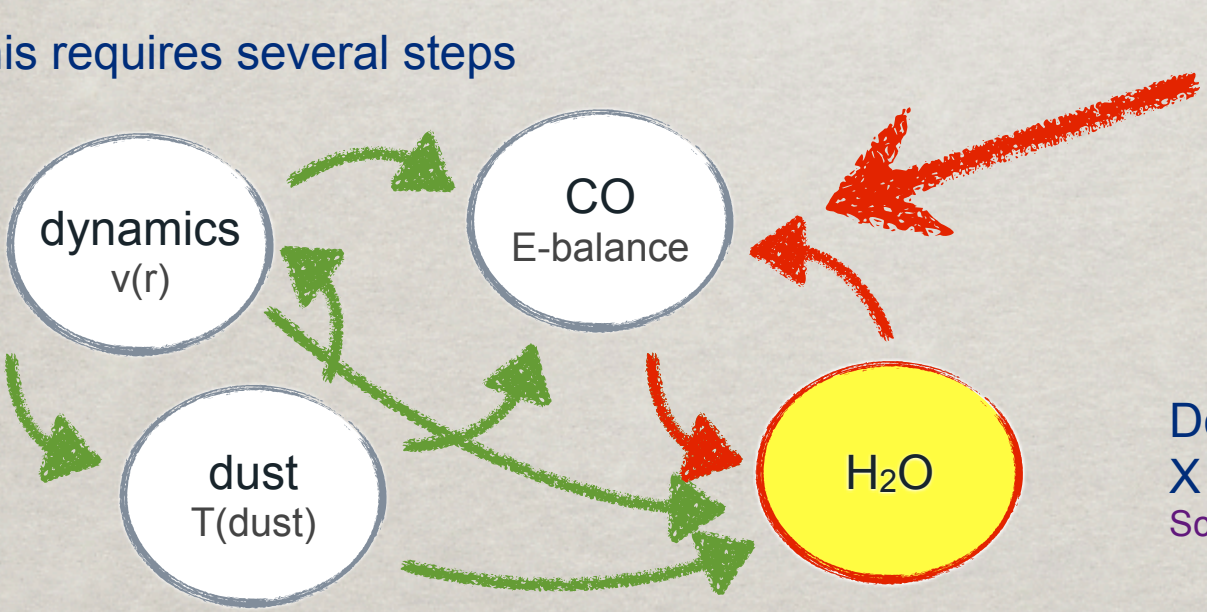
Justtanont et al. 2012

Radiative transfer modelling

For full radiative transfer modelling we need

- ➡ expansion velocity vs. radius
- ➡ temperature vs. radius
- ➡ radiation from the central source
- ➡ additional free parameters (abundances, CSE size, ...)

This requires several steps



H_2O - cooling critical for T-structure!

Done for the S-type AGB star X Cyg (also part of HIFISTARS)
Schöier et al. 2011

H_2O cooling and model problems

The main heating and cooling terms in the inner envelope

- ➡ heating due to dust - gas collisions
- ➡ cooling due to H_2O

T-profile
with H_2O

$[H_2O]/H_2$
Maercker et

extreme

Implementing H_2O cooling

Taissa Danilovich
at Onsala Space Observatory

with support from

Matthias Maercker
Per Bergman
Kay Justtanont
Hans Olofsson

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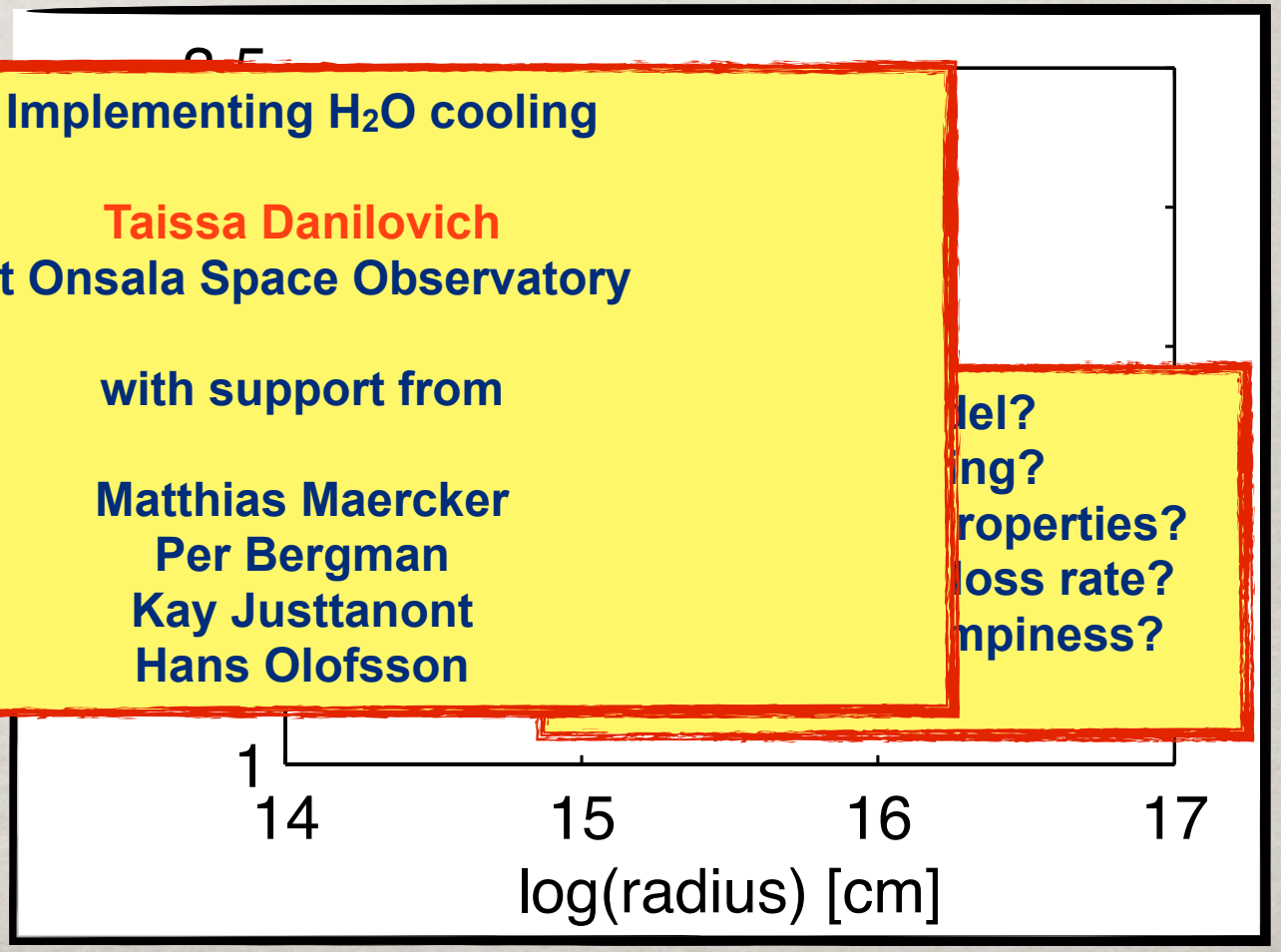

Conclusions

✓ main target are high-excitation CO and H_2O lines

✓ detection of additionally 7 molecules, as well as isotopologues

➡ chemistry in oxygen-rich AGB stars

✓ HIFI data probes different excitation regions

➡ physics of the circumstellar envelope

✓ H_2O modelling important, H_2O-cooling critical

➡ difficult, with a likely change of previous results

➡ **but it's possible because of many H_2O lines in many sources!**

Conclusions

✓ main target are high-excitation CO and H_2O lines

✓ detecti

➡ ch

✓ HIFI d

➡ p

✓ H_2O m

➡ di

➡ **but it's possible because of many H_2O lines in many sources!**

more on astrochemistry/dynamics based on H_2O

talk by L. Decin (Thursday, Session 11b)

HCN cooling in carbon stars

poster by E. De Beck (P64, Session A)

spectral scan of the carbon AGB star Il Lup

poster by E. De Beck (P63, Session A)