Sub-millimeter H_2O emission from water fountain nebulae

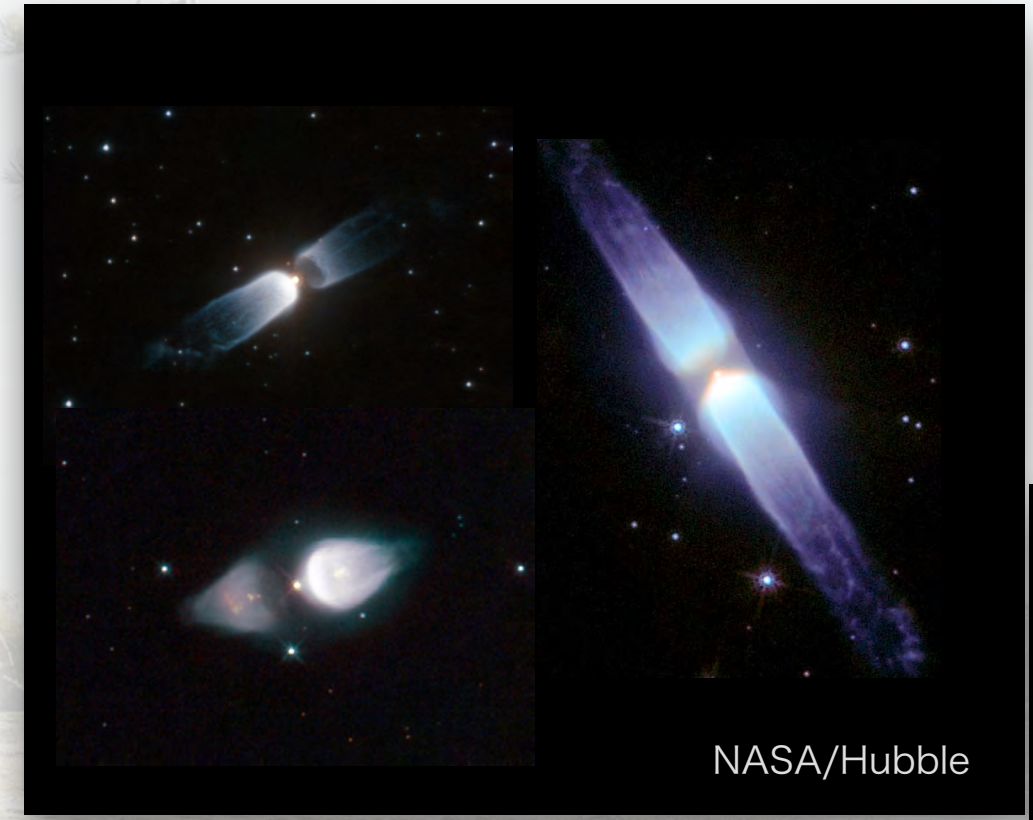
Daniel Tafoya

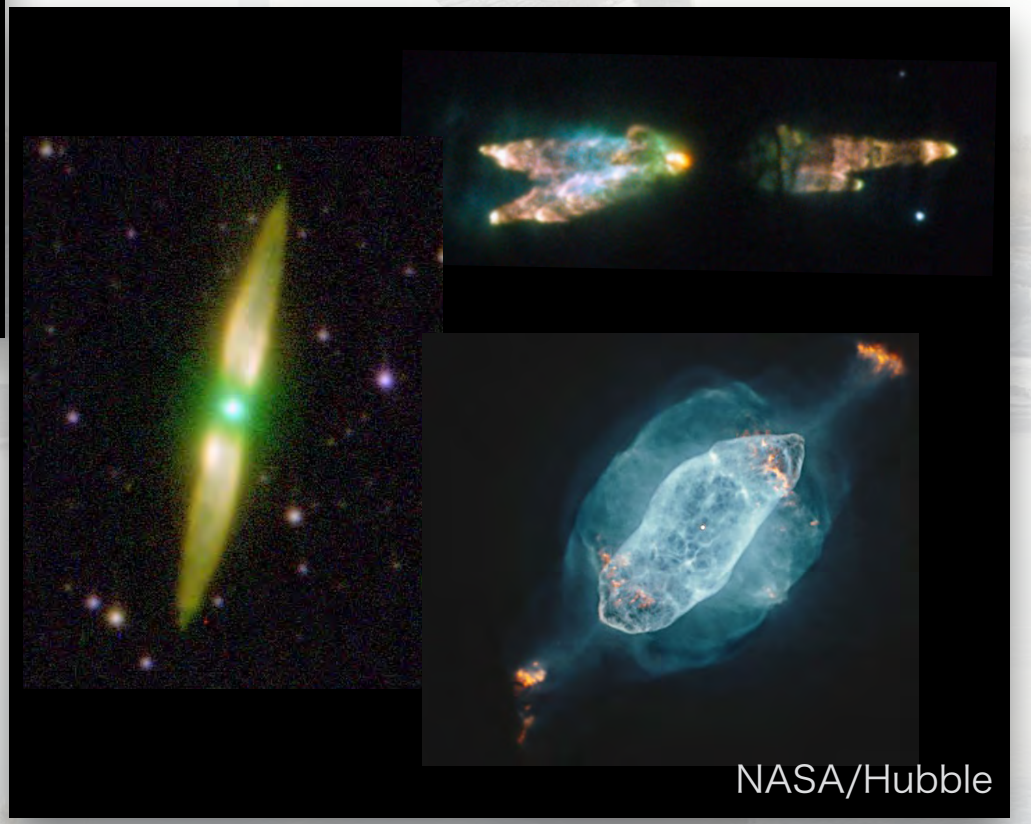
Chalmers University of Technology, Onsala Space Observatory

Wouter Vlemmings, Andrés Pérez-Sánchez, Jessica Chapman
Ramiro Franco and Guido Garay

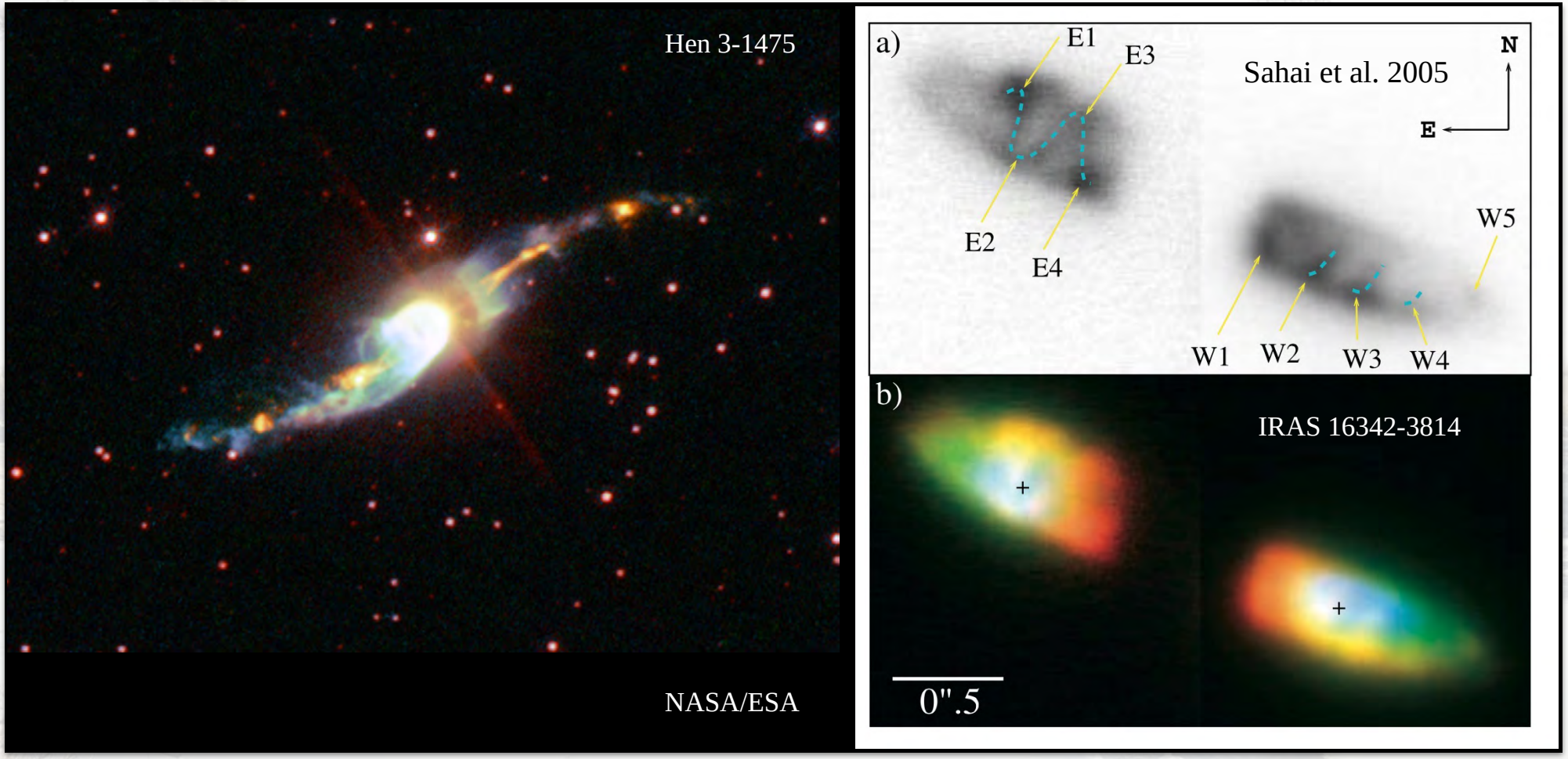
IAU Symposium 336 - Astrophysical masers: Unlocking the Mysteries of the Universe
Cagliari, 4-8 September 2017

The importance of WFN in the understanding the shapes of Pre-planetary and Planetary Nebulae



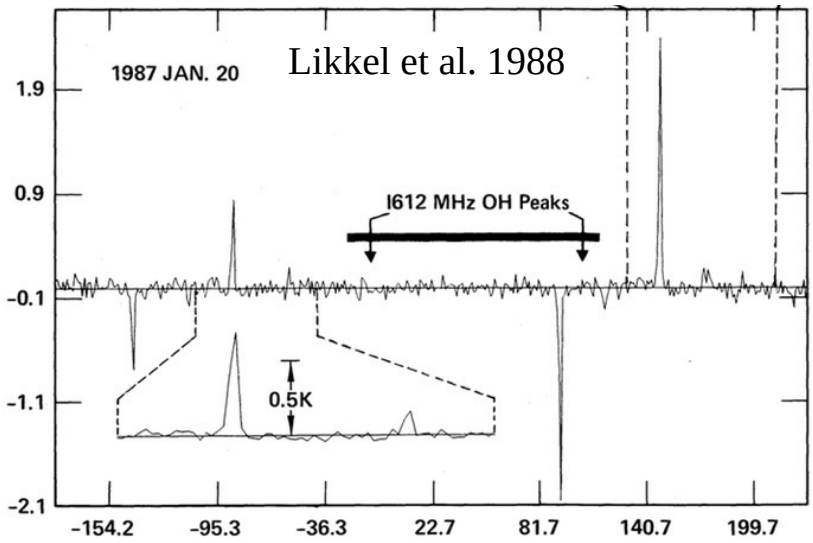


Recently, growing consensus that jet-like collimated outflows shape pre-planetary nebulae



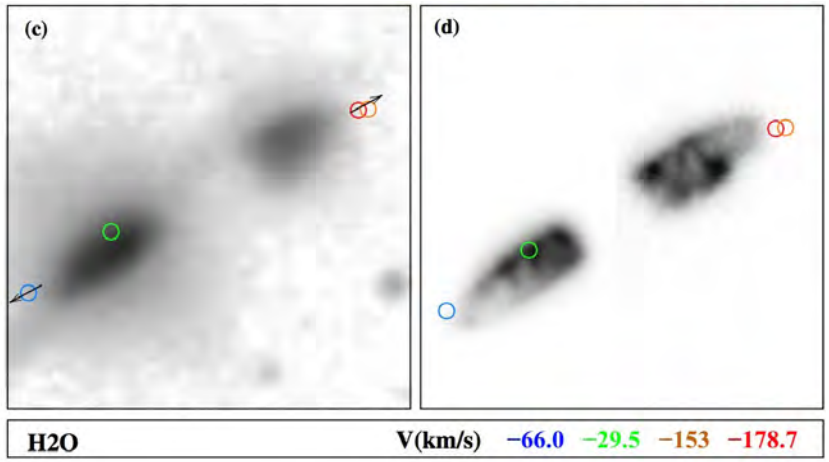
water fountain nebula: one of the best tools to probe and study such collimated outflows.

Collimated outflows traced by 22 GHz water maser emission

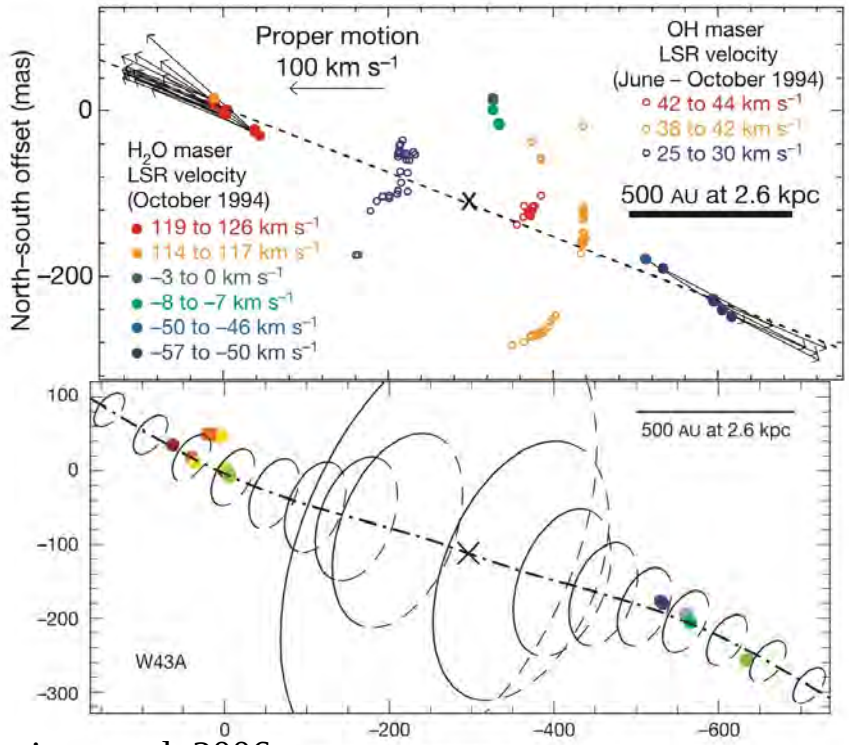


Likkel et al. 1988

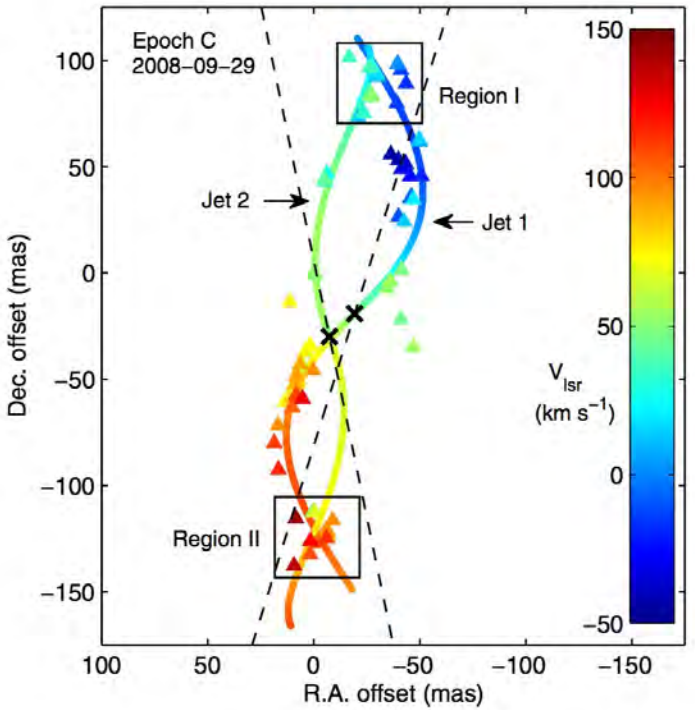
Claussen et al. 2009



Imai et al. 2002

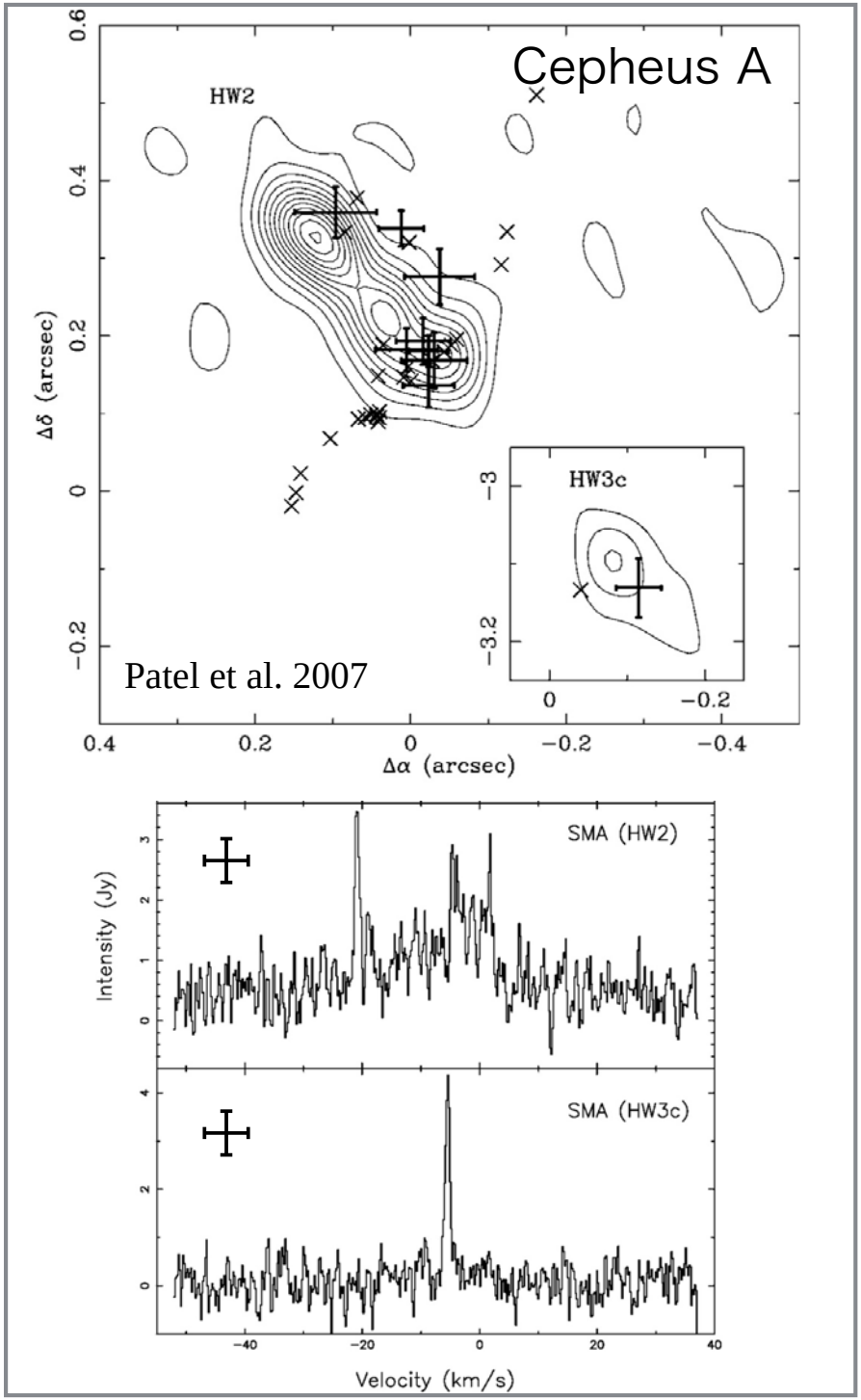


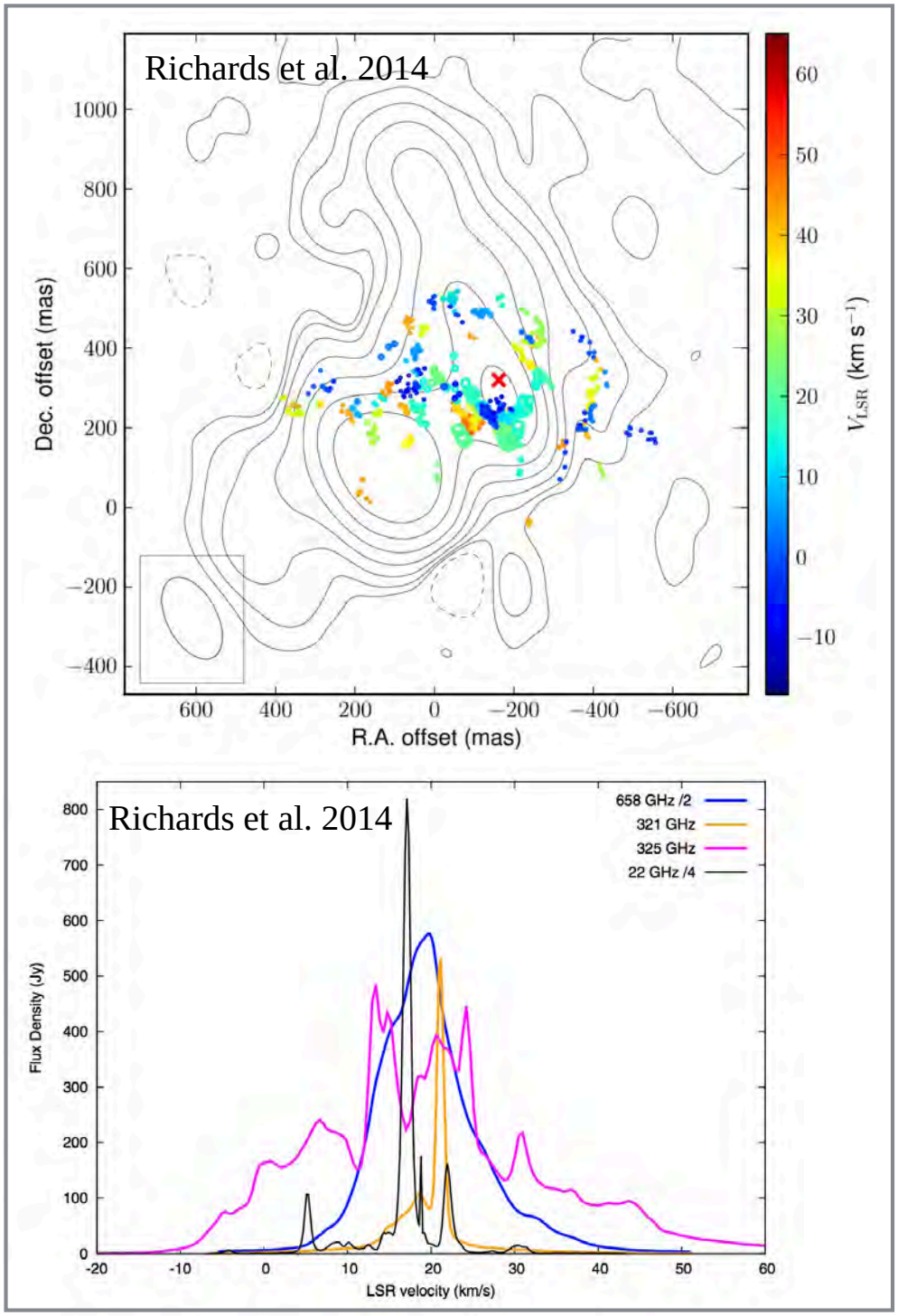
Vlemmings et al. 2006



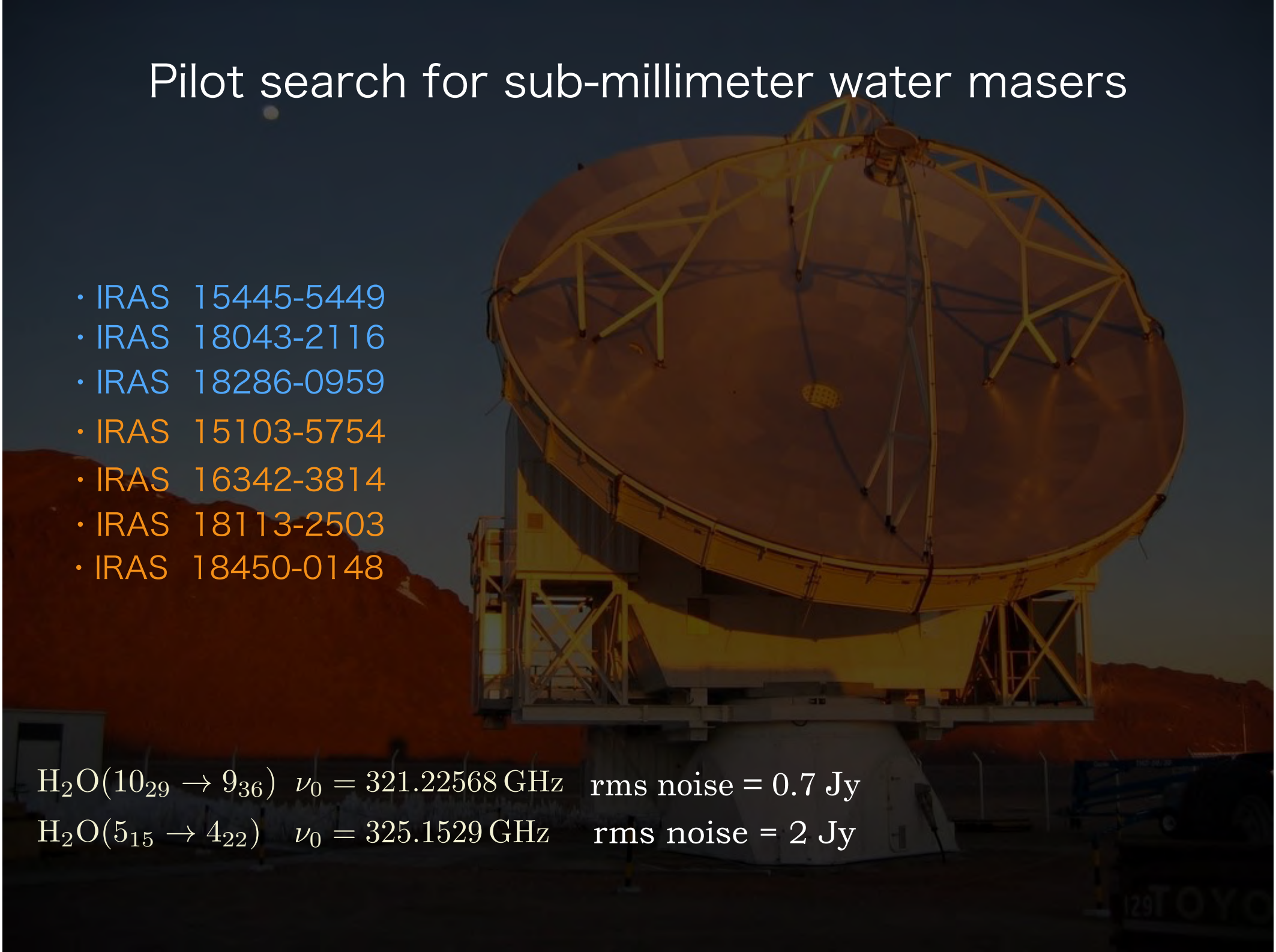
Yung et al.

Sub-mm H_2O maser emission in other astrophysical contexts





Pilot search for sub-millimeter water masers

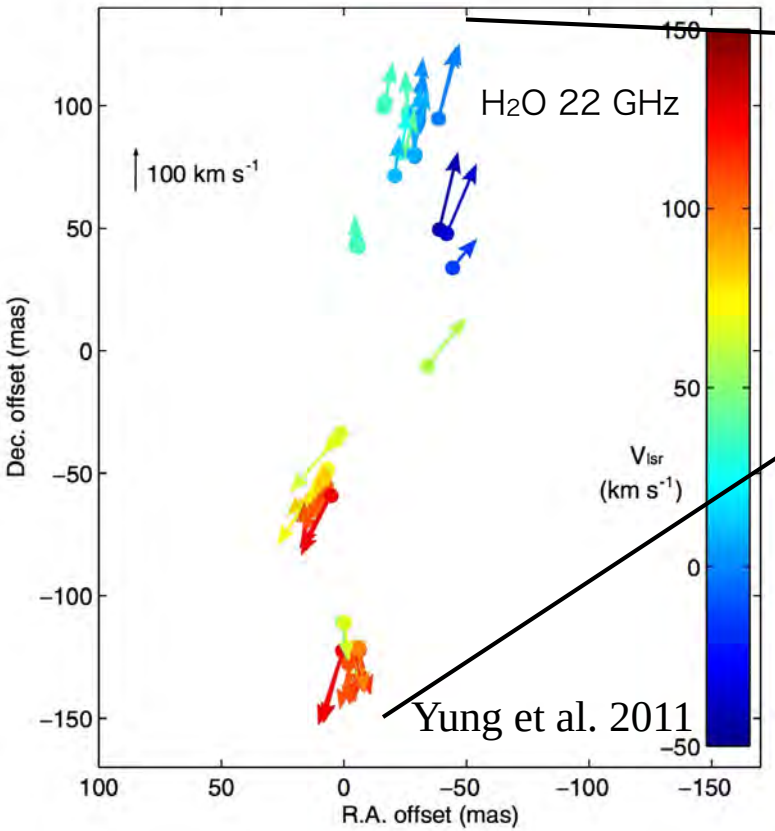


- IRAS 15445-5449
- IRAS 18043-2116
- IRAS 18286-0959
- IRAS 15103-5754
- IRAS 16342-3814
- IRAS 18113-2503
- IRAS 18450-0148

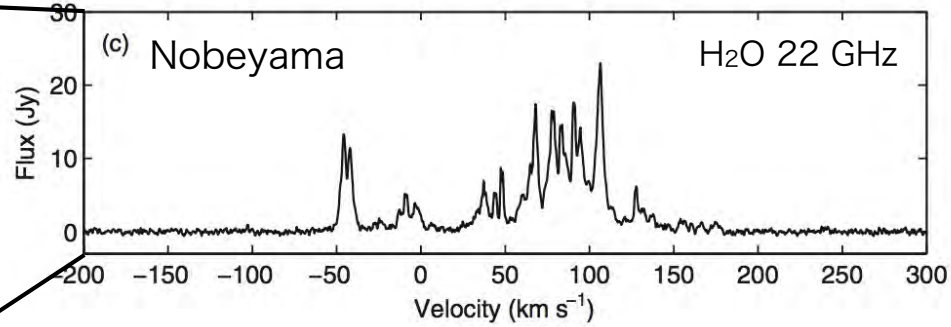
$\mathrm{H_2O}(10_{29} \rightarrow 9_{36})$ $\nu_0 = 321.22568\,\mathrm{GHz}$ rms noise = 0.7 Jy

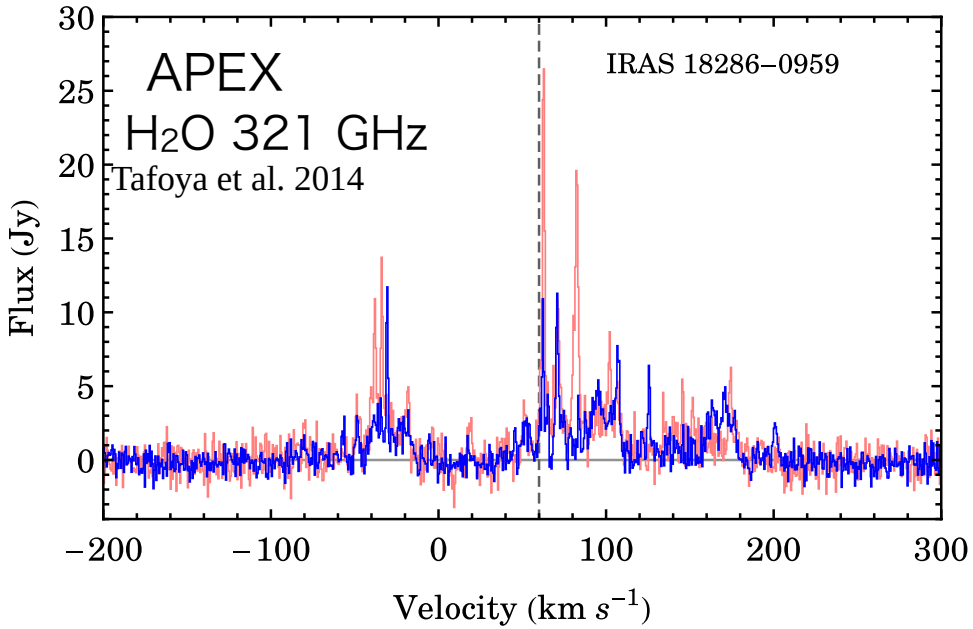
$\mathrm{H_2O}(5_{15} \rightarrow 4_{22})$ $\nu_0 = 325.1529\,\mathrm{GHz}$ rms noise = 2 Jy

IRAS 18286-0959

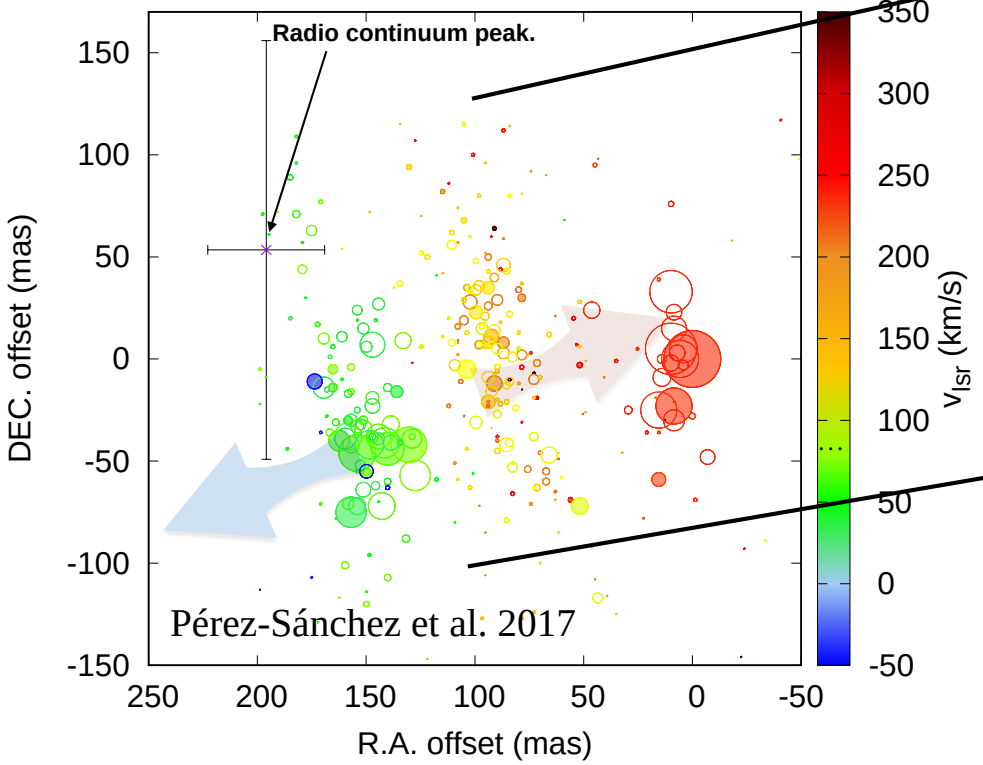


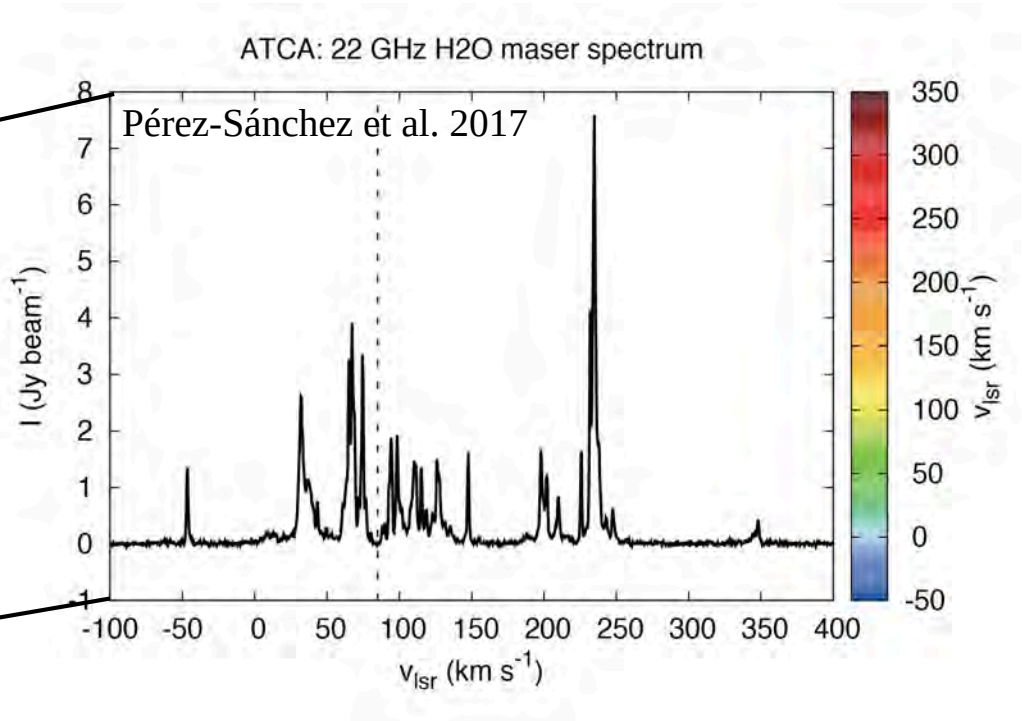
Deguchi et al. 2007

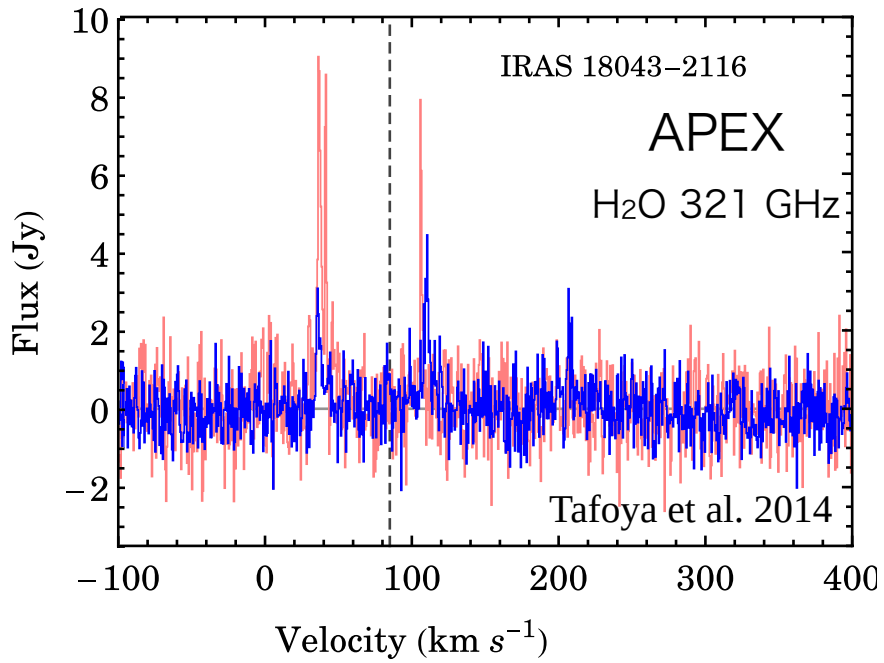




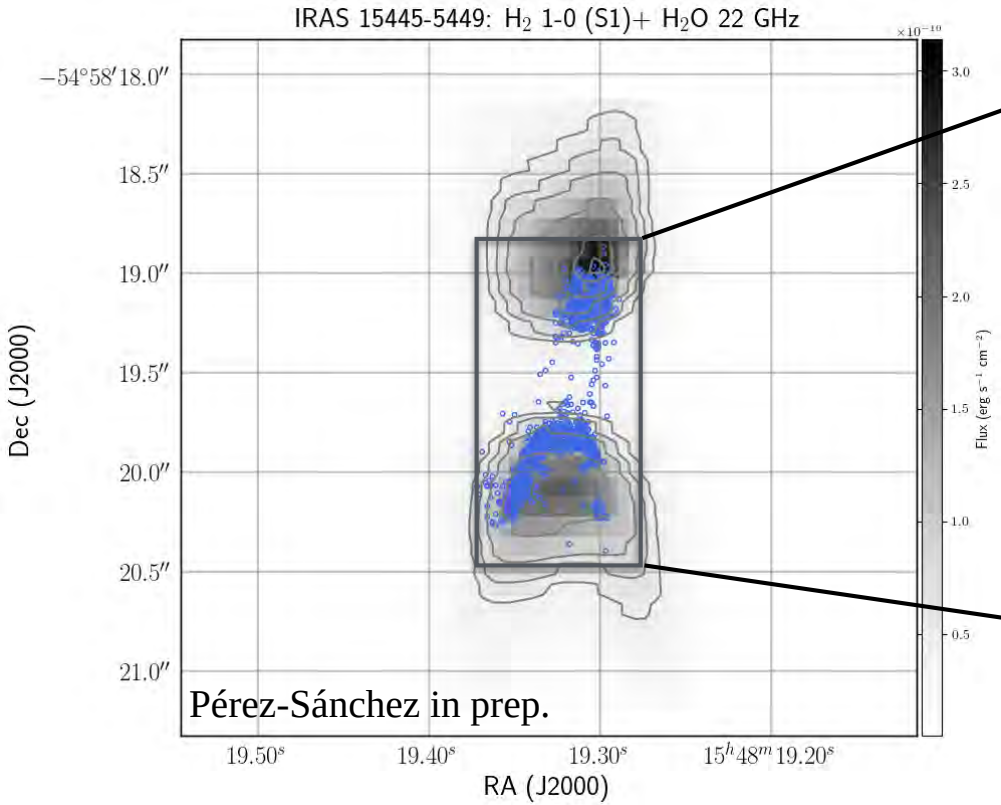
IRAS 18043-2116

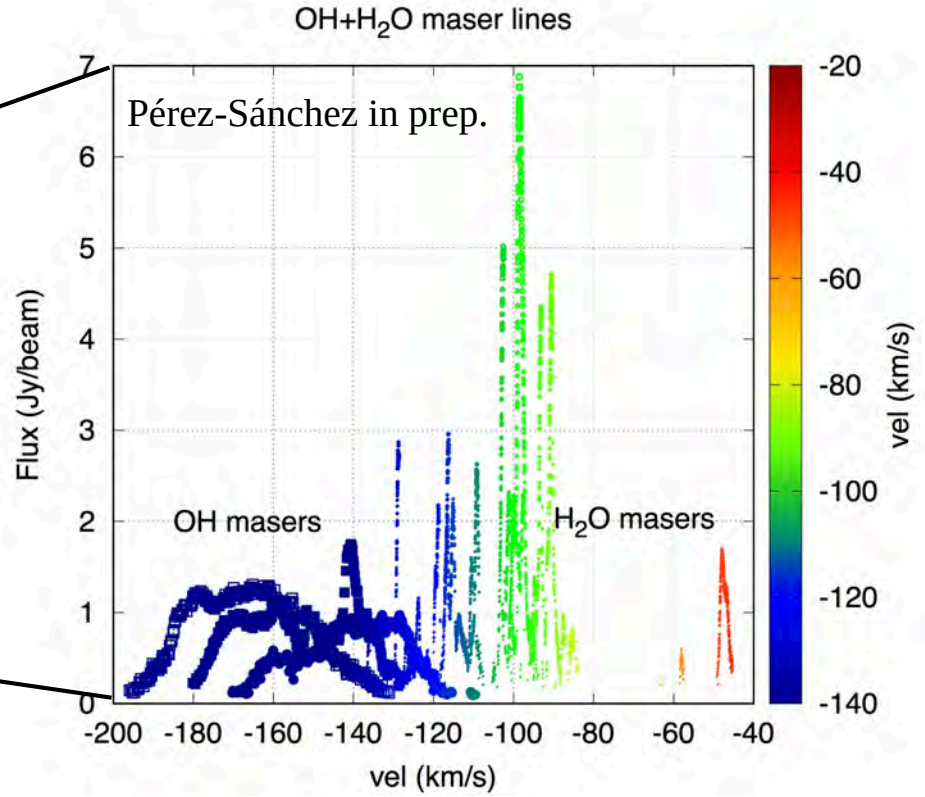


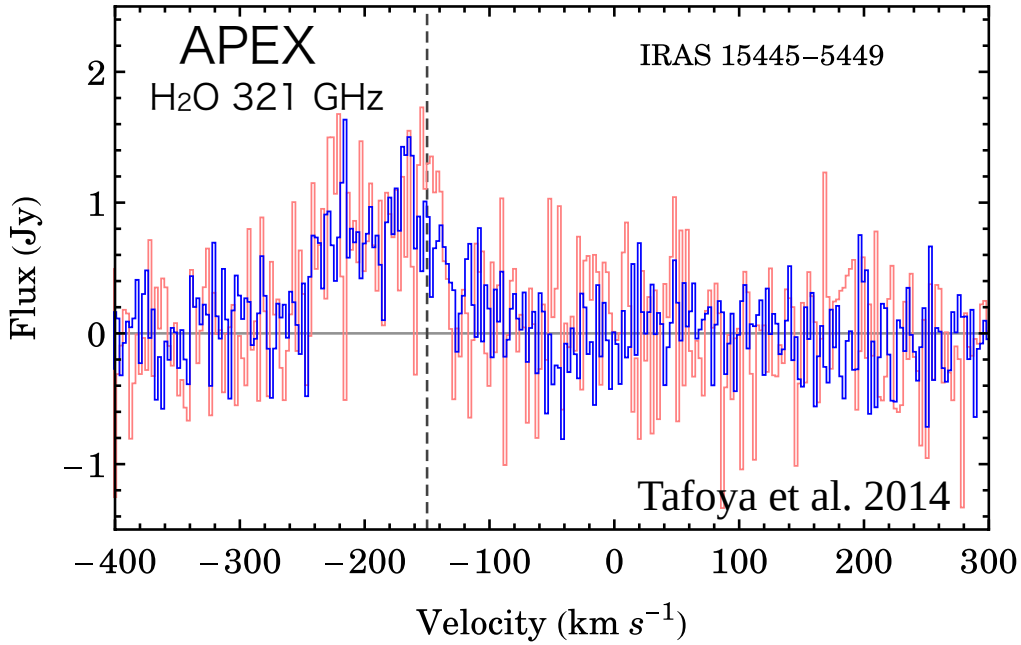




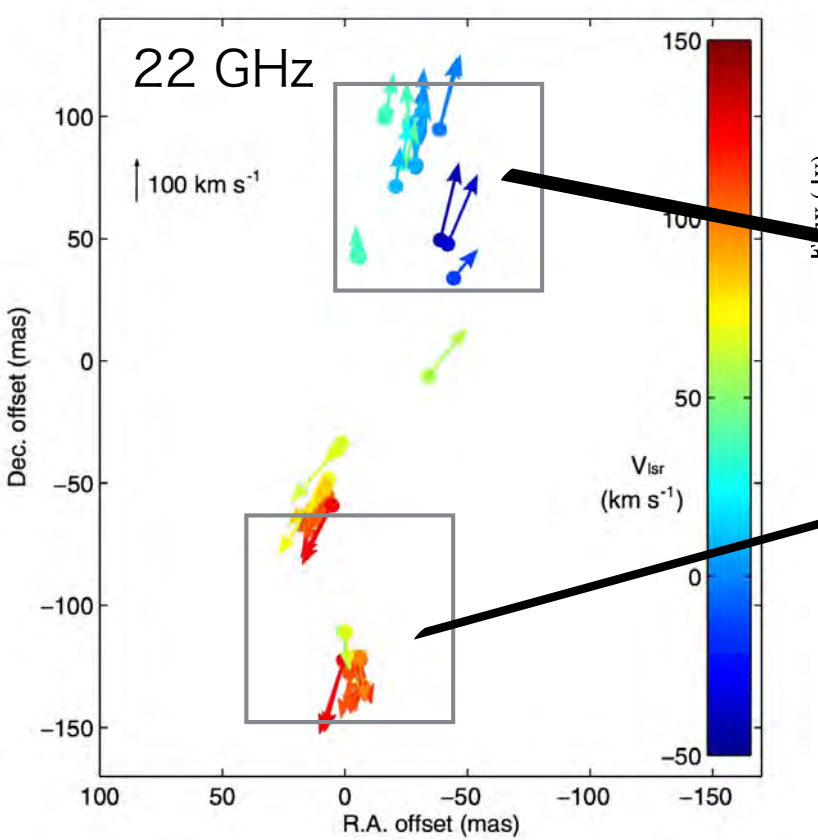
The mysterious IRAS 15445-5449



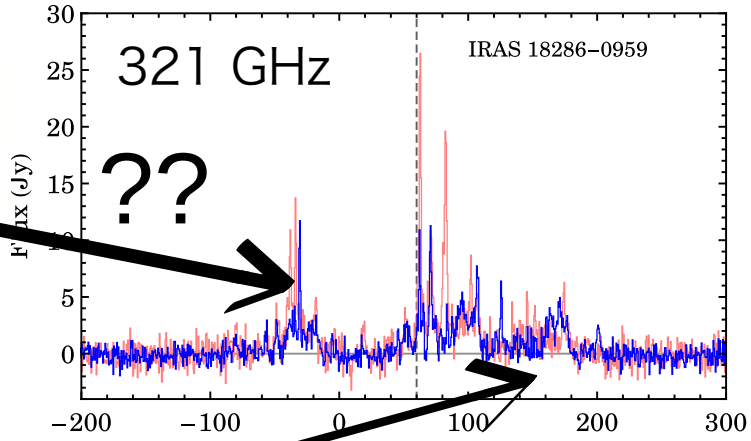




Where are the 321 GHz H_2O masers located?



Yung et al. 2011

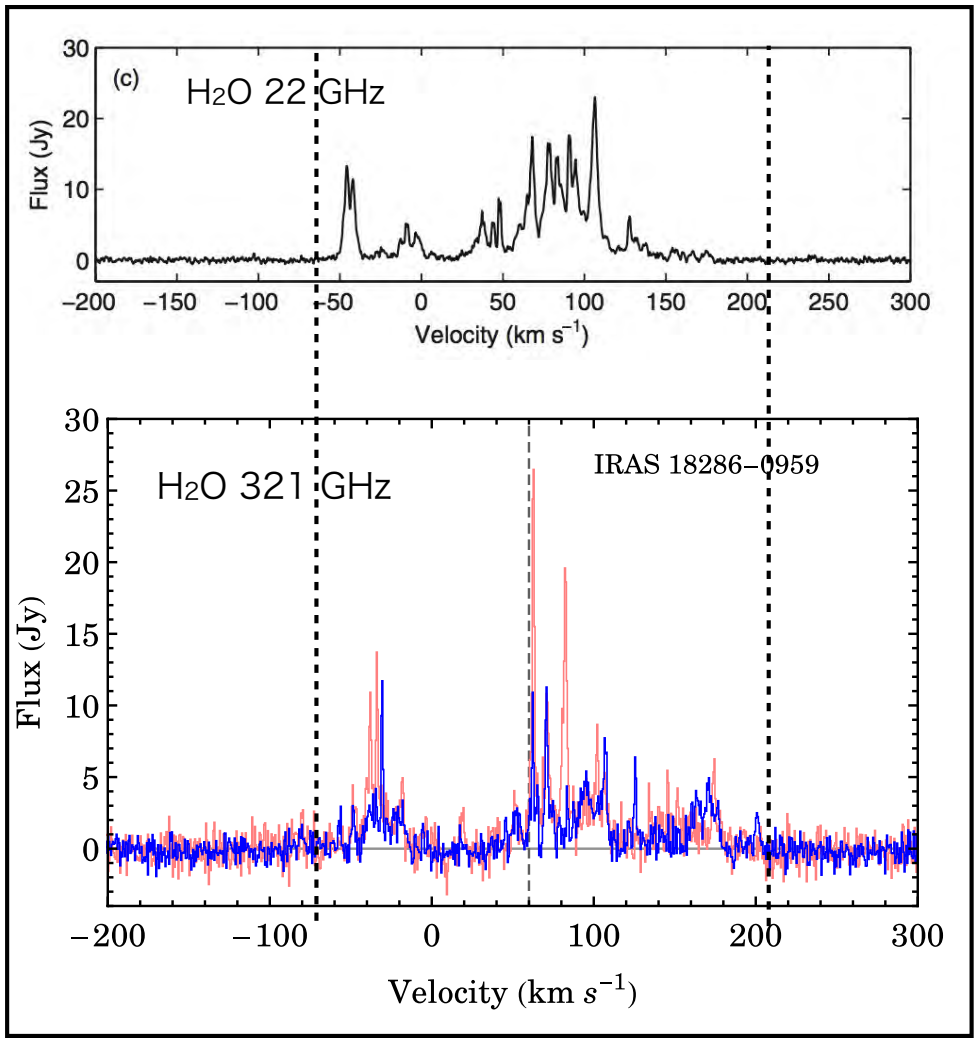


Tafoya et al. 2014

??

ALMA proposal to map the sub-mm water masers, observations recently carried out, no images yet 😕

Collocated 22 and 321 GHz H_2O masers?



- Similar velocity range

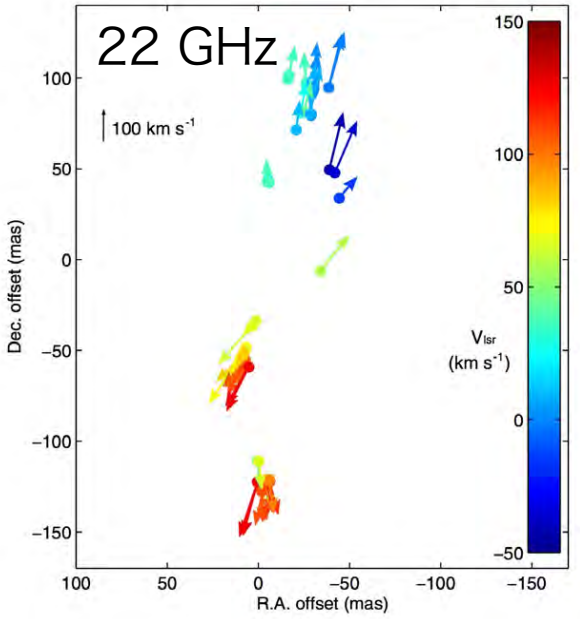
⇒ likely to be arising in the same region.

- $L_{22\ GHz}/L_{321\ GHz} \sim 1$

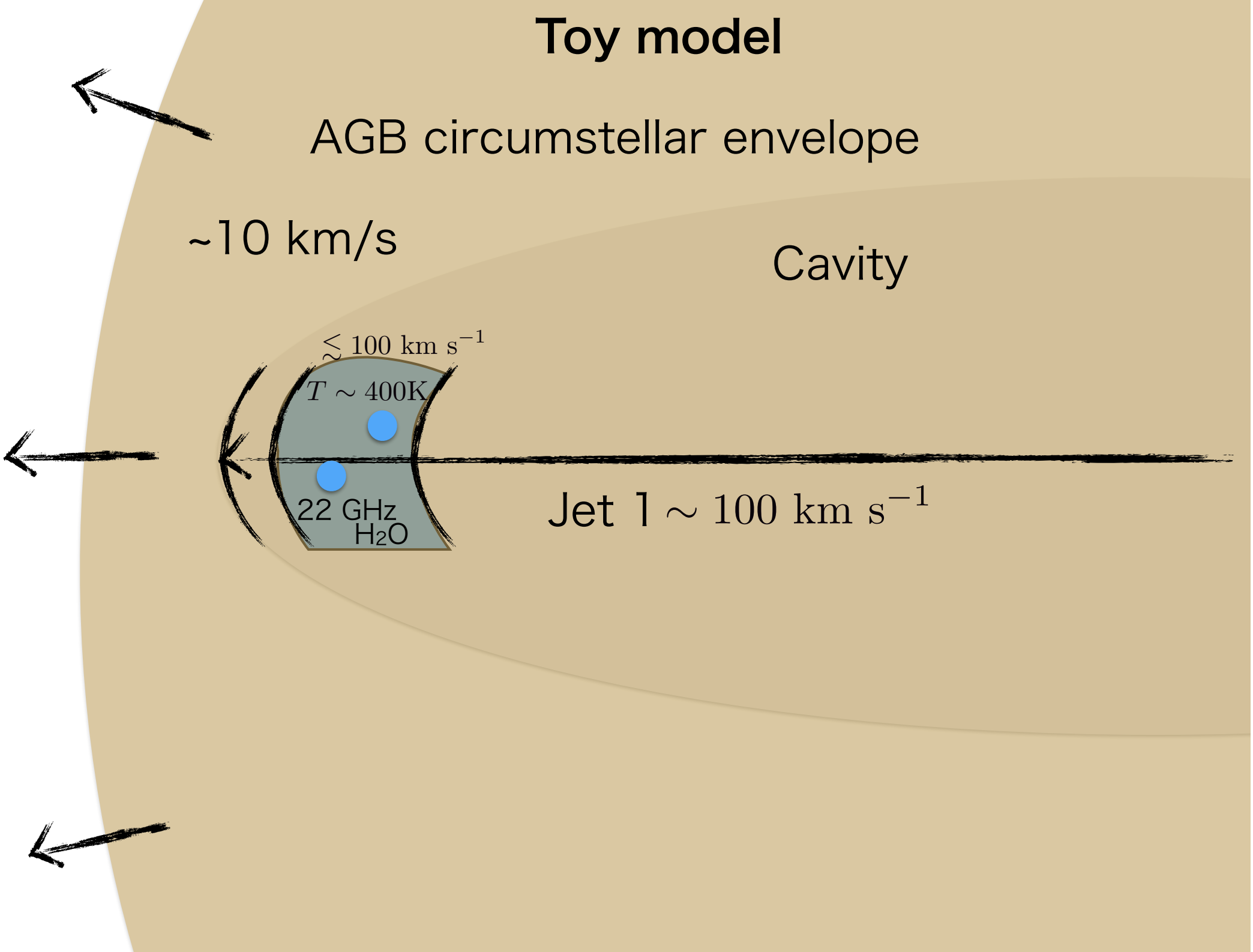
Neufeld & Melnick 1990; Yates et al. 1997

⇒ T≳1000 K

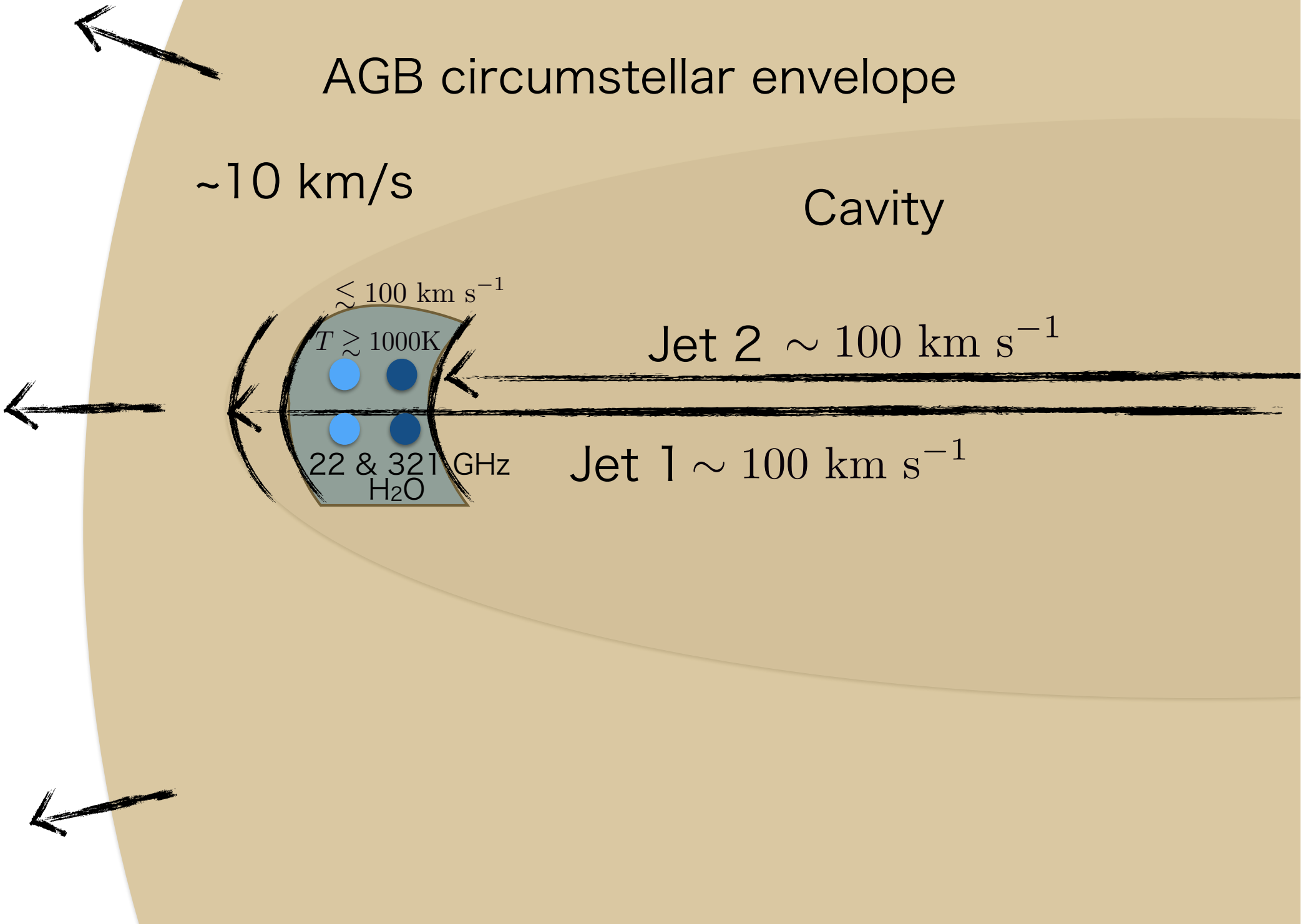
⇒ warm water fountain nebulae



Toy model


AGB circumstellar envelope
~10 km/s
Cavity
$\lesssim 100$ km s^{-1}
$T \sim 400$K
22 GHz
H_2O
Jet ? ~ 100 km s^{-1}

Toy model


AGB circumstellar envelope
~10 km/s
Cavity
$\lesssim 100$ km s^{-1}
$T \gtrsim 1000$K
22 & 321 GHz
H_2O
Jet 2 ~ 100 km s^{-1}
Jet 1 ~ 100 km s^{-1}

ALMA

HD 101584

$^{12}C^{17}O/^{13}C^{17}O \approx 9^{+4}_{-2}$

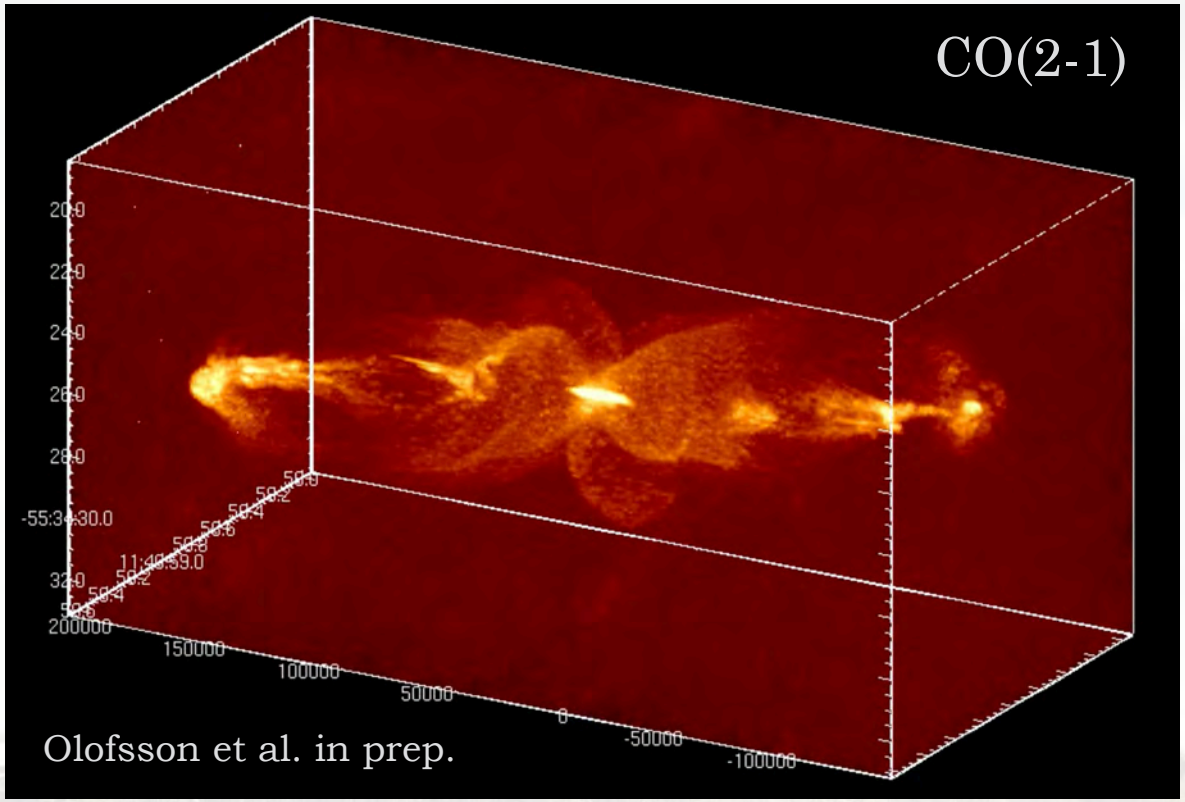
from radiative transfer model

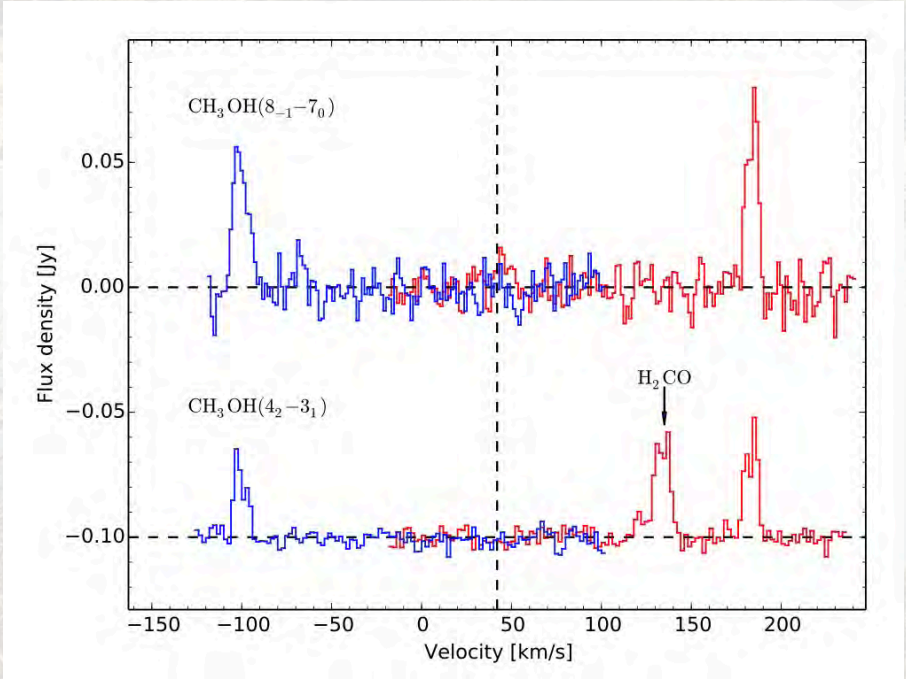
$^{12}CO/^{13}CO \approx 9$

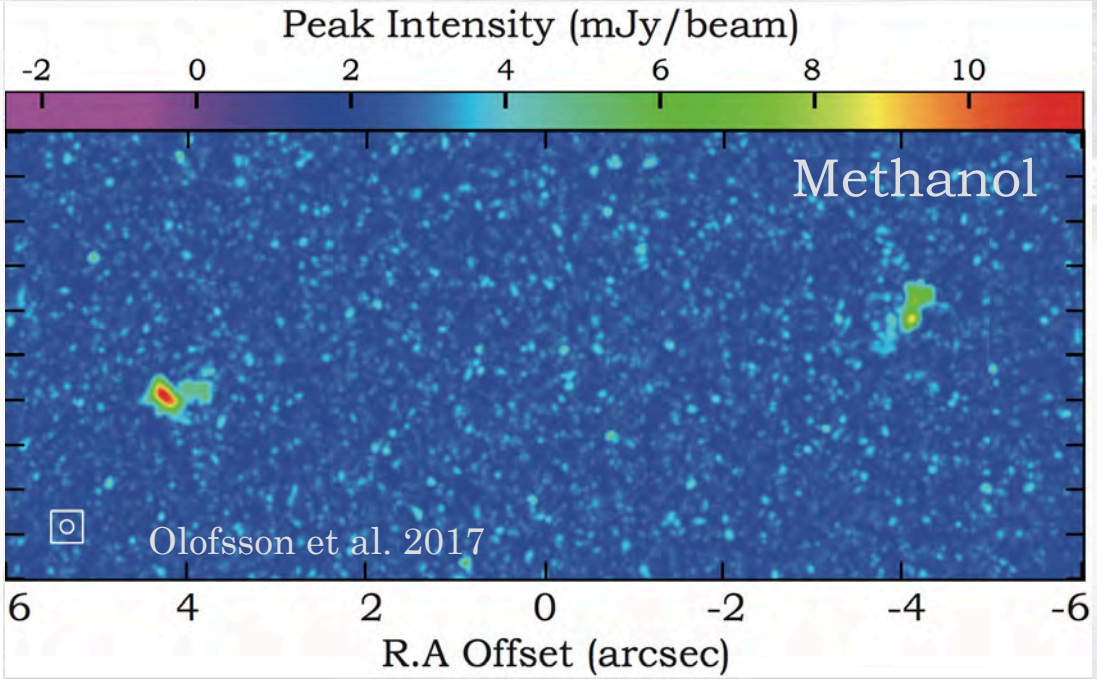
$\Rightarrow$ evolved star

First detection of methanol toward an evolved star

Olofsson et al. 2017







Conclusions

- Detection of 321 GHz water masers toward 3/7 water fountain nebulae.
- The velocity range of the 321 GHz water masers is similar to that of the 22 GHz water masers.
- The ratio $L_{321\ GHz}/L_{22\ GHz}$ implies a relatively high temperature of the gas
- ALMA interferometric observations will confirm (or rule out) that the 321 GHz water masers arise in the same region as the 22 GHz masers
- In any case, these results open a new spectral window to study water fountain nebulae.