Deep into the Water fountains:

A detailed study towards IRAS 15445-5449

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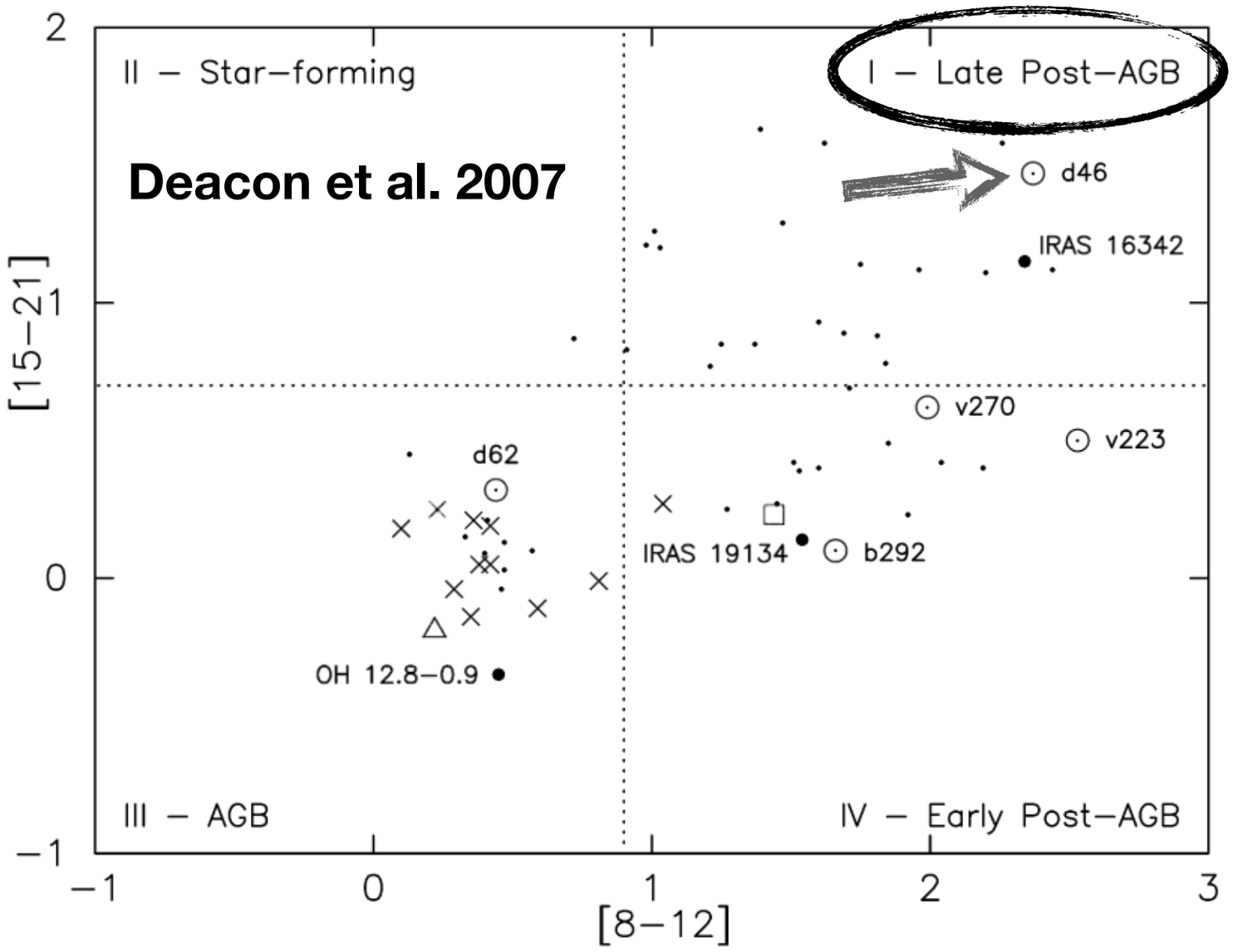
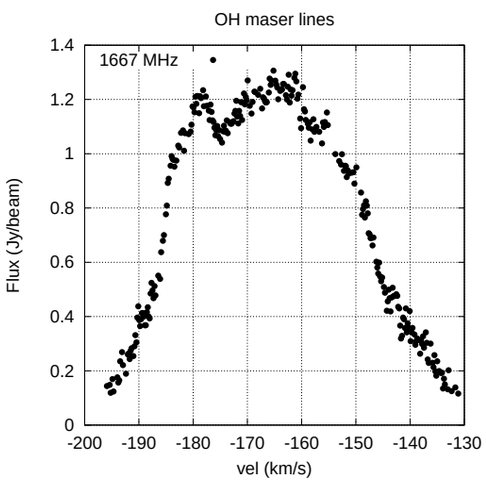
D. Tafoya (OSO, Chalmers), W. Vlemmings (OSO, Chalmers).

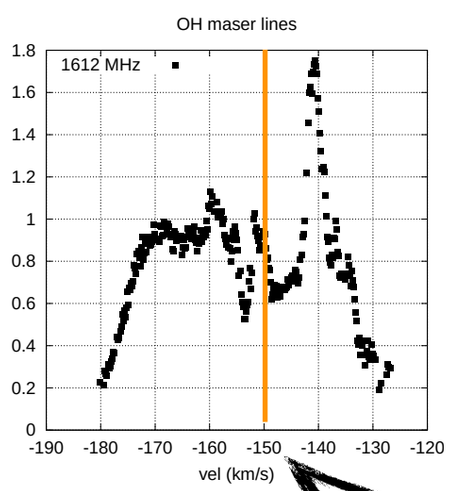
IAU Symposium 336.
September 7, 2017.
Cagliari, Italy.

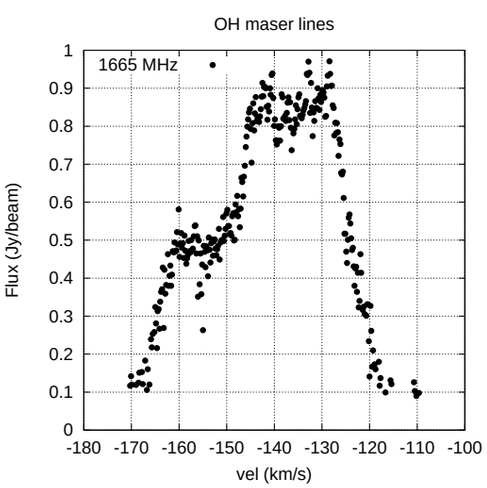
- **Deacon et al. 2007,** from its position at the MSX color-color diagram: "IRAS 15445-5449 is an evolved post-AGB star with **highly unusual maser properties** (...)"

- OH spectral line emission: **Irregular and broad emission lines** (1665 MHz, 1667 MHz, 1612 MHz).
  - Irregular OH line-profiles could indicate a departure from the spherical symmetric scenario.
  - Systemic velocity defined by the center of the irregular line-profile of the OH 1612 MHz line: Vsys=-150 km/s. Water maser emission tracing red-shifted molecular gas!!
  - All the OH maser lines are blue-shifted with respect to the Water maser spectral features.









Systemic velocity -150.0 km/s

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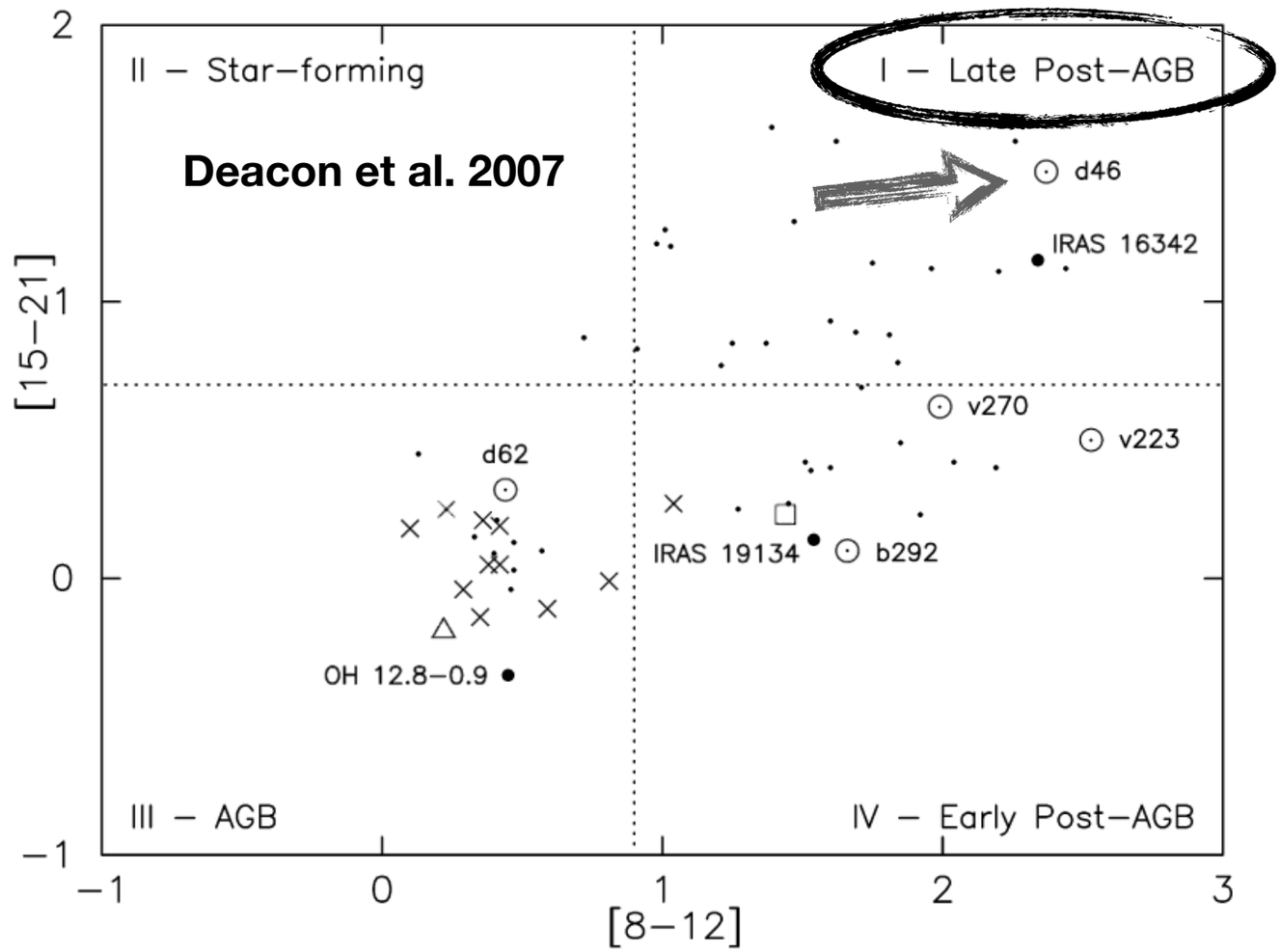
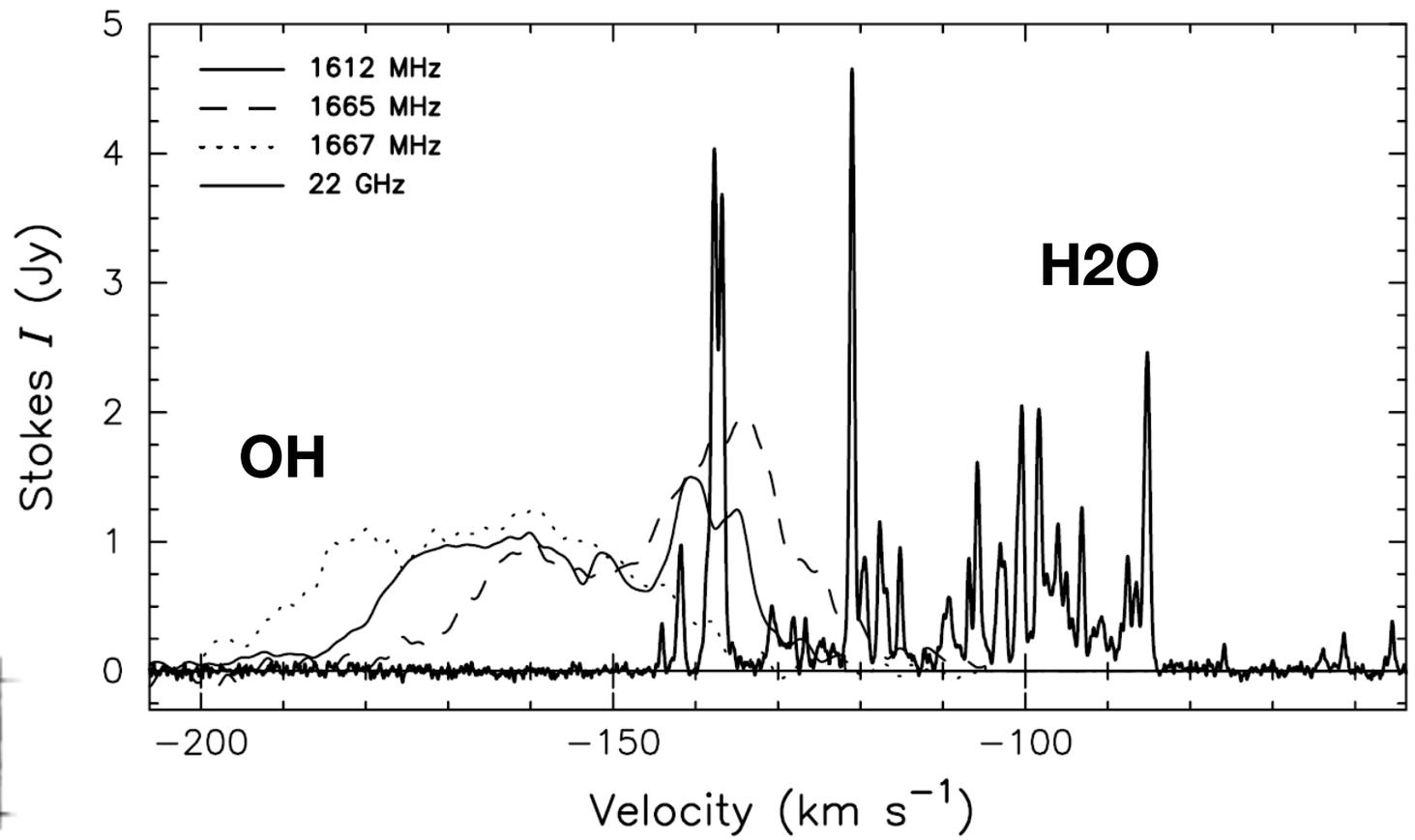




Submillimeter studies: **D. Tafoya's talk today!**

Radio emission detected at 4.8 GHz and 8.6 GHz Bains et al. (2009) —>

- 2005 observations yield negative spectral index of ~ **-0.3**, evident variation of both flux density and spectral index.

DUSTY models: **best fit indicates Teff=11900 K, not high enough to be a source of ionization...** the model was spherically symmetric...

Cohen et al. (2005) based on unpublished data taken at 3, 6 and 13 cm in 1998: **Spectral index ~ -0.8.**

Teff derived from models coupled with strong non-thermal emission strongly support presence of wind-shock interactions

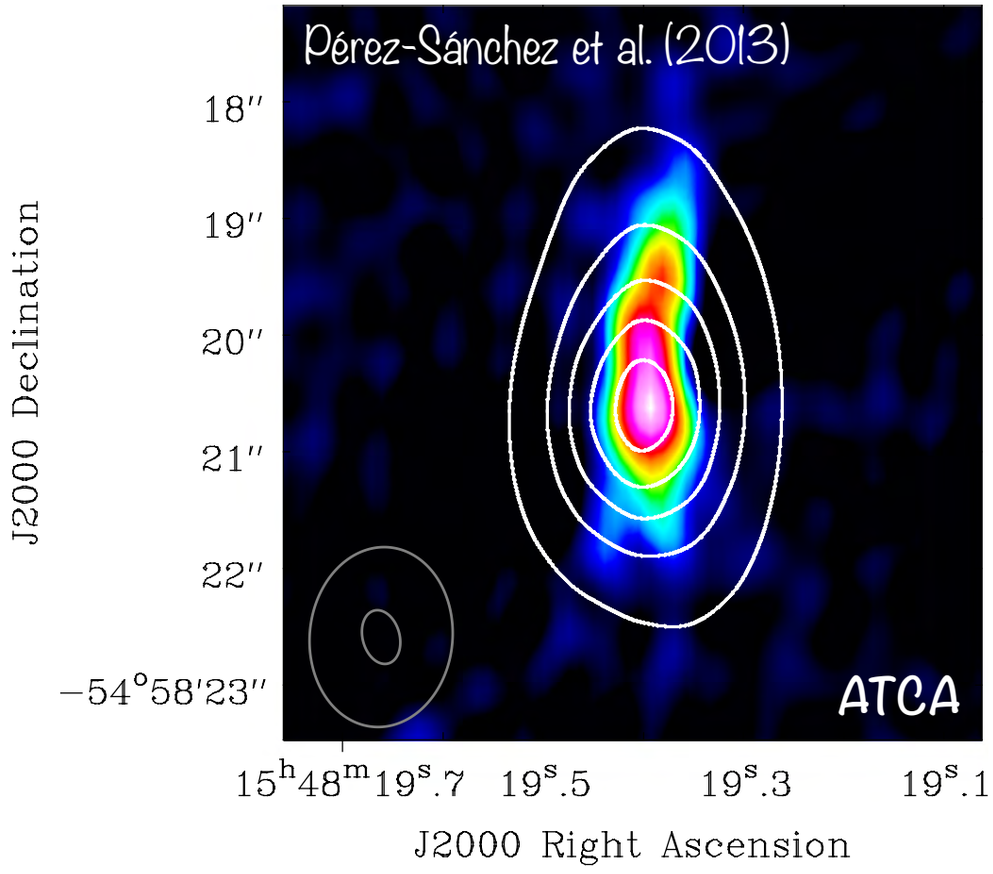
Pérez-Sánchez et al. (2013) spectral index of the **non-thermal component** -0.68±0.01

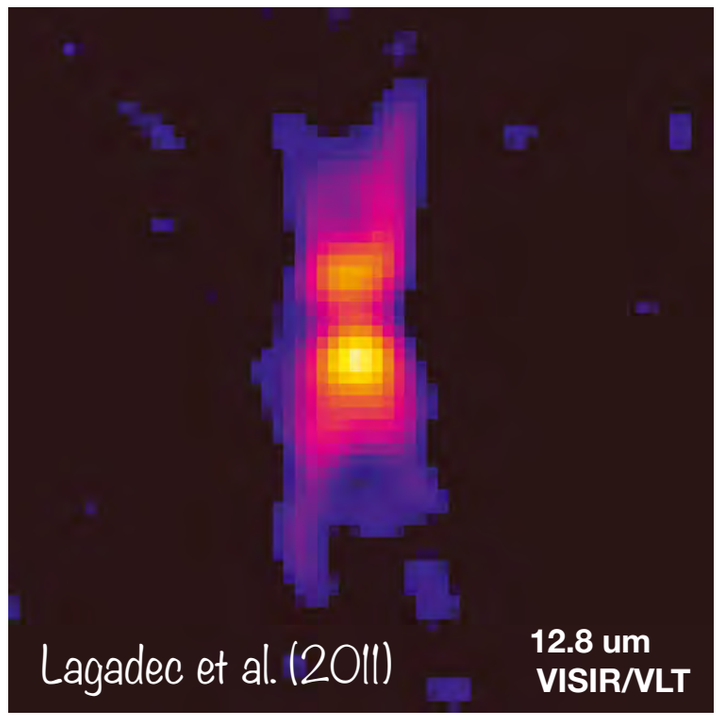
Radio-continuum 'jet' spatially resolved at 22GHz!

Table 1. Flux density of IRAS 15445−5449.

Epoch 2012[a]			Epoch 2005[b]			Epoch 1998/99		
Frequency (GHz)	Flux (mJy)	Beam (arcsec^2)	Frequency (GHz)	Flux (mJy)	Beam (arcsec^2)	Frequency (GHz)	Flux (mJy)	Beam (arcsec^2)
–	–	–	–	–	–	0.84	32.5 ± 4.1[c]	–
2.1	20.36 ± 0.14	5.6×3.0	–	–	–	1.4	23.0 ± 5.3	7.6×4.9[d]
2.5	21.72 ± 0.05	4.7×2.6	–	–	–	2.5	31.2 ± 6.2	3.3×3.0[e]
5.0	25.41 ± 0.04	1.9×1.5	4.8	22.81 ± 1.11	5.6×2.1	4.8	18.4 ± 2.4	2.0×1.6[e]
5.8	23.59 ± 0.05	1.6×1.3	–	–	–	–	–	–
8.5	18.45 ± 0.05	1.1×0.9	8.6	18.67 ± 0.47	3.0×1.2	8.6	10.7 ± 2.3	1.2×0.8[e]
9.3	17.70 ± 0.03	1.0×0.8	–	–	–	–	–	–
22.0	12.31 ± 0.03	0.48×0.34	–	–	–	–	–	–

[a]This Letter. [b]Bains et al. (2009). [c]Observations carried out on 1998 June 13 (D. Hunstead, private communication; Murphy et al. 2007). [d]Observations taken on 1999 September 2 (ATCA archive). [e]Observations carried out on 1998 November 9–14 (Deacon et al. 2007).





IR observations (Legadec et al. 2011)): Hourglass shape at 12.8 um!!

ATCA:

Observations: Sep. 2012.

OH at 1.6 GHz

H2O at 22.2 GHz

Continuum at 1.5 GHz, 3.0 GHz, 6.0 GHz and 22 GHz

Zoom bands:

High-spectral resolution: 0.013 km/s.

Beam at 22-GHz:

0.48 arsec x 0.34 arcsec

SINFONI/VLT:

Observations: June 2015.

K-band: 1.9 um to 2.5 um

AO-mode, seing 0.8 arcsec.

SINFONI/VLT:

H2 ro-vibrational transitions detected

suggest **shock-excitation**

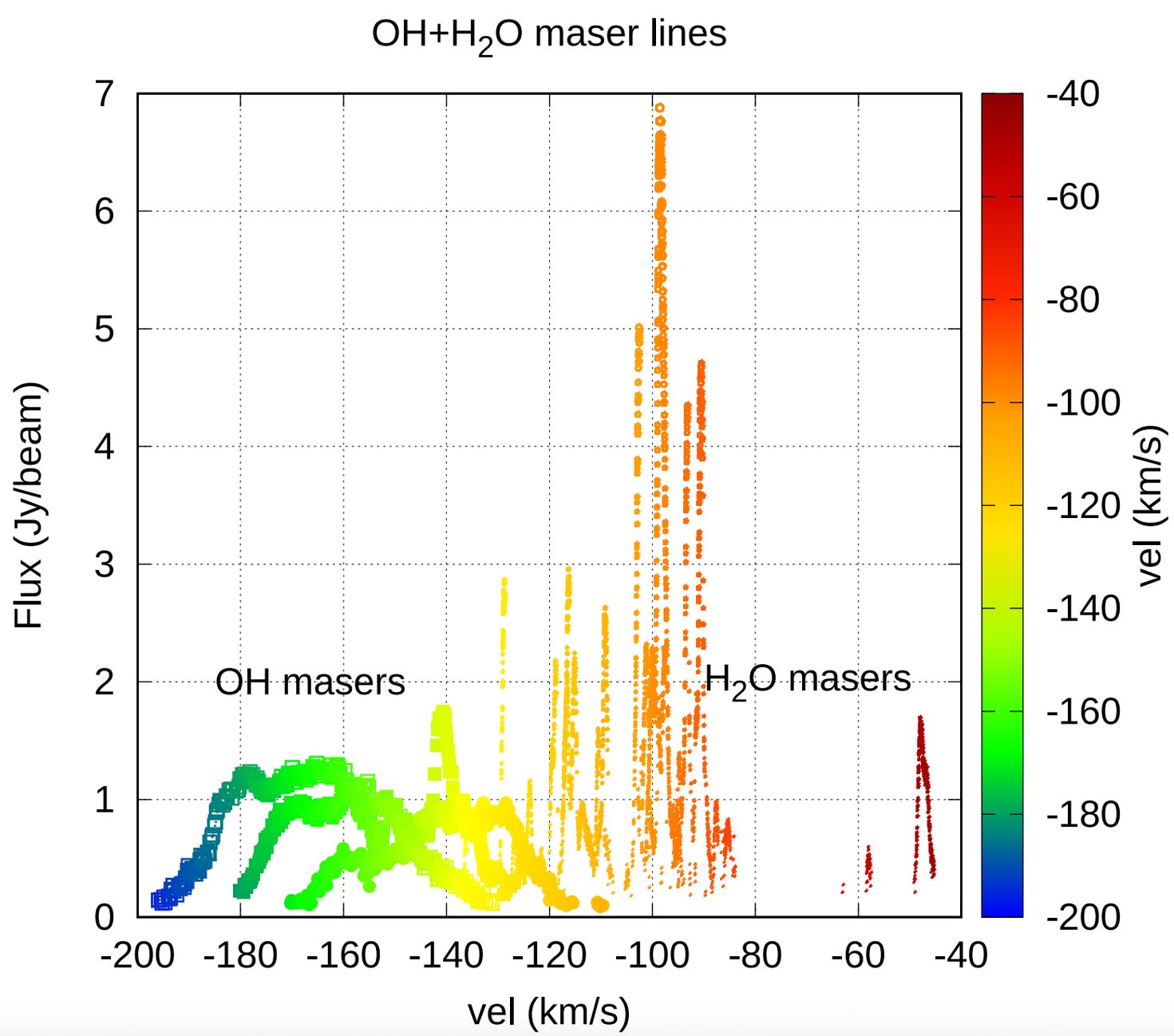
Brightest line **H2 1-0 S(1)**

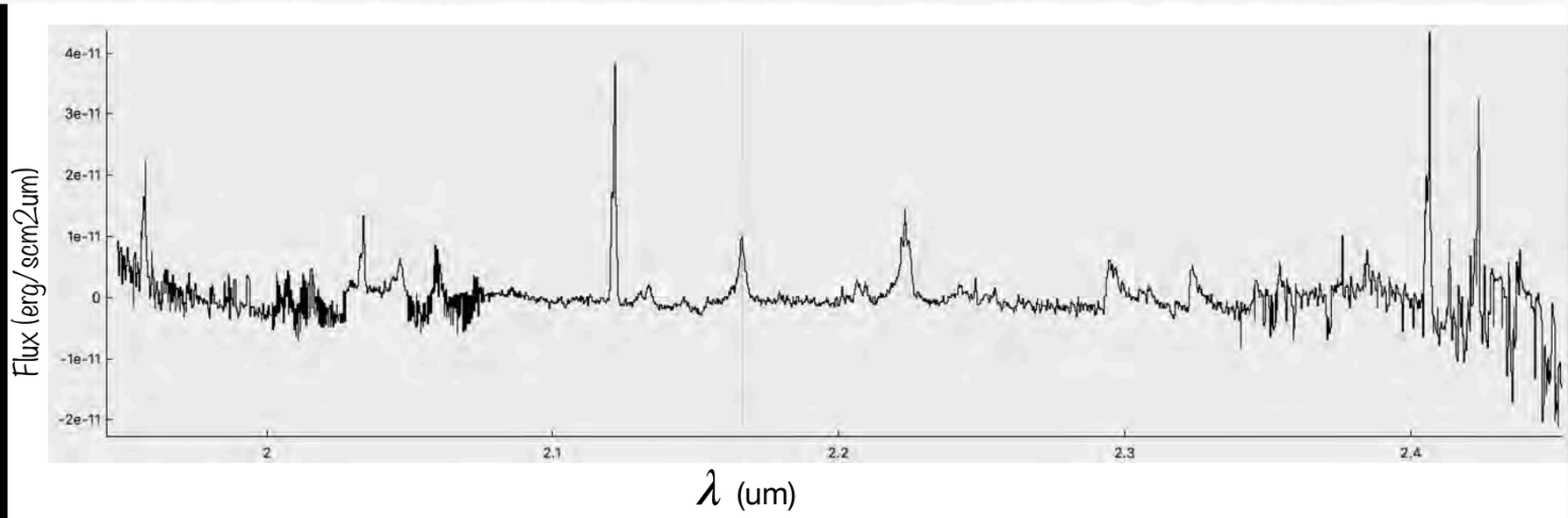
CO overtone, bandhead transitions.

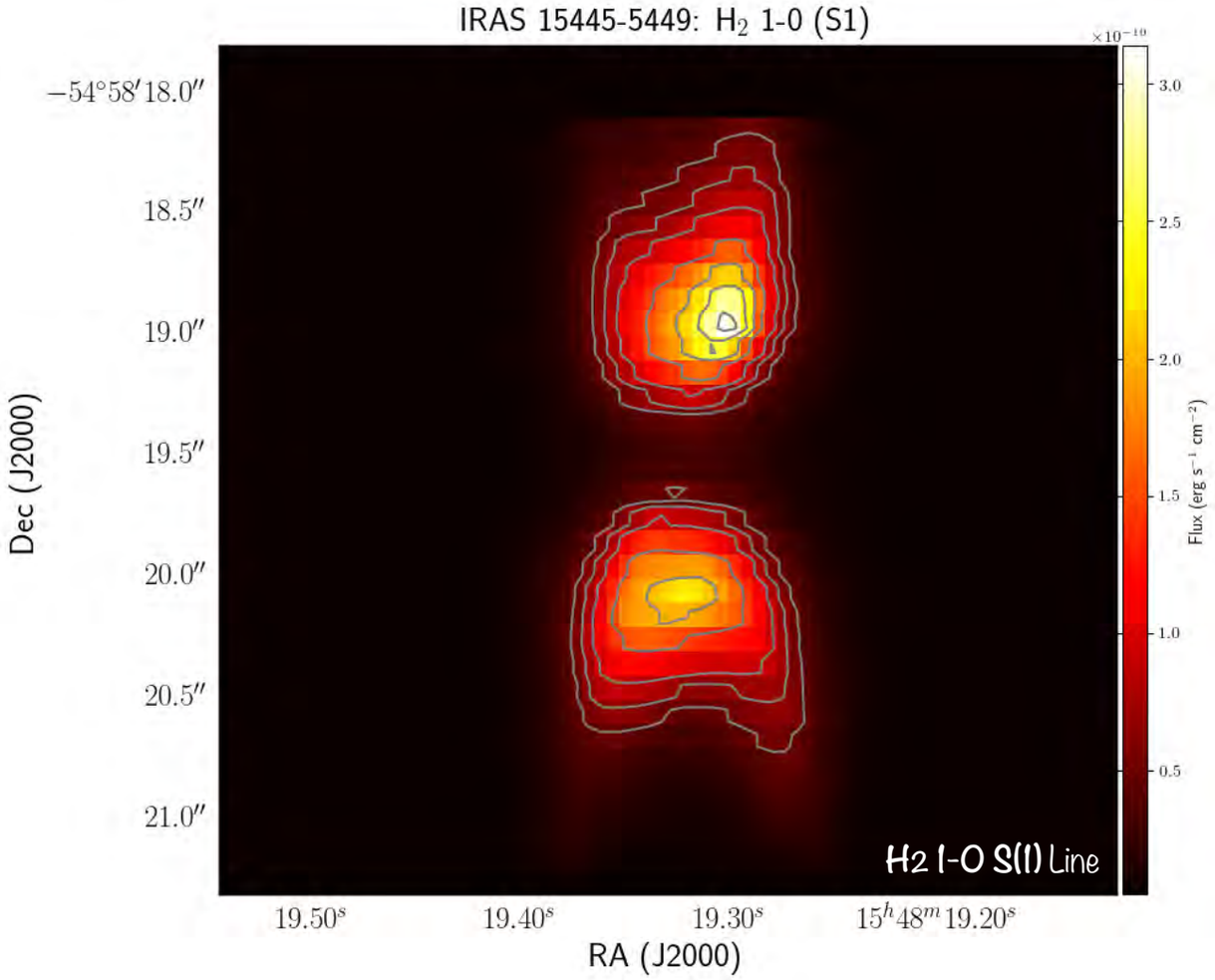
Atomic lines in emission:

Br-**γ**

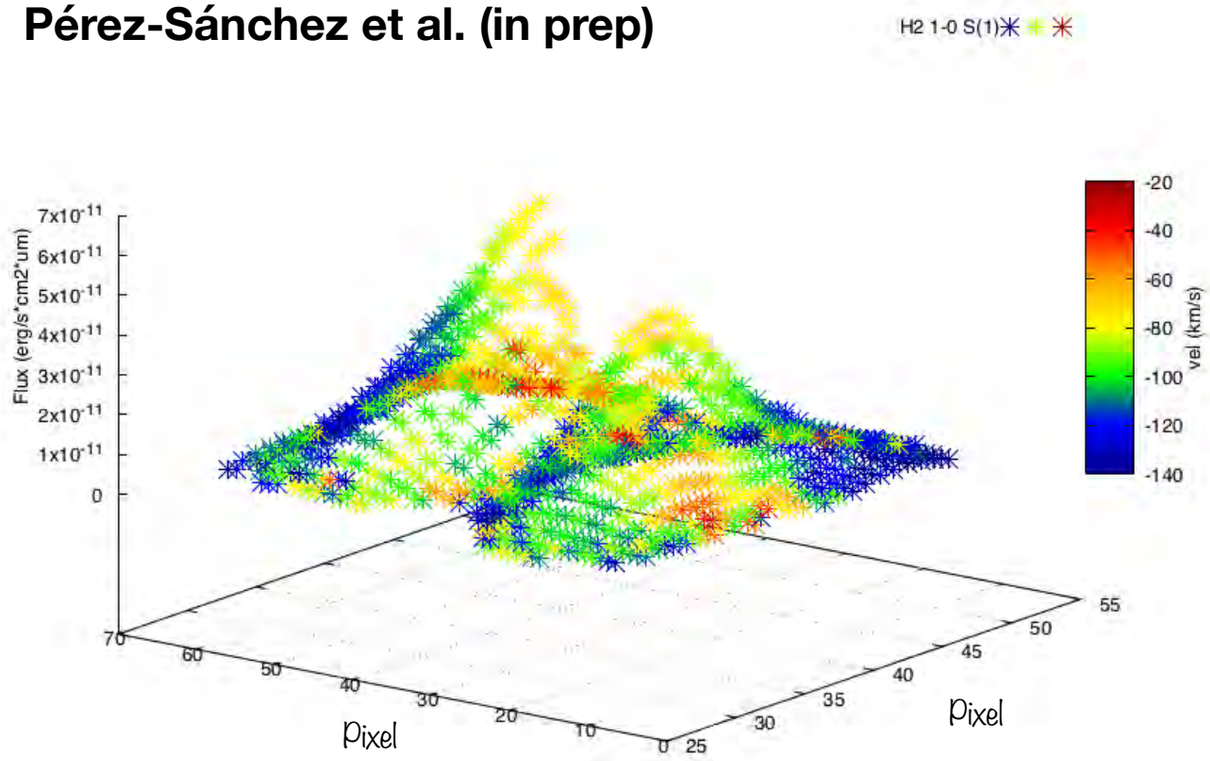
He[I]....

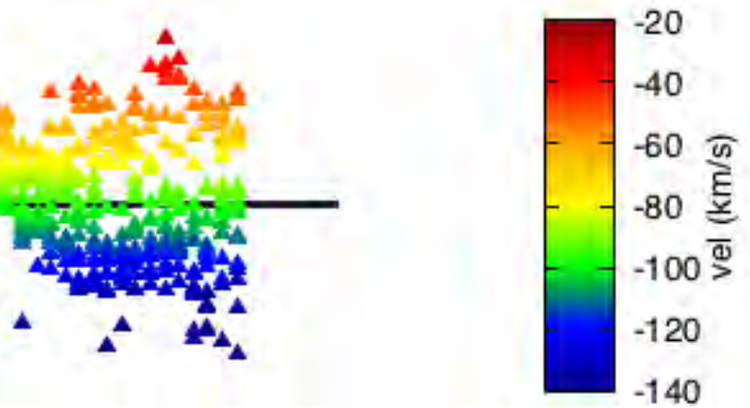






Pérez-Sánchez et al. (in prep)

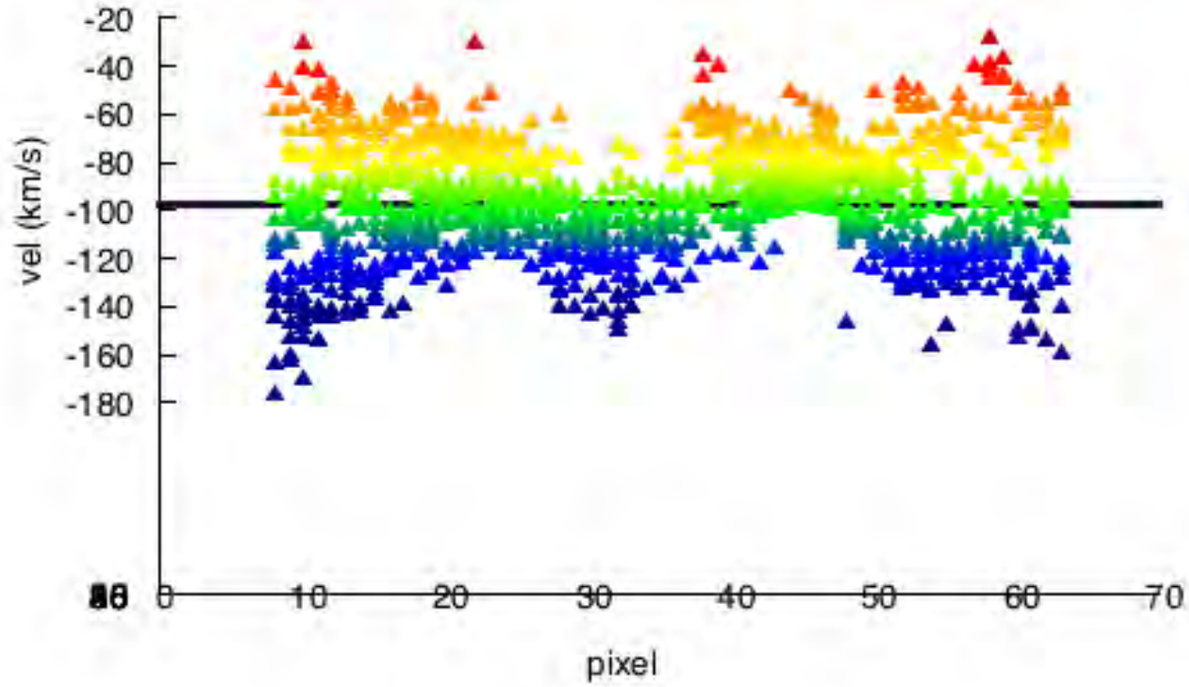


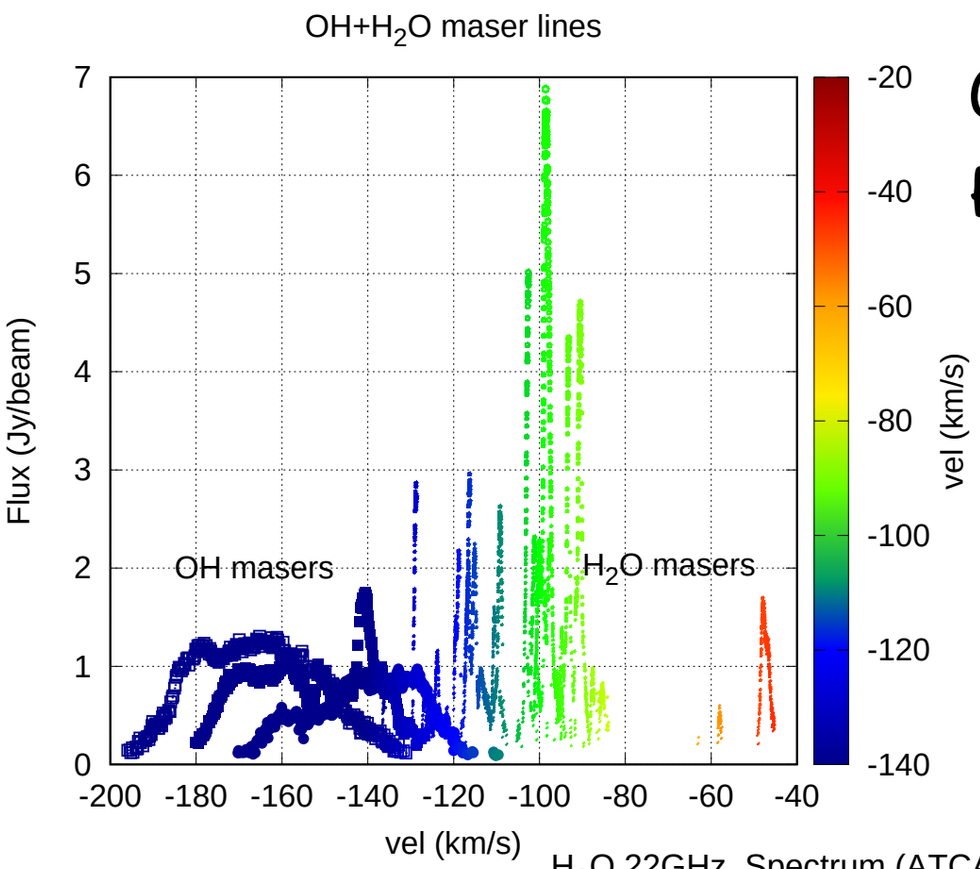


In [1]: run analyParams.py
H2 1-0 S1
meanVel=-96.527421 km/s
minVel=-153.866522 km/s
maxVel=-28.258314 km/s
maxFlux=6.207869e-11 erg/(s*cm2*um)
minFlux=3.712760e-12 erg/(s*cm2*um)
fluxMean=1.745520e-11 erg/(s*cm2*um)
restFreq =2.121800 um
lambdaM = 2.121117 um
<FWHM> = 1.043868e-03 um
<FWHM>/specRes = 4.26

Vsys=(-96.5 ± 34) km/s

Velocity distribution of the emission in each pixel of the SINFONI cube

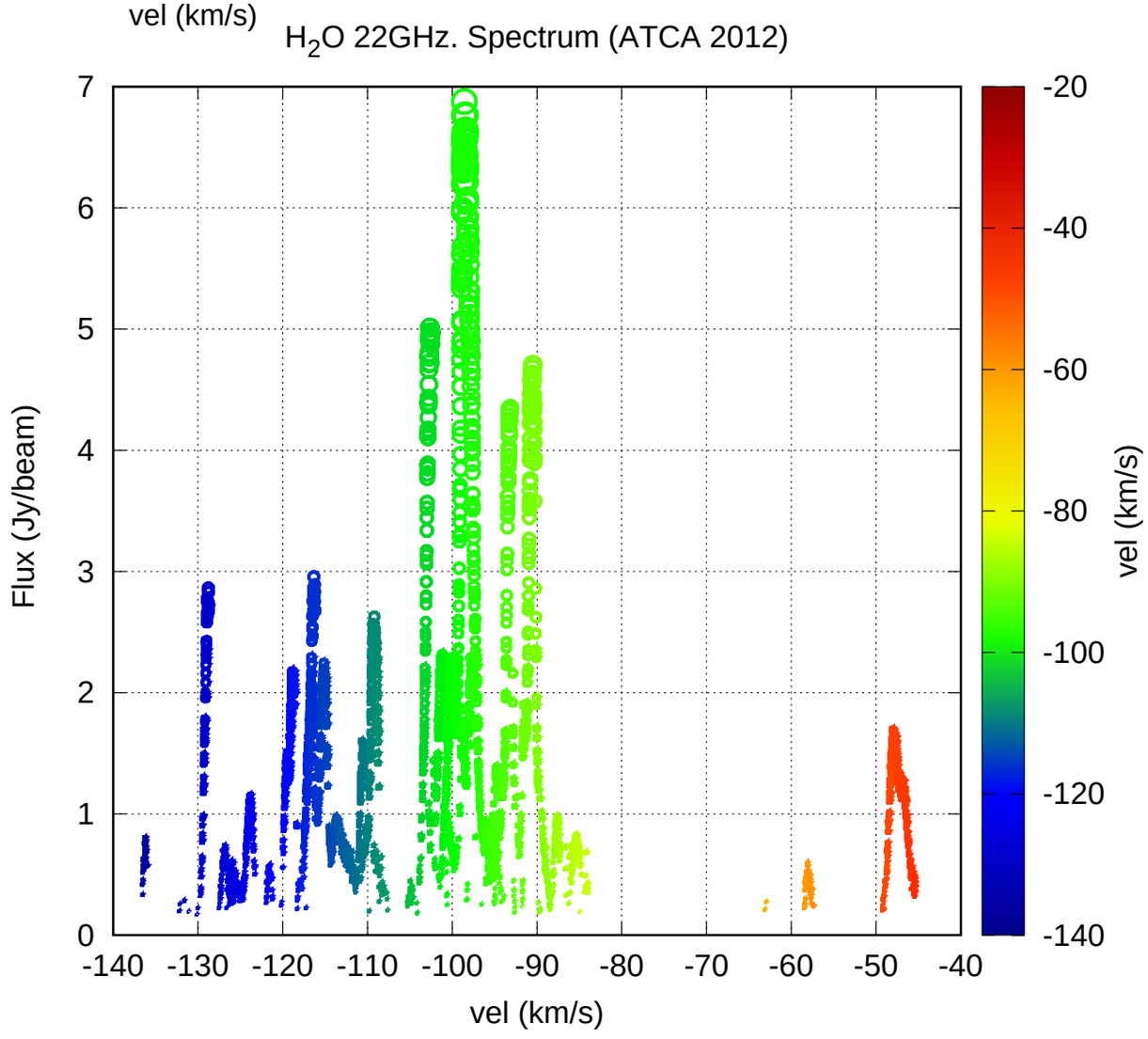


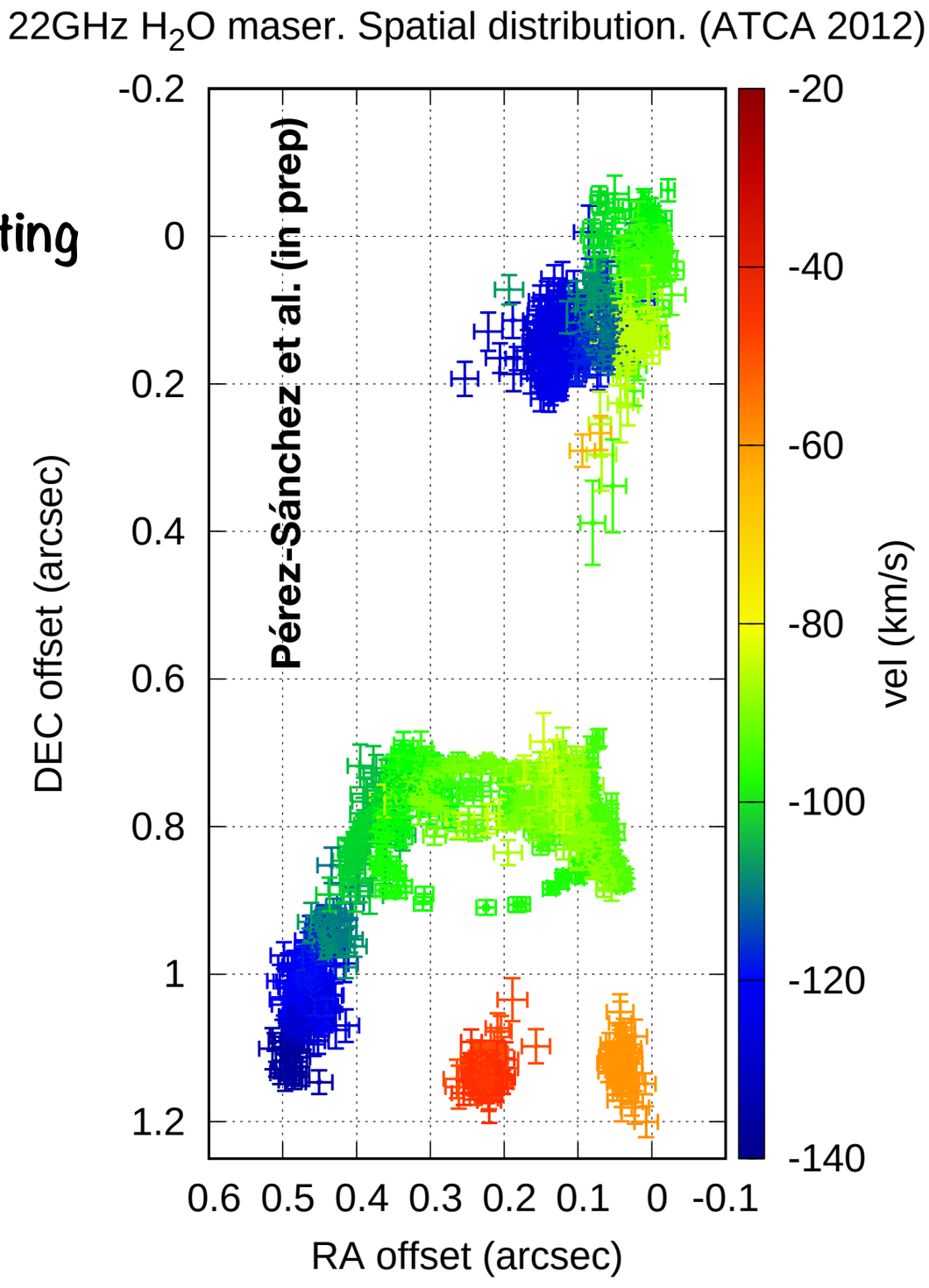


OH masers blue-shifted!!

H2O maser have red-shifted and blue-shifted features!!

Component fitting





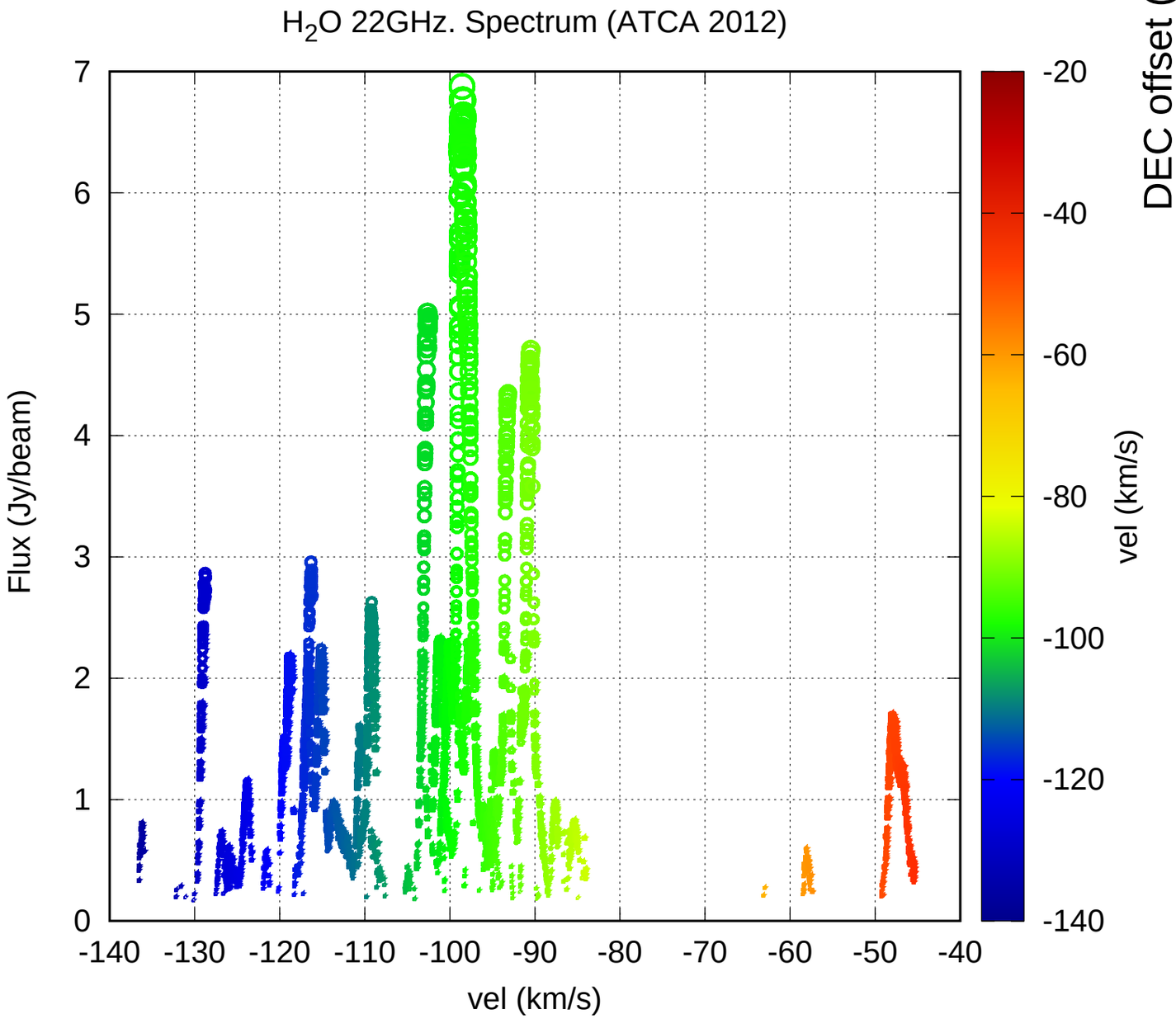
Assuming that Vsys~ (-96.0 ± 34) km/s:

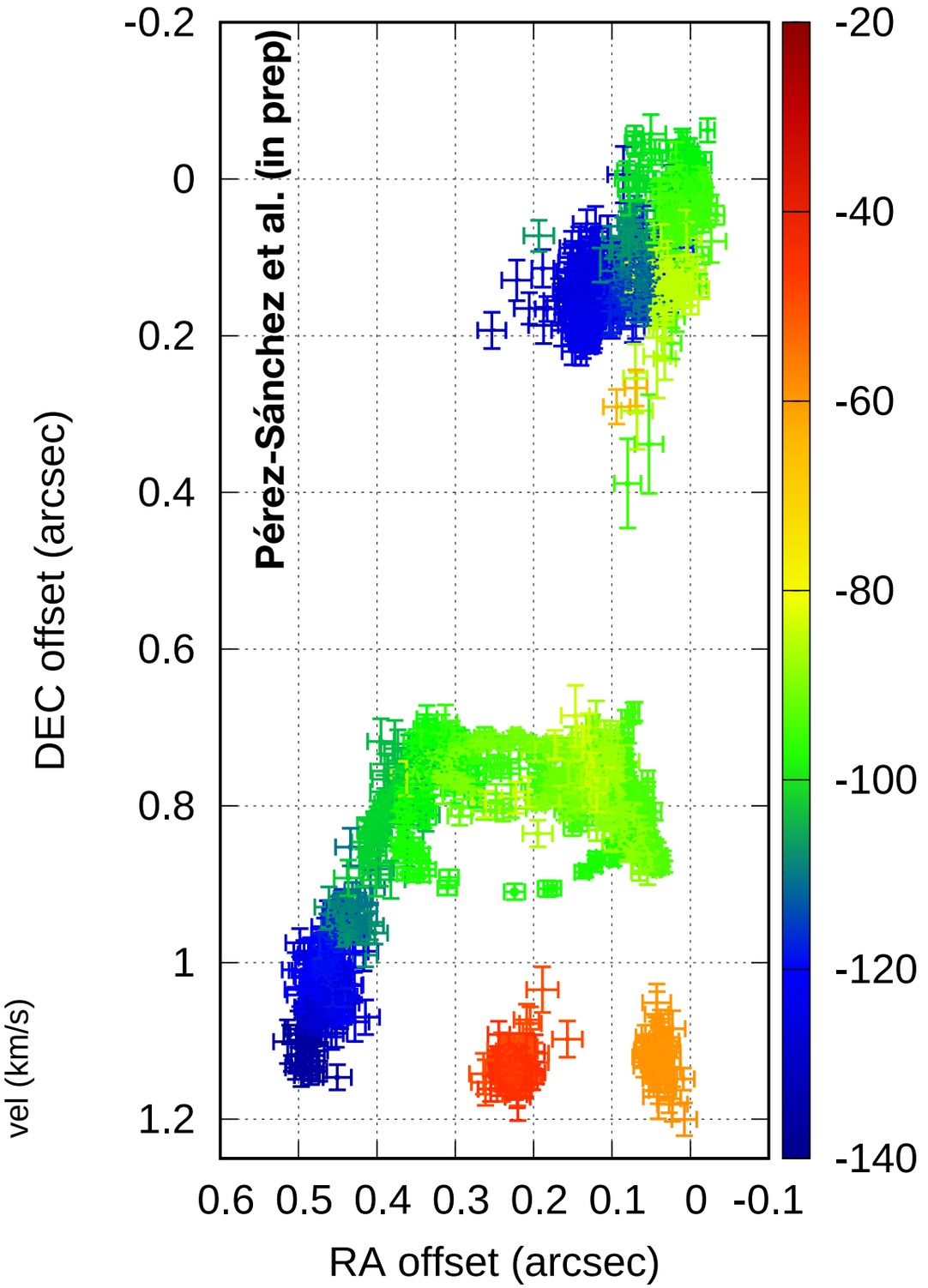
Using the Revised kinematic distance calculator (Reid et. al. 2014)...

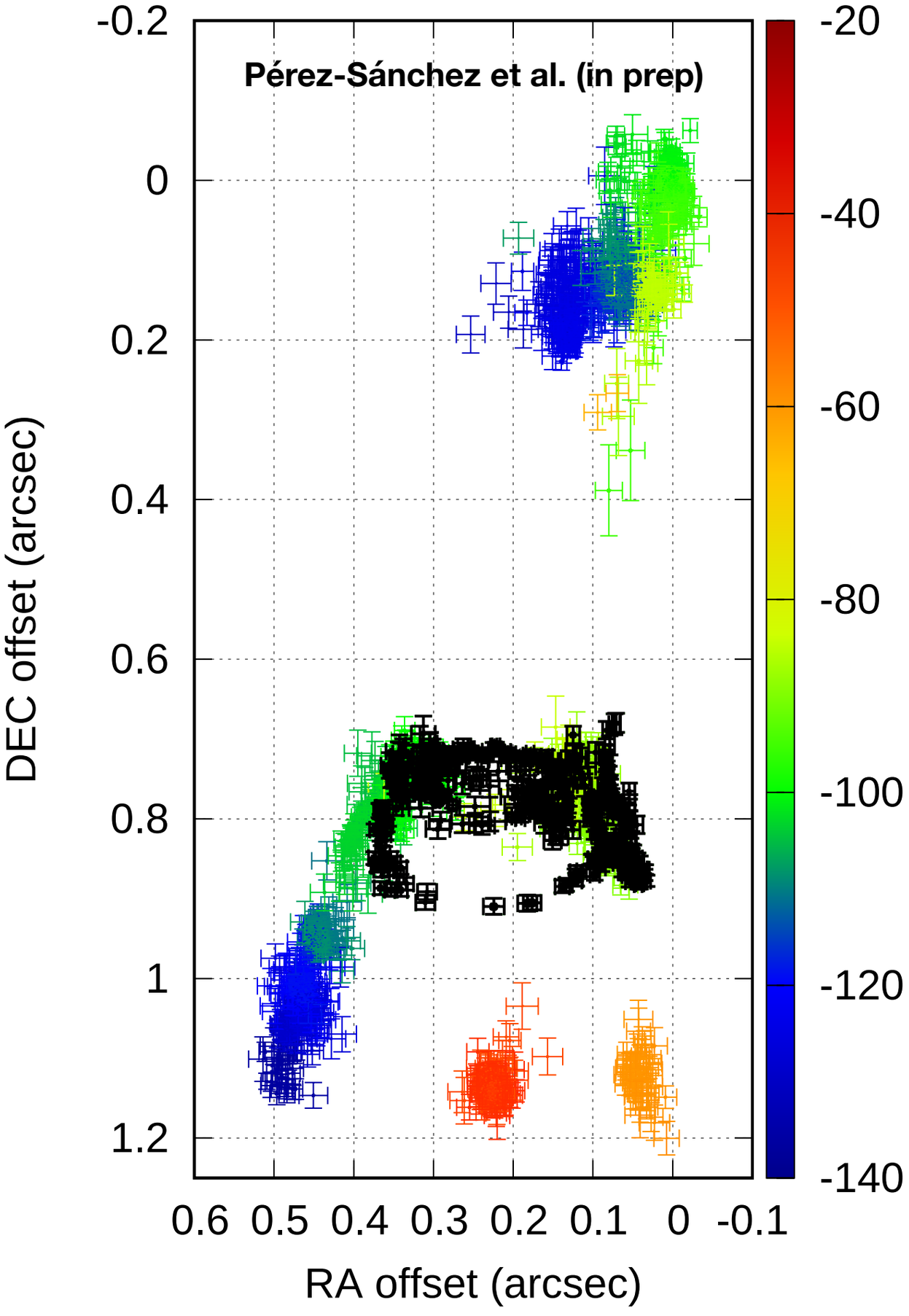
New kinematic distances

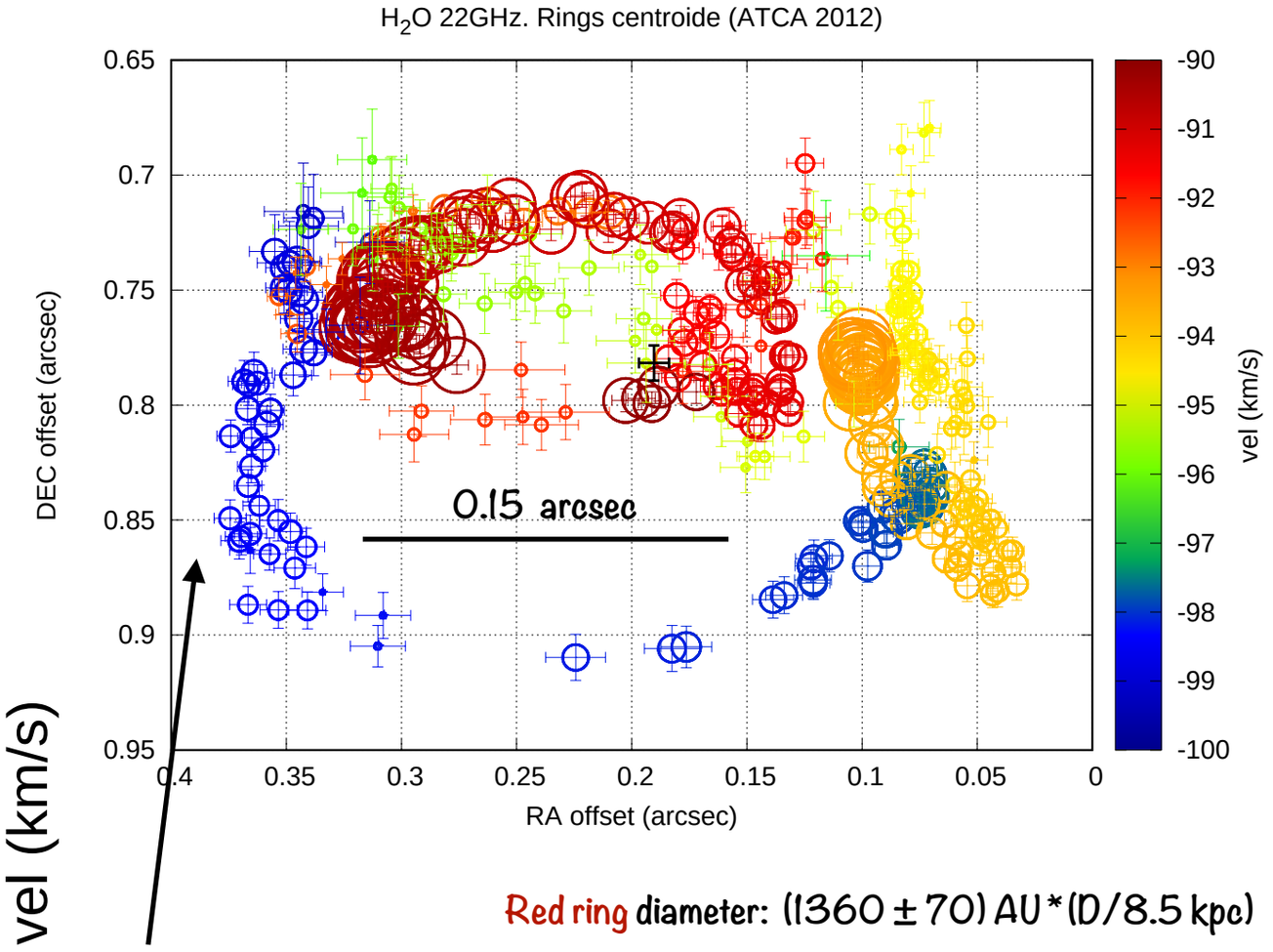
Near (5.6 ± 0.44) kpc

Far (8.5 ± 0.45) kpc







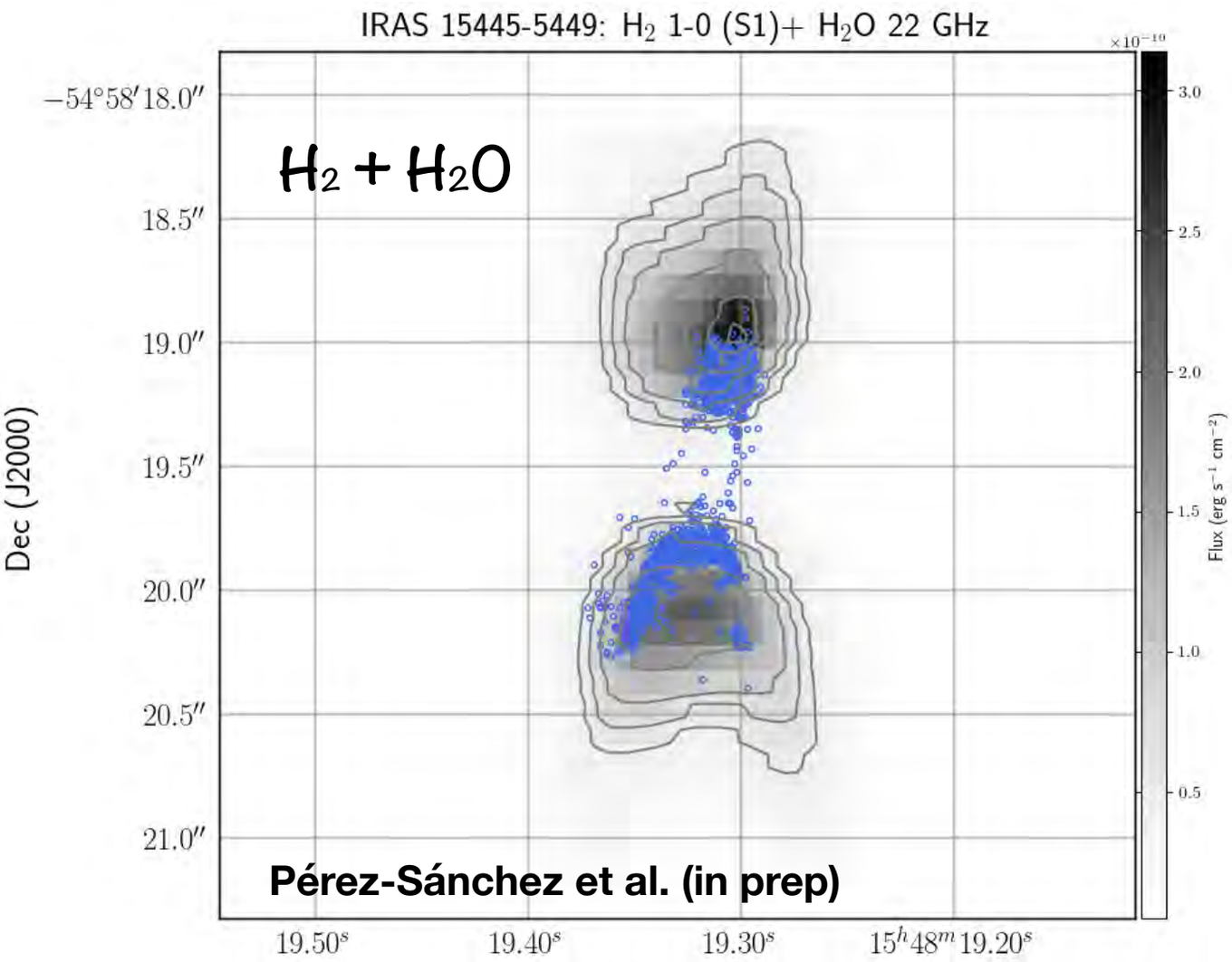


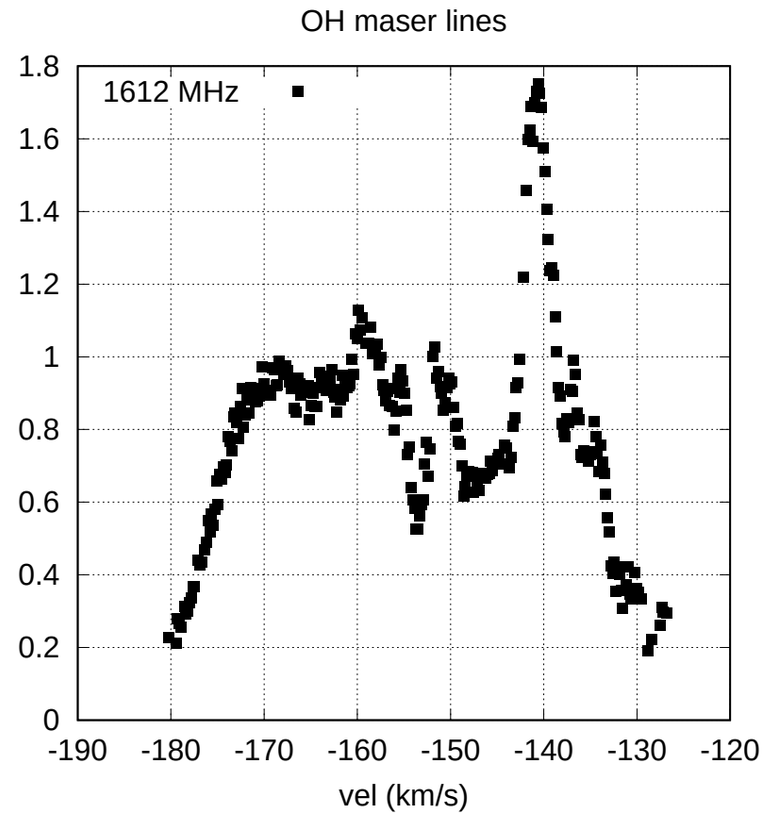
Red ring diameter: (1360 ± 70) AU*(D/8.5 kpc)

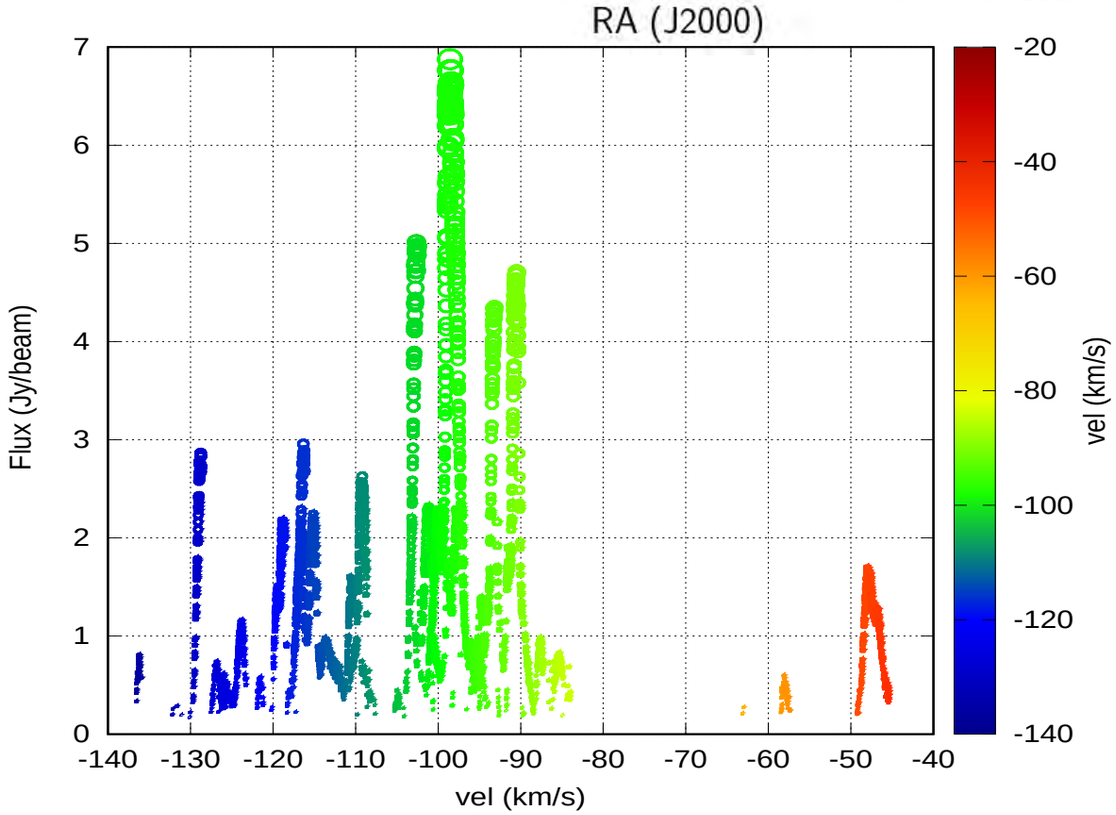
Blue "vertical" bow shock : (2550 ± 70) AU*(D/8.5 kpc)

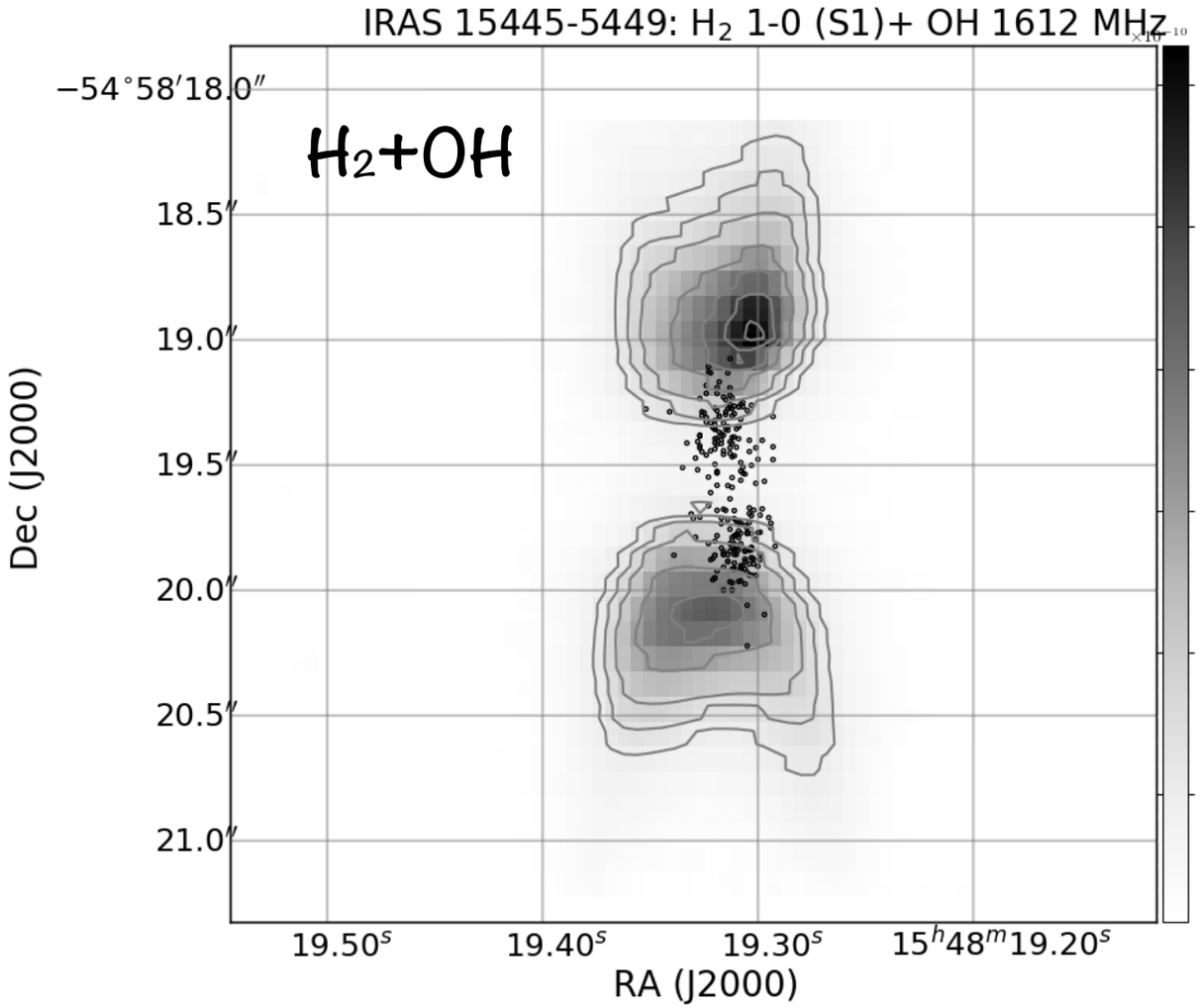
22 GHz H2O Masers tracing two different structures:

- Maser emission tracing high-velocity outflows: **~50 km/s w.r.t Vsys**.
- Slower wind: **Interaction between the outflow cavity and** a the molecular component of **a Torus**.


IRAS 15445-5449: H_2 1-0 (S1)+ H_2O 22 GHz
$H_2 + H_2O$
Pérez-Sánchez et al. (in prep)
Dec (J2000)
RA (J2000)
Flux (erg s^{-1} cm^{-2})
$\times 10^{-16}$
−54°58′18.0″
18.5″
19.0″
19.5″
20.0″
20.5″
21.0″
19.50^s
19.40^s
19.30^s
15^{h}48^{m}19.20^s


OH maser lines
1612 MHz
vel (km/s)
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-190
-180
-170
-160
-150
-140
-130
-120


Flux (Jy/beam)
vel (km/s)
7
6
5
4
3
2
1
0
-140
-130
-120
-110
-100
-90
-80
-70
-60
-50
-40
-20
-40
-60
-80
-100
-120
-140


IRAS 15445-5449: H_2 1-0 (S1)+ OH 1612 MHz
H_2+OH
Dec (J2000)
RA (J2000)
$\times 10^{-16}$
−54°58′18.0″
18.5″
19.0″
19.5″
20.0″
20.5″
21.0″
19.50^s
19.40^s
19.30^s
15^{h}48^{m}19.20^s

- 22 GHz H2O maser emission traces two different large-scale structures within the CSE of IRAS 15445-5449: **Shaping the CSE LIVE!**
- OH spectral features: Too broad, too blue-shifted…. What does that mean???

  OH maser emission seems to correlate with a large-scale equatorial structure: Dissociation of H2O molecules in a ~80 km/s wind along the line of sight??
- IRAS 15445-5449: Many inputs parameters for MHD and radiative transfer models!!

  Models aiming to describe this source need to account for the coexistence of:

  Radio **continuum emission with a strong non-thermal component** +**Atomic lines** detected with SINFONI + **Shocked molecular layers: H2, H2O and OH** + **Dust emissions** observed in the mid-IR.**!**
- Observational **correlation** between the **spatial distributions** of **H2 ro-vibrational lines** and the **H2O maser lines** suggest that the maser emission traces shocked regions towards IRAS 15445-5449.
- From SINFONI data:

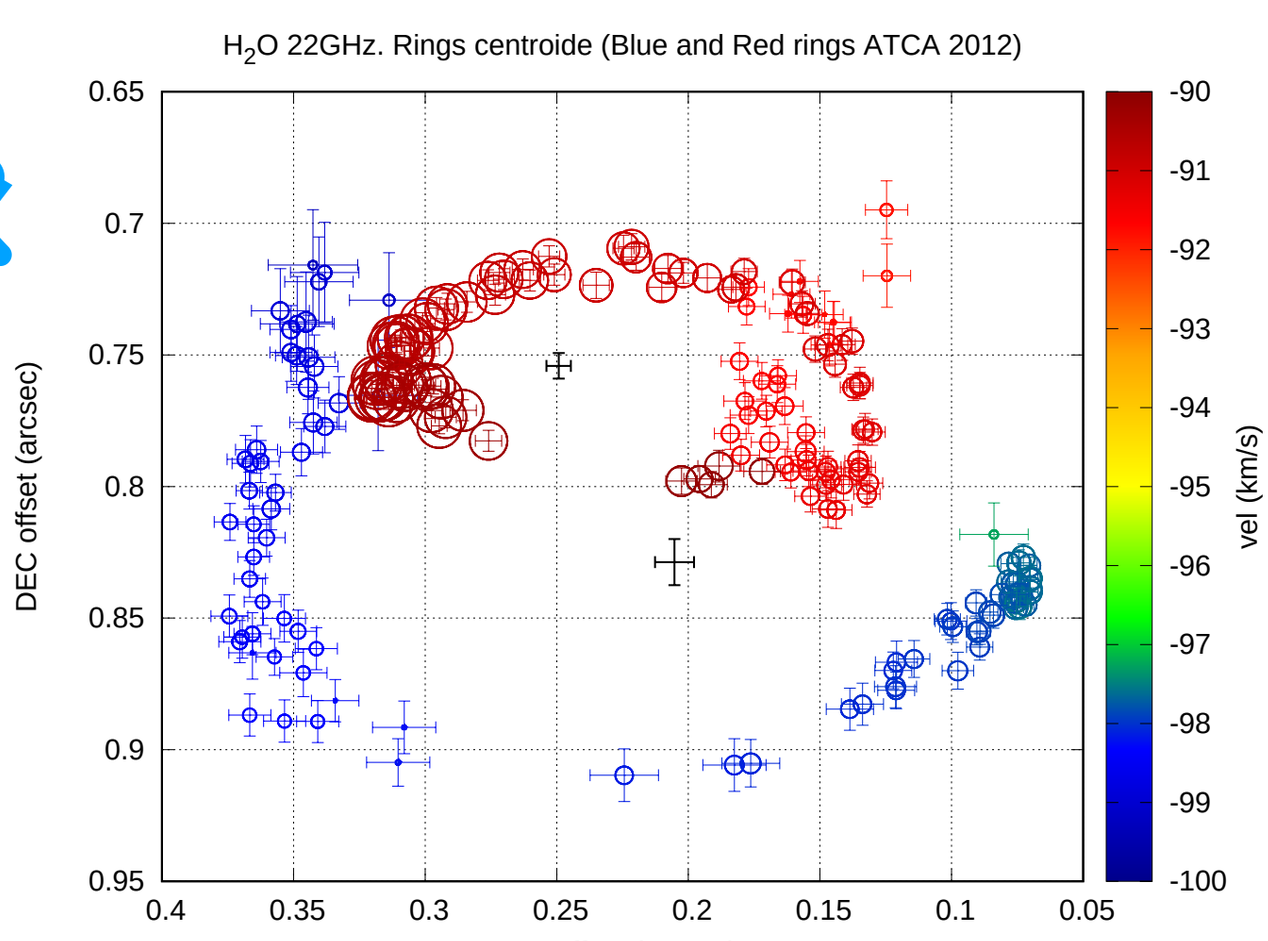
  Estimate the kinetic temperature of the shocked H2.

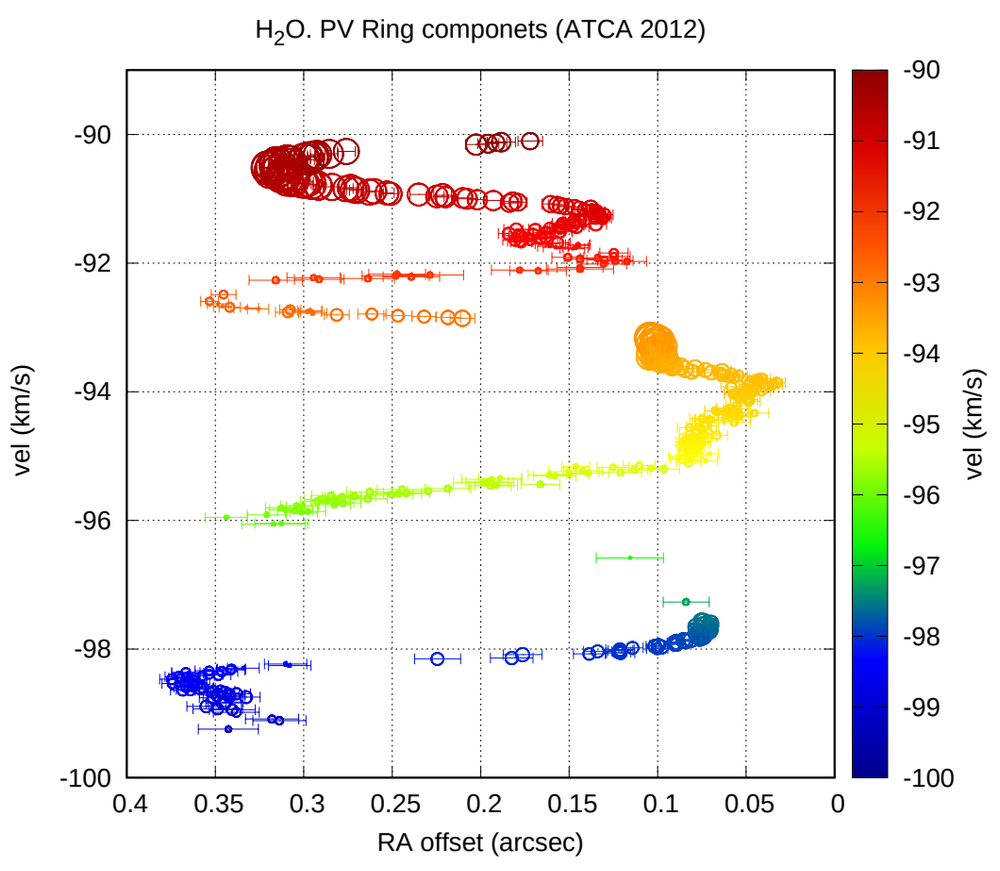
  Column densities and the mass of the shocked H2

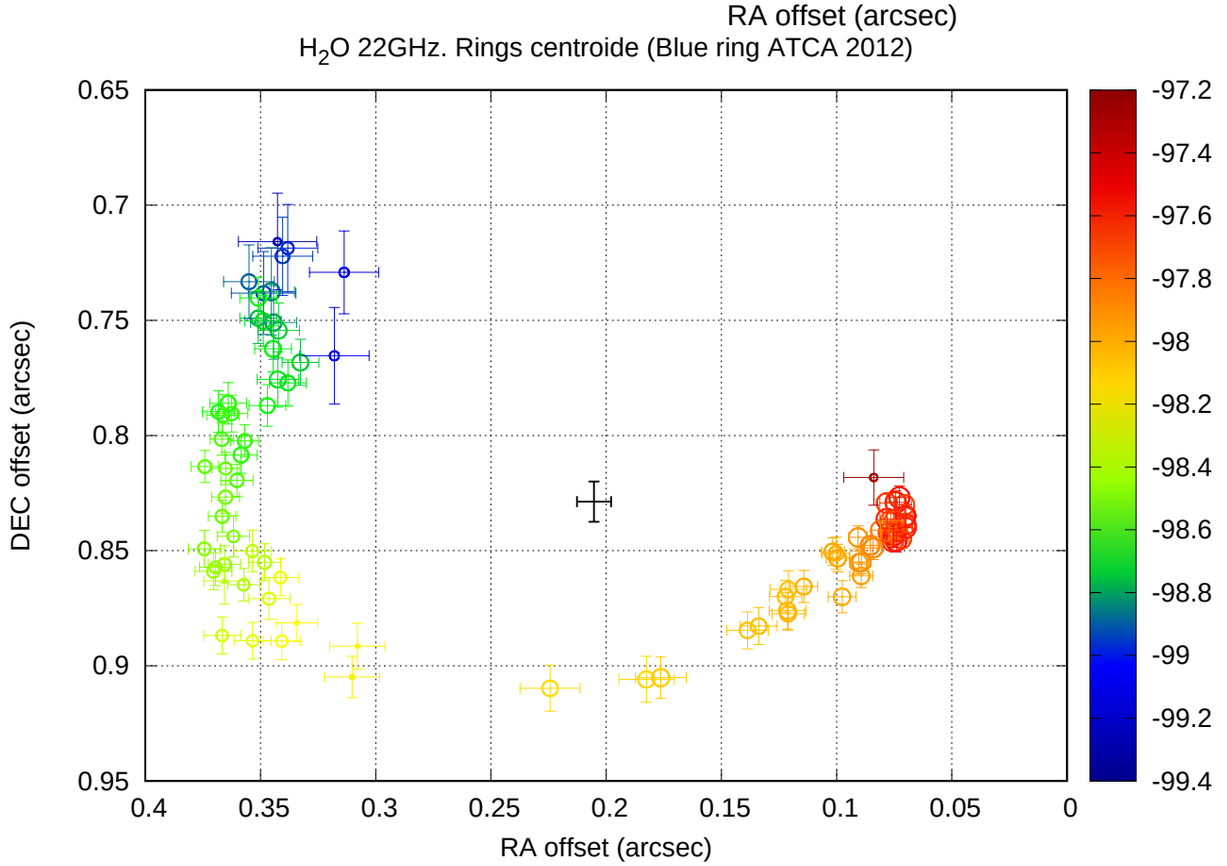
This is, for sure, an ~~amazing~~ Galactic source!! 😍

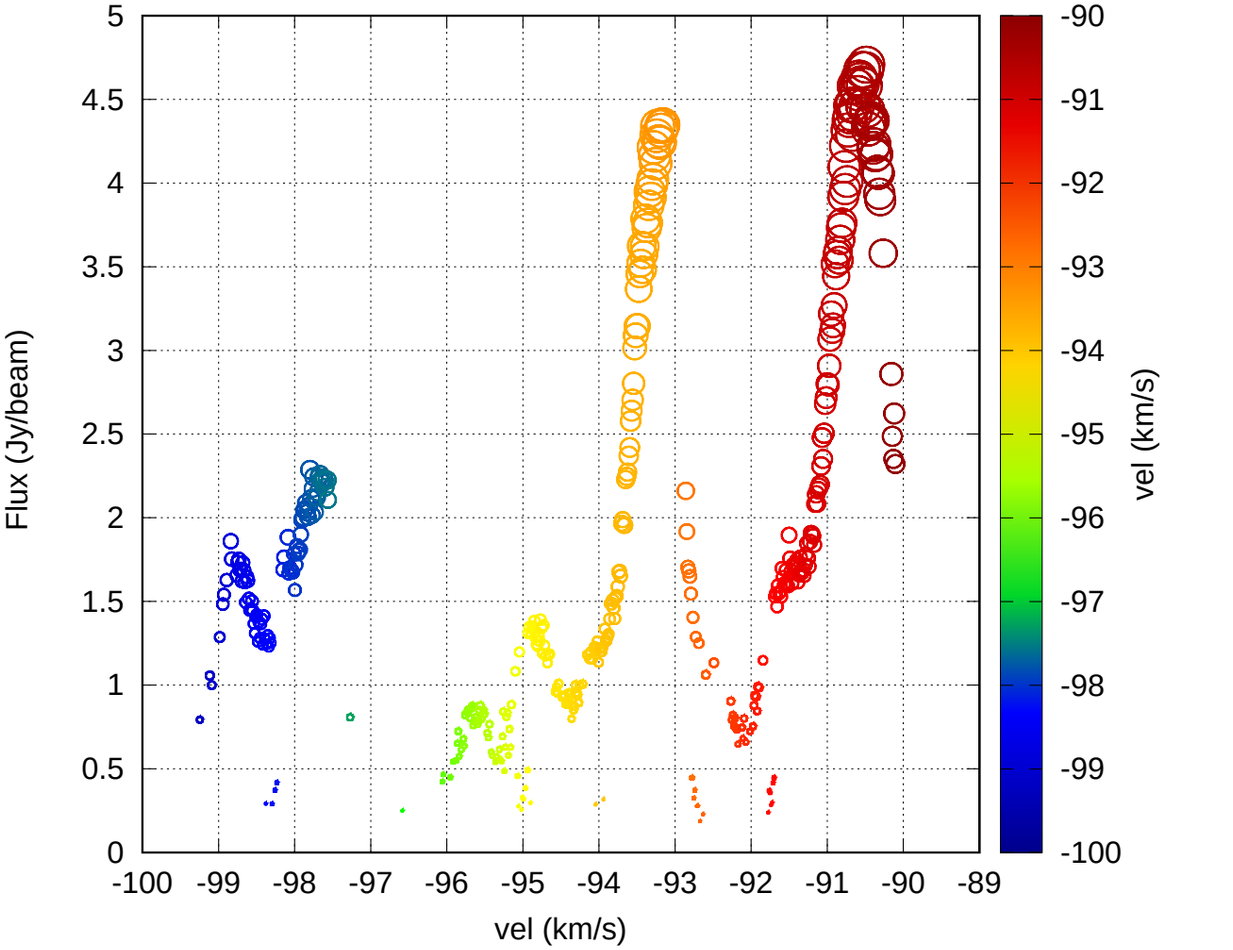
a-masing

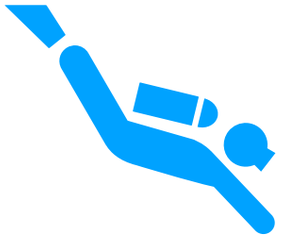


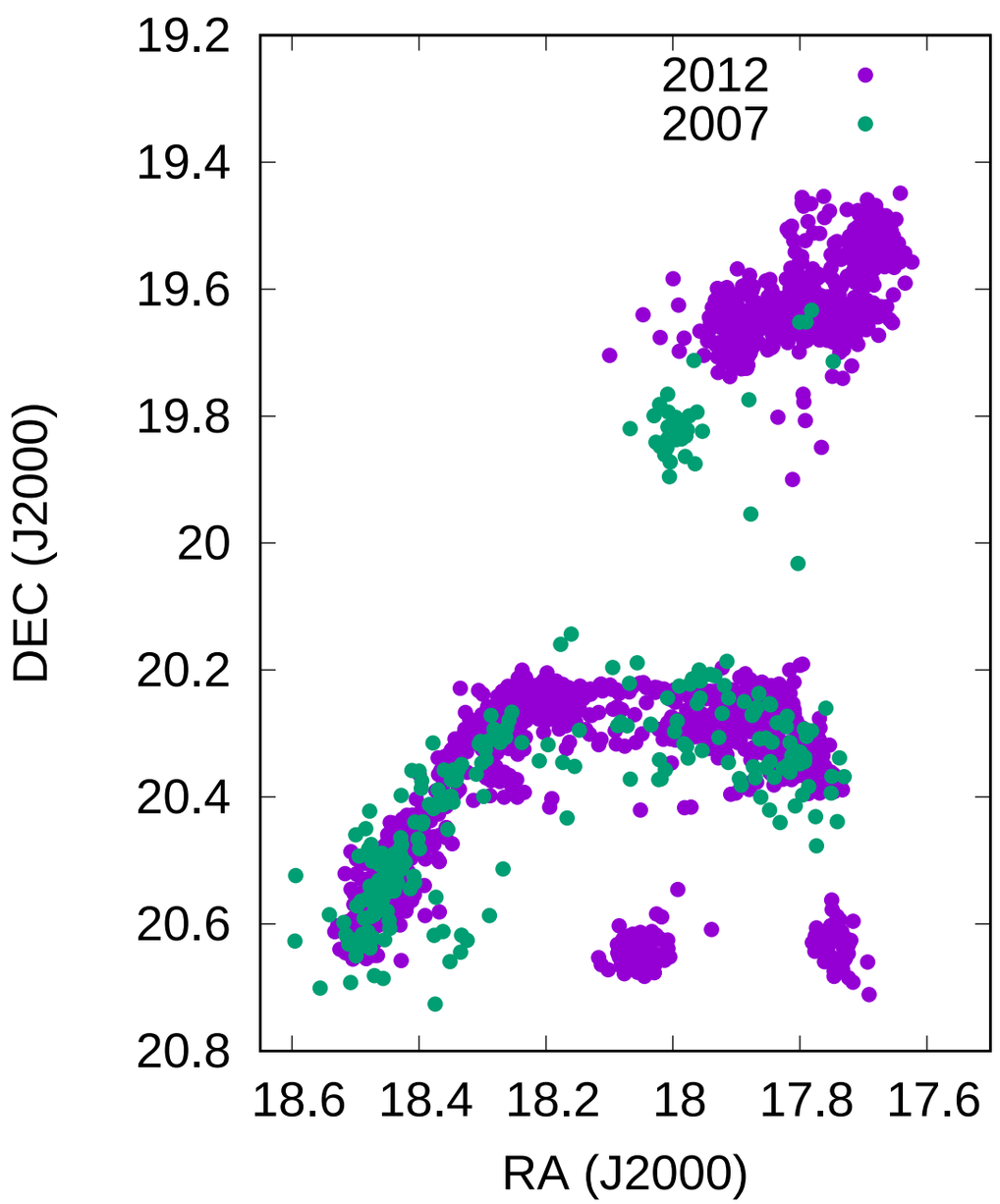

H2O 22GHz. Rings centroide (Blue and Red rings ATCA 2012)
DEC offset (arcsec)
RA offset (arcsec)
vel (km/s)

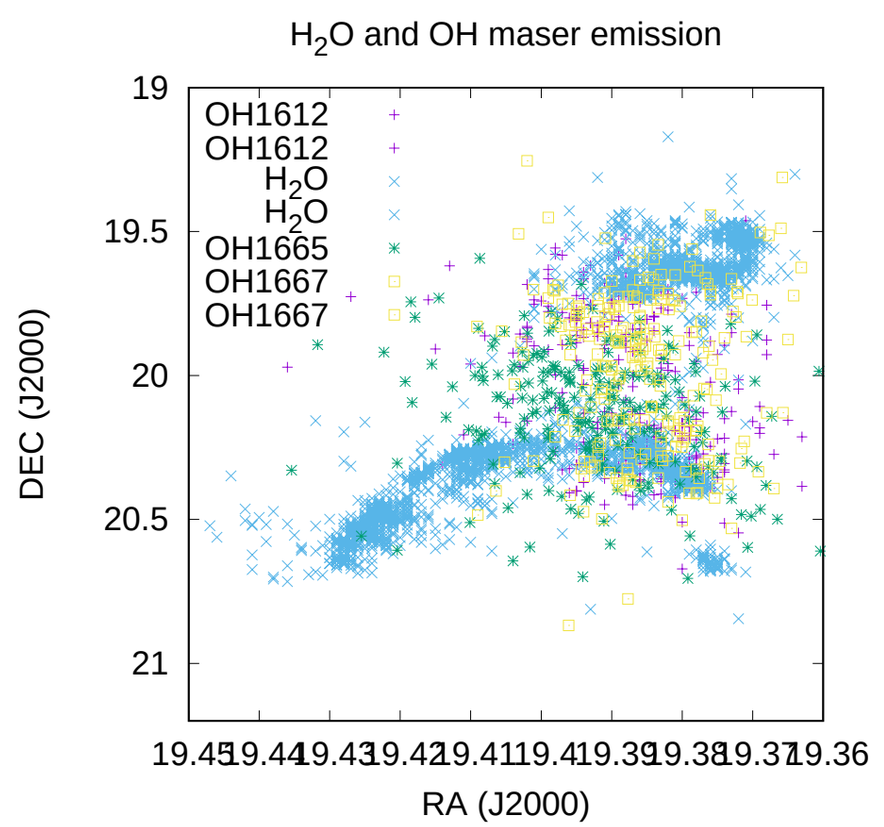

H2O. PV Ring componets (ATCA 2012)
vel (km/s)
RA offset (arcsec)
vel (km/s)

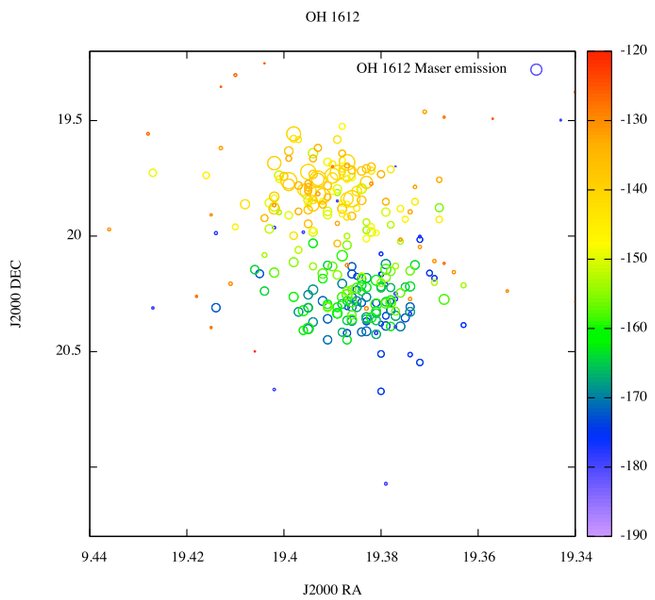

H2O 22GHz. Rings centroide (Blue ring ATCA 2012)
DEC offset (arcsec)
RA offset (arcsec)
vel (km/s)

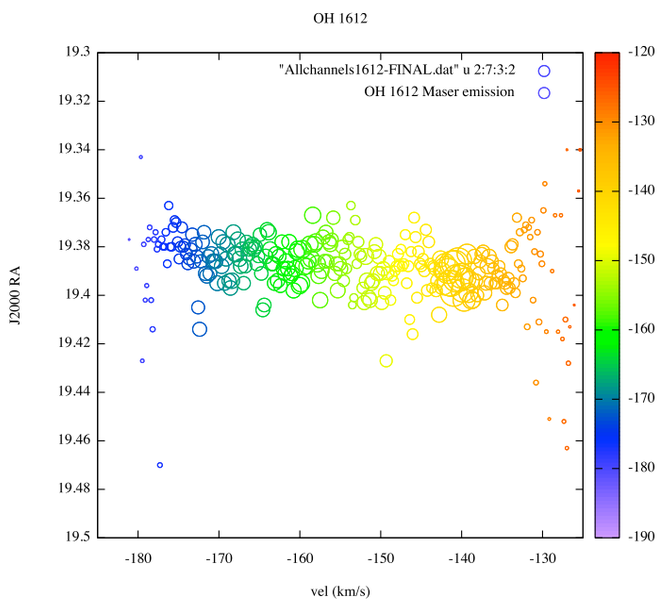

H2O 22GHz. Spectra Rings (ATCA 2012)
Flux (Jy/beam)
vel (km/s)
vel (km/s)

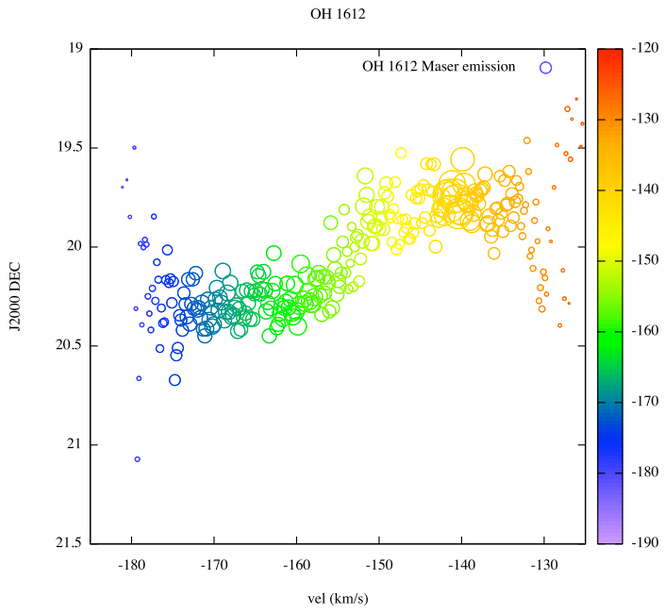



2012
2007
DEC (J2000)
RA (J2000)


H2O and OH maser emission
OH1612
OH1612
H2O
H2O
OH1665
OH1667
OH1667
DEC (J2000)
RA (J2000)


OH 1612
OH 1612 Maser emission
J2000 DEC
J2000 RA


OH 1612
"Allchannels1612-FINAL.dat" u 2:7:3:2
OH 1612 Maser emission
J2000 RA
vel (km/s)


OH 1612
OH 1612 Maser emission
J2000 DEC
vel (km/s)