XKCD: Time (frame 2395)
http://xkcd.com/1190/

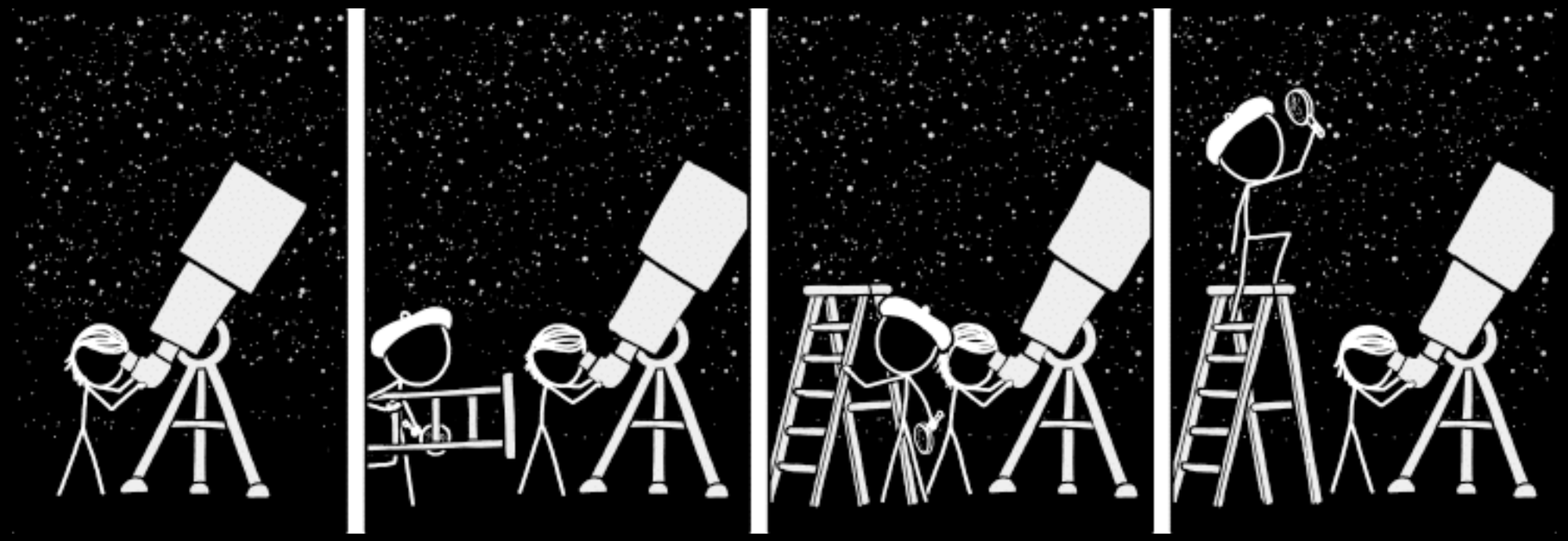
Astrometry of Water Fountains

(and some circumstellar OH masers)

Gabor Orosz
Kagoshima, Japan

2016.08.10.
Quy Nhon, Vietnam

XKCD: Astronomy
http://xkcd.com/1522/



Hiroshi Imai

Richard Dodson

Maria Rioja

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Ross Burns

Dieter Engels

Sandra Etoka

Yoshiharu Asaki

Hiroyuki Nakanishi

Sandor Frey

Jose Francisco Gomez

Ricardo Rizzo

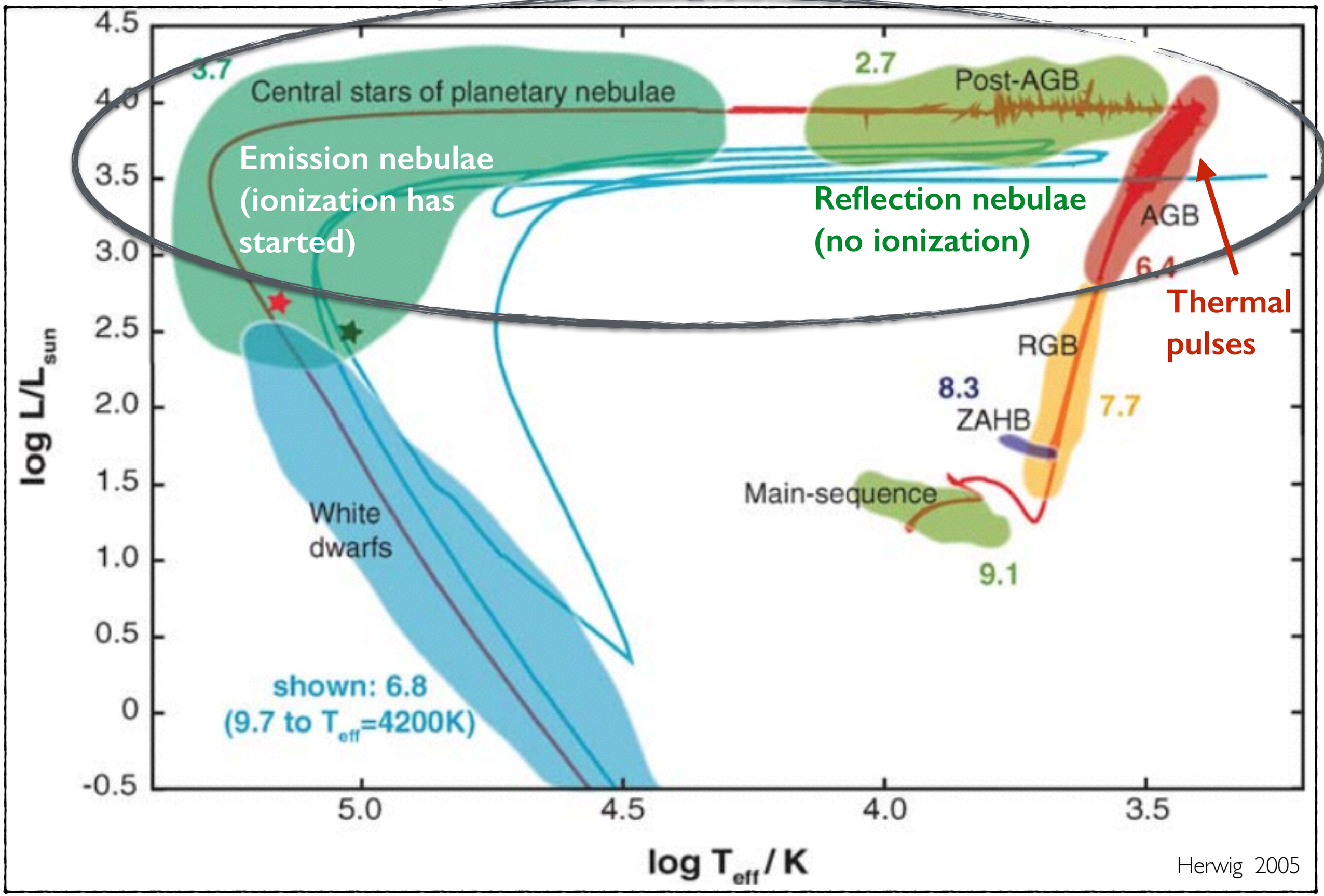
Olga Suarez

Steve Goldman

Daniel Tafoya

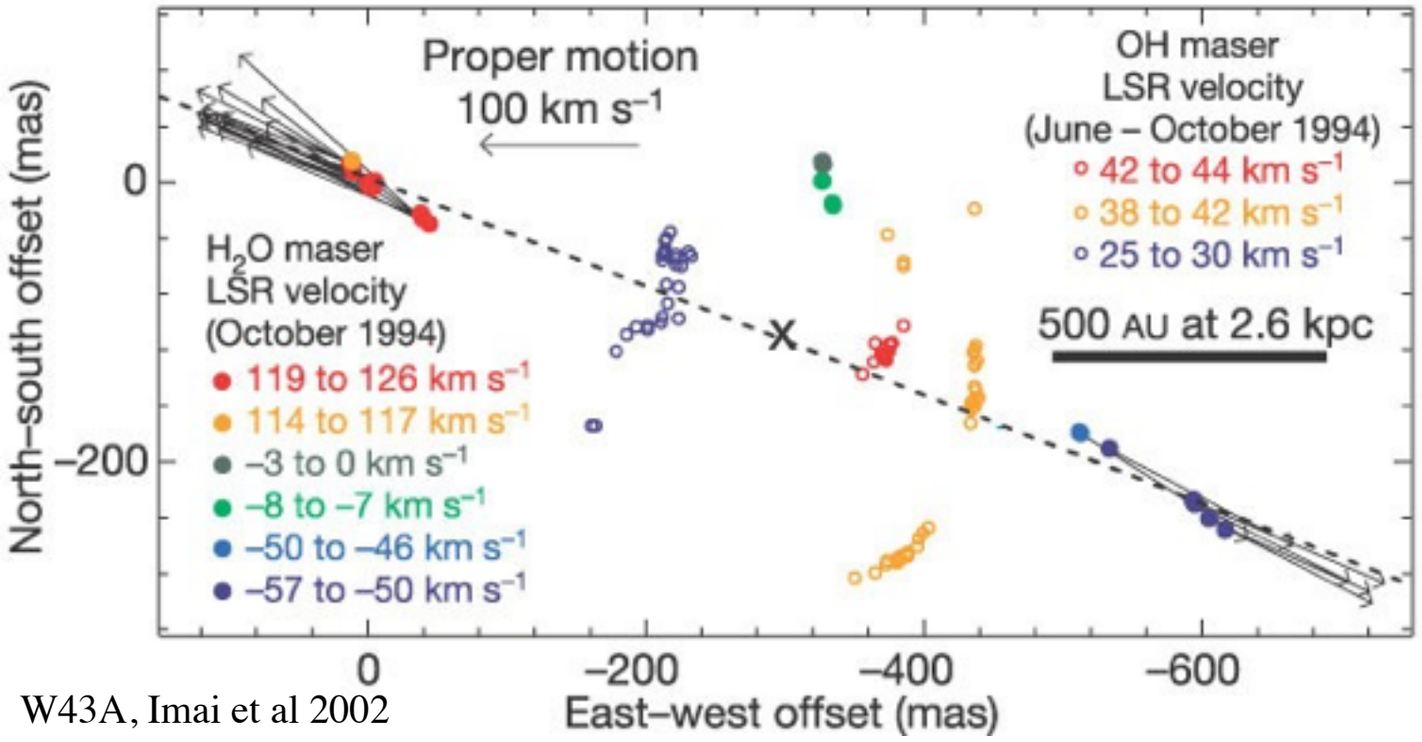
Andres Perez Sanchez

HR diagram of stellar evolution

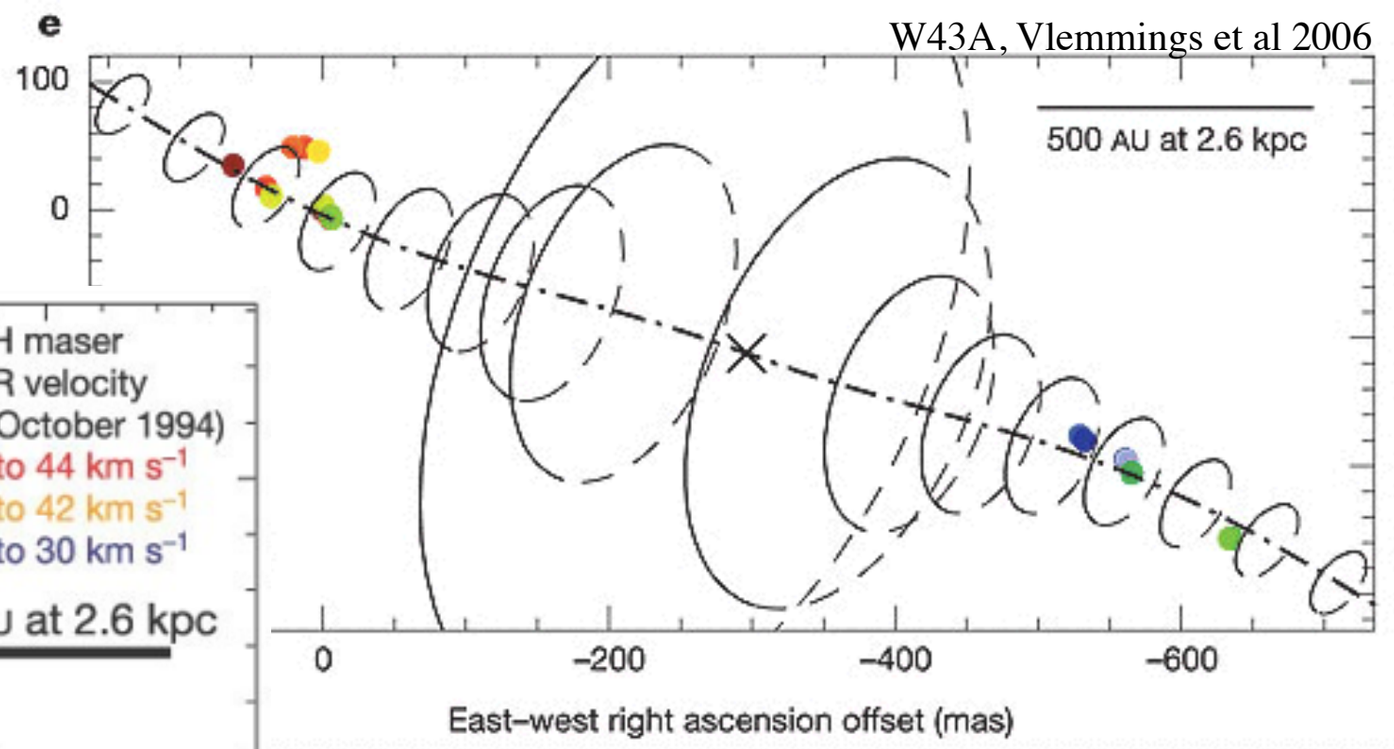


Herwig 2005

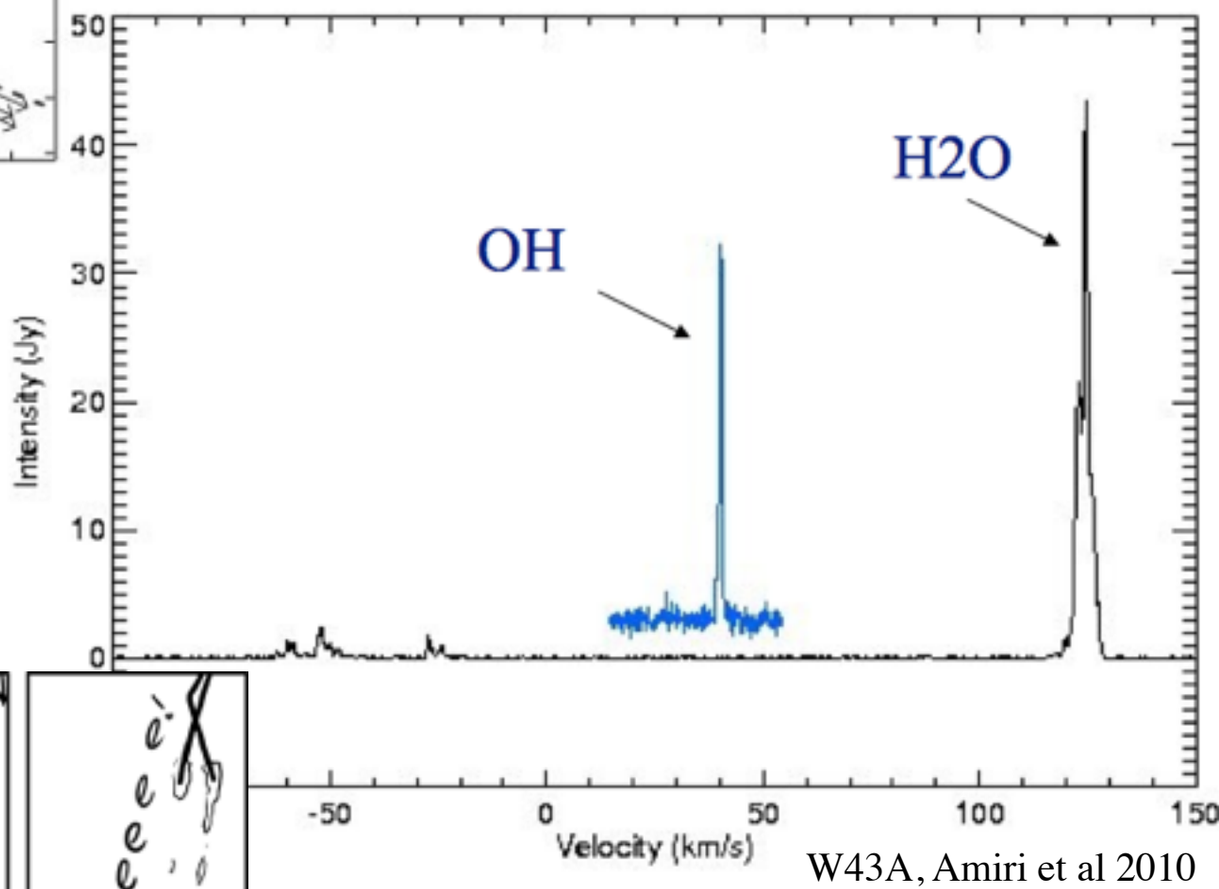
Water fountain sources



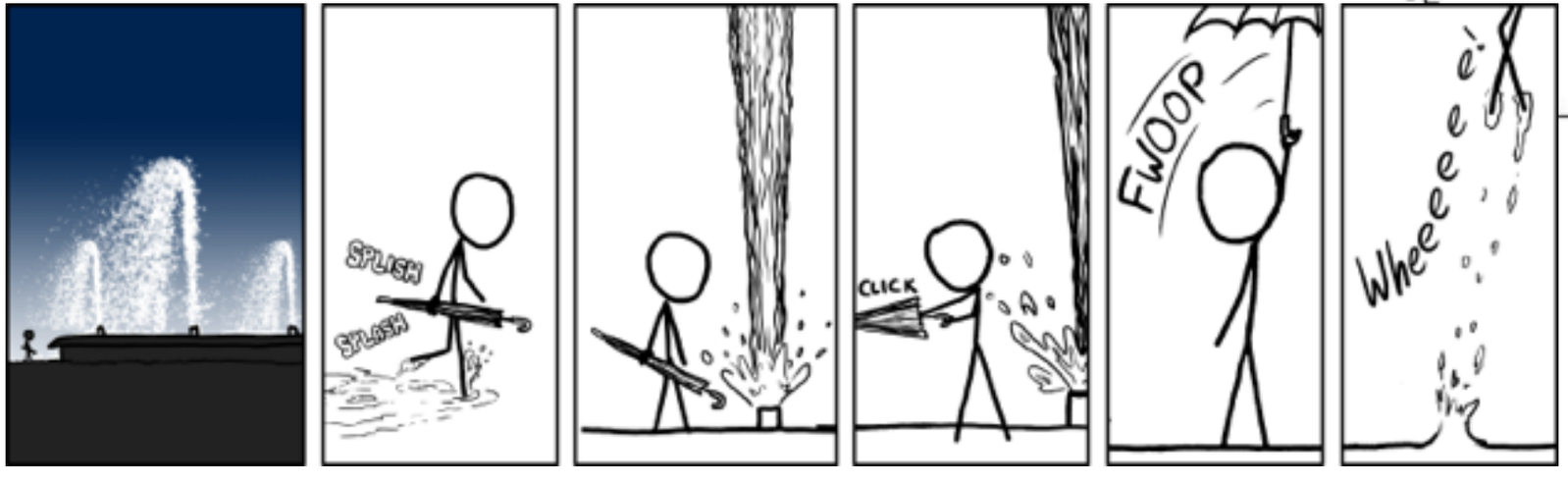
W43A, Imai et al 2002



W43A, Vlemmings et al 2006



W43A, Amiri et al 2010



XKCD: Fountain
http://xkcd.com/1038/

AGB CSE

~10 km/s

T~10-20 K
H H_2 CO etc.

H_2O masers
22GHz, T ~ 400K
321GHz?

Cavity

Jet

fast molecular outflow

V ~100 km/s M ~0.1 $M_\odot$

very high momentum and energy

episodic event?

Probably a binary system

stellar or planetary (Jupiter-class)

common envelope binaries?

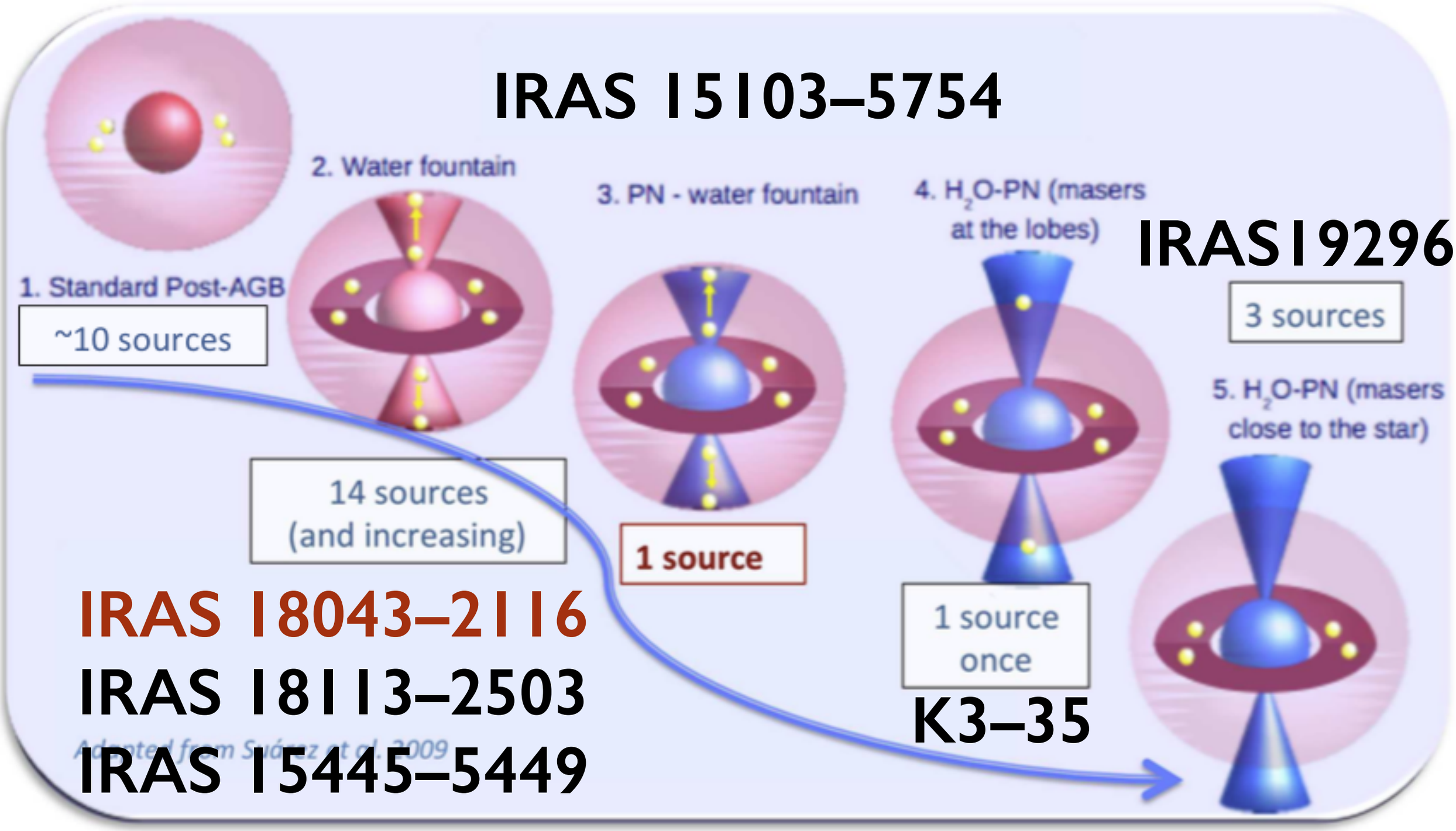
Magnetic field

Accretion disk

e.g. Bujarrabal et al 2001 (observations), Frank & Blackman 2003, De Marco 2009, Blackman & Lucchini 2014 (models)

Observatoire de la CÔTE d'AZUR

Sketch of the possible water maser evolution



from a 2014 talk by Olga Suarez

All known and confirmed water fountains

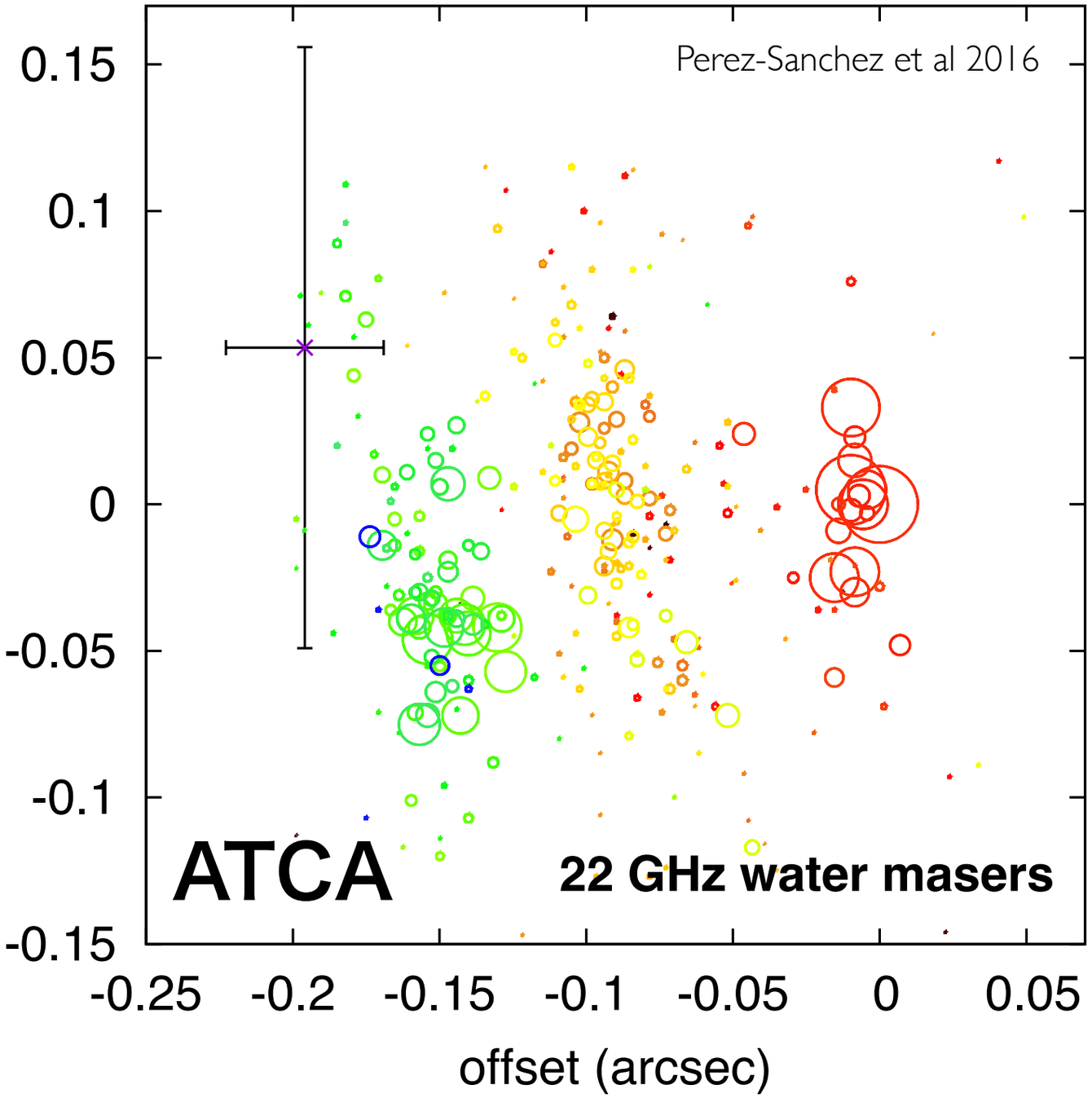
as of March, 2016

IRAS name	Alt. name	V_{range}	Morphology	References
15103−5754	GLMP 405	70	BJA	Suárez et al. 2009
15445−5449	OH 326.5−0.4	90	TJA	Pérez-Sánchez et al. 2011
16342−3814	OH 344.1+5.8	260	TJ	Claussen et al. 2009
16552−3050	GLMP 498	170	TJ	Suárez et al. 2008
18043−2116	OH 9.1−0.4	400	BE	Walsh et al. 2009
18113−2503	PM 1−221	500	TJ	Gómez et al. 2011
18139−1816	OH 12.8−0.9	50	TJ	Boboltz & Marvel 2005
18286−0959	OH 21.80−0.13	200	BJ	Yung et al. 2011
18450−0148	W43A	180	TE	Imai et al. 2002
18455+0448		40	BJ	Vlemmings et al. 2014
18460−0151	OH 31.0−0.2	310	TEA	Imai et al. 2013
19134+2131		100	TJ	Imai et al. 2007b
19190+1102	PM 1−298	100	TE	Day et al. 2010

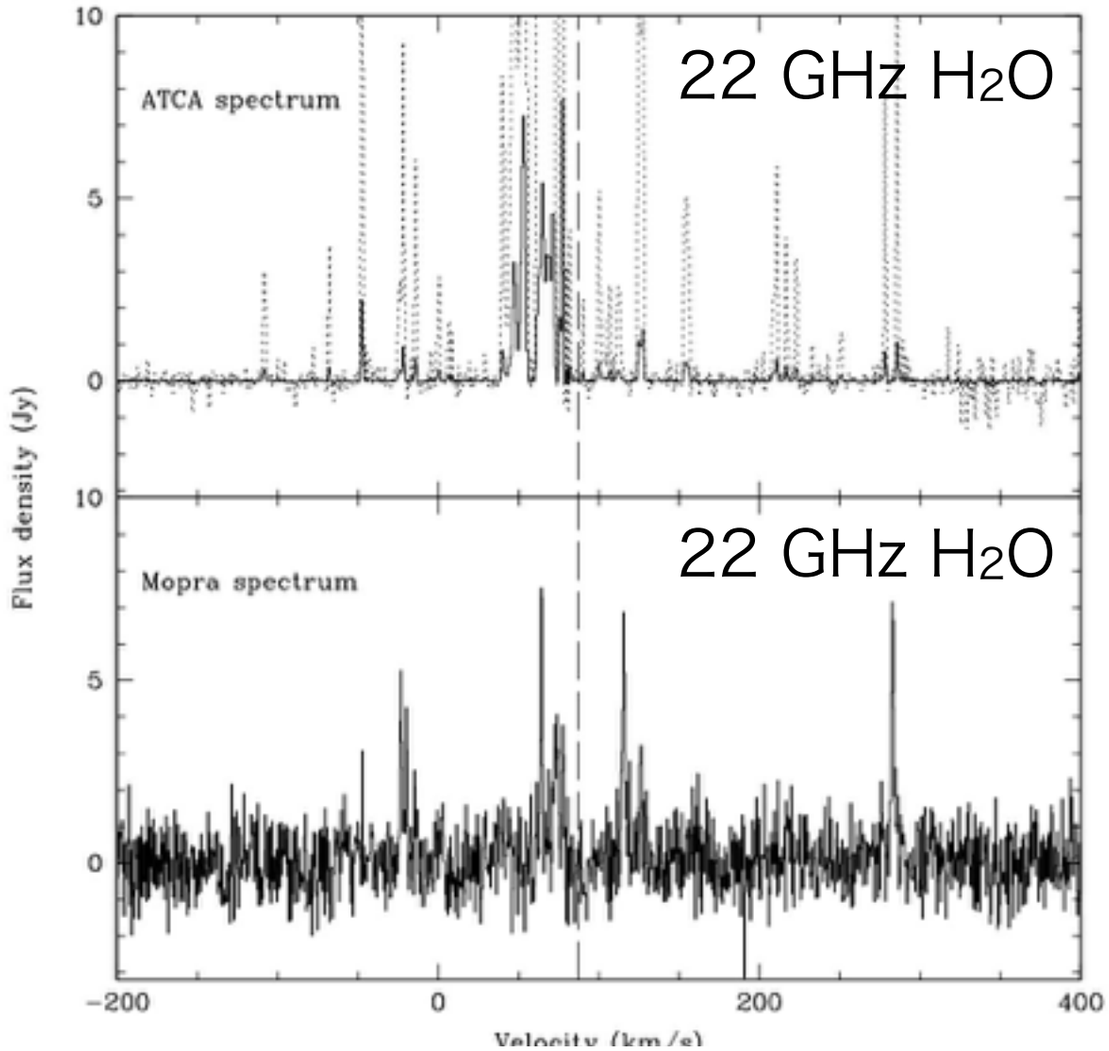
Tidbinbilla 70m single-dish monitoring project (T215)

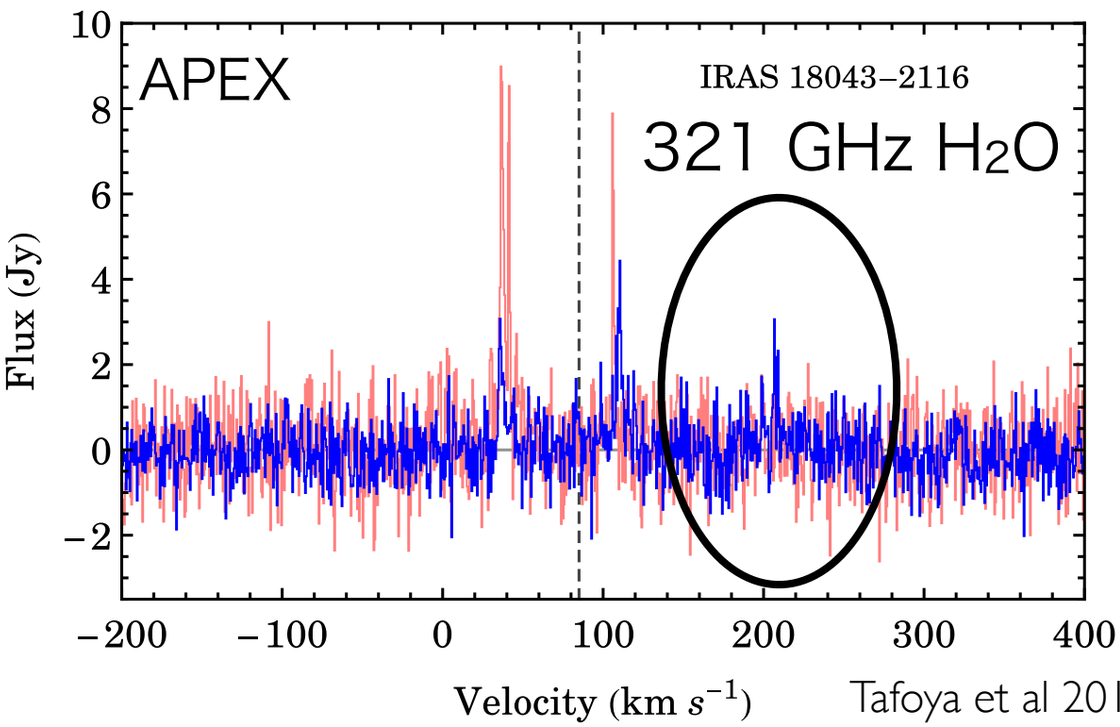
Today's detective story: the mystery of IRAS 18043…

IRAS 18043–2116
a HOT water fountain?



unresolved continuum emission at 22 GHz
(shock-induced synchrotron dampened by free-free)



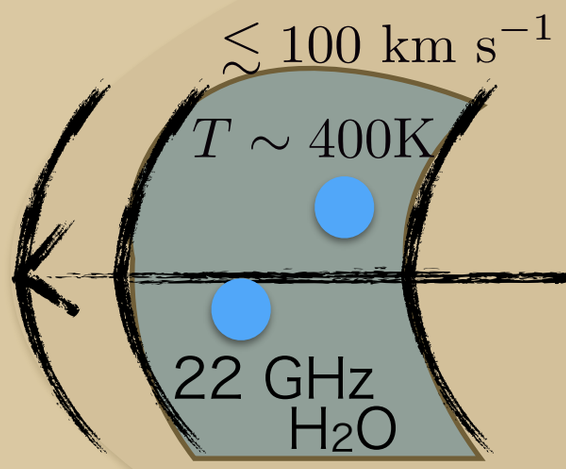


Tafoya et al 2014

AGB CSE

Tafoya et al 2014

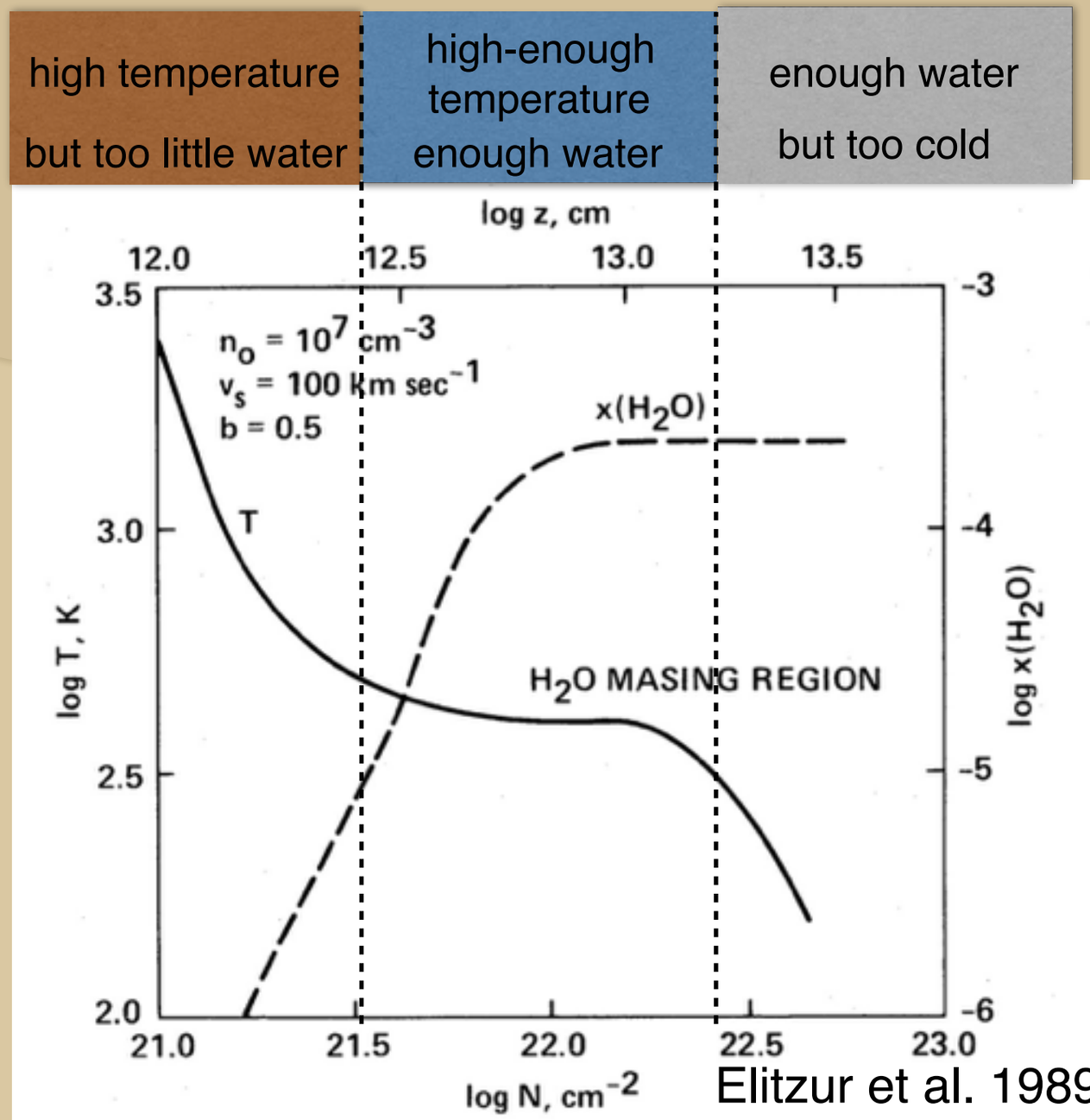
Cavity



Jet ? ~ 100 km s^{-1}

~10 km/s

from Daniel Tafoya

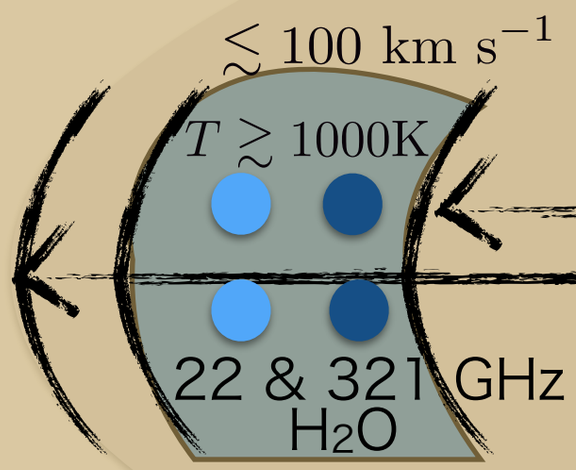


Elitzur et al. 1989

AGB CSE

Tafoya et al 2014

Cavity

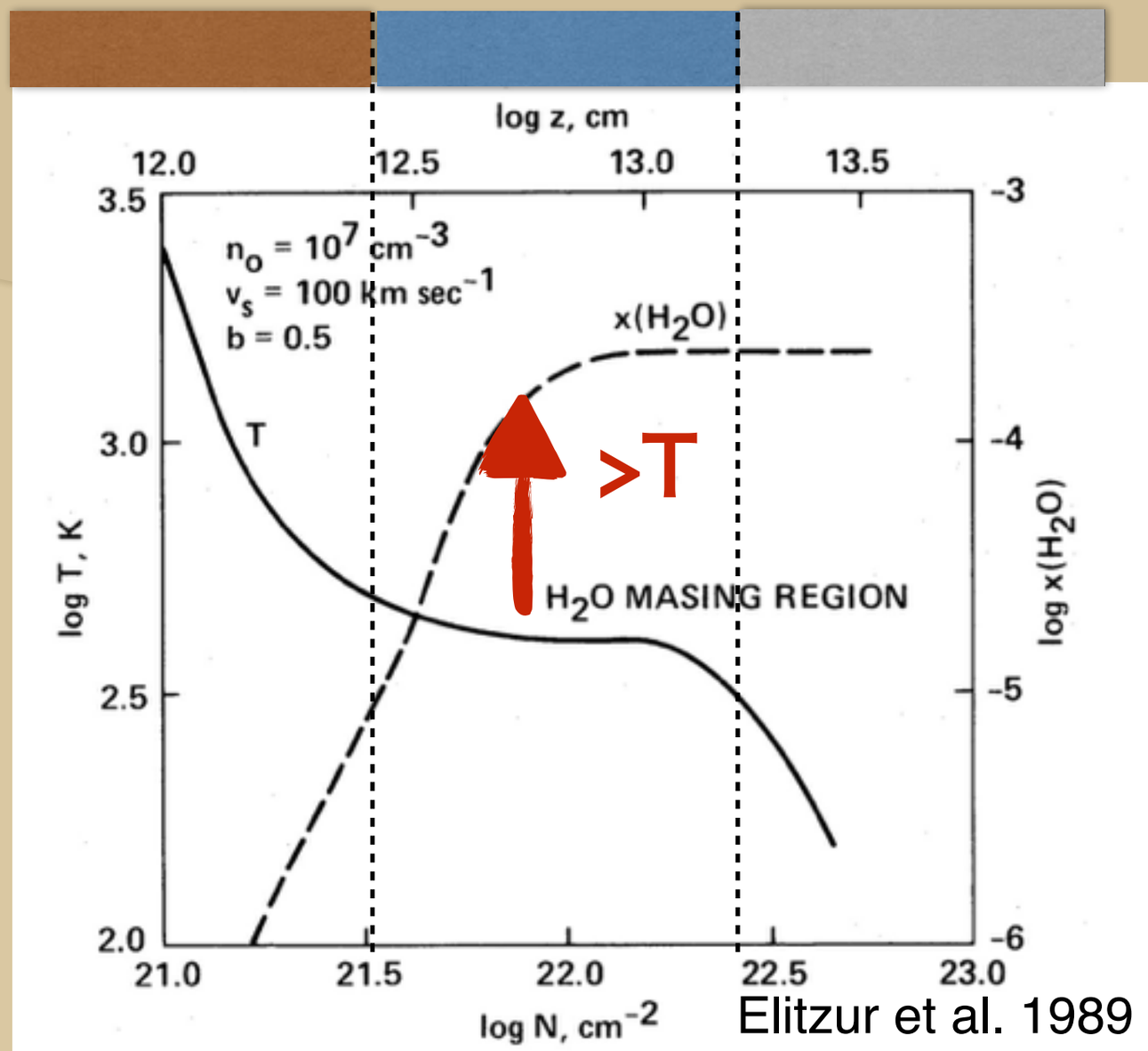


Jet 2 ~ 100 km s^{-1}

Jet 1 ~ 100 km s^{-1}

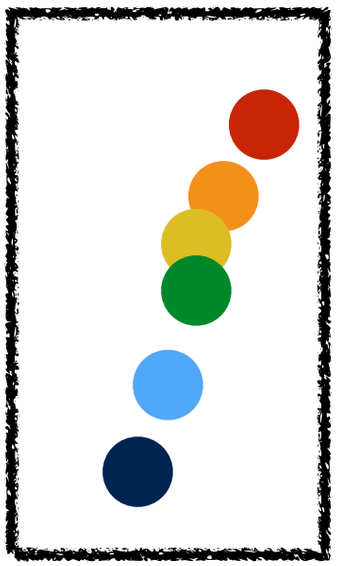
~10 km/s

from Daniel Tafoya



Elitzur et al. 1989

mas-scale



maser feature

VLBA

22 GHz water masers

Dec. offset (mas)

R.A. offset (mas)

1 mas/yr

z=0

R

z

v_{LSR} (km/s)

ATCA

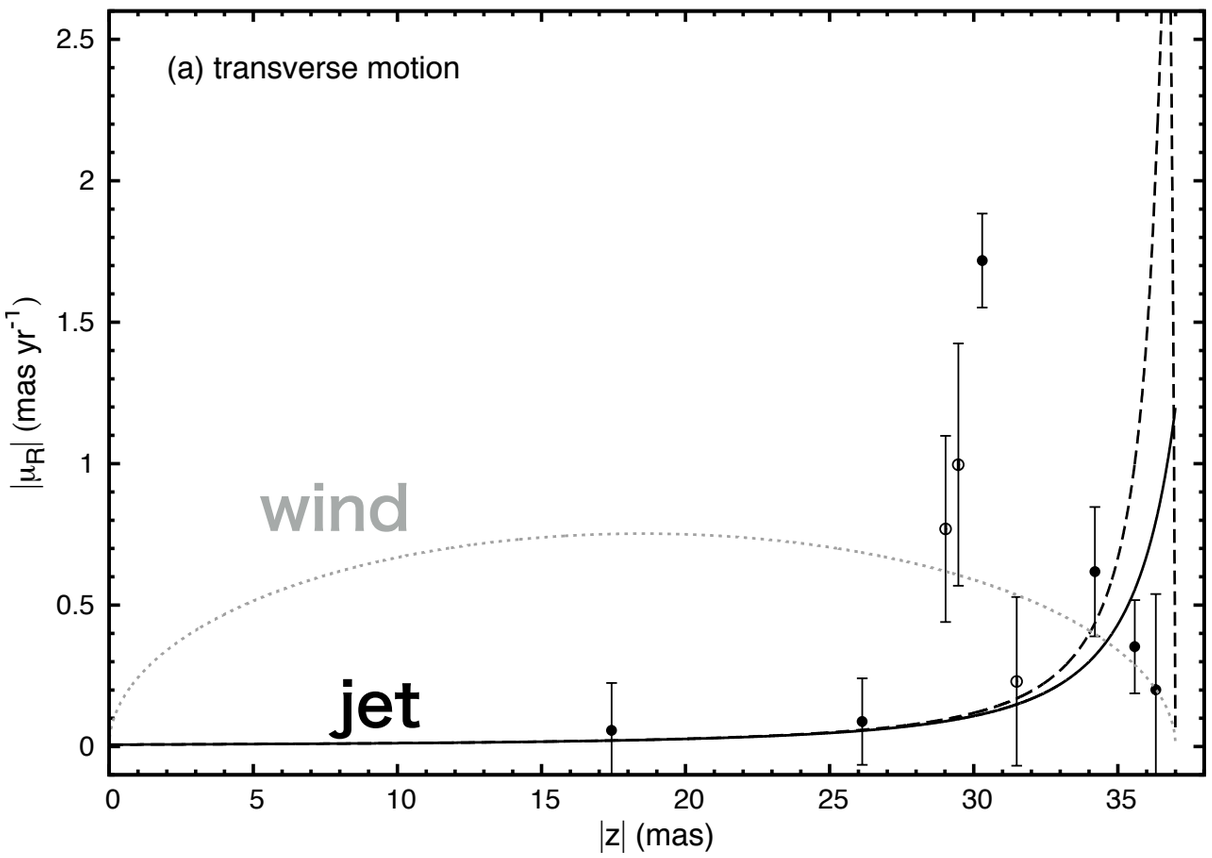
μ_{exp} ~ 1 mas/yr

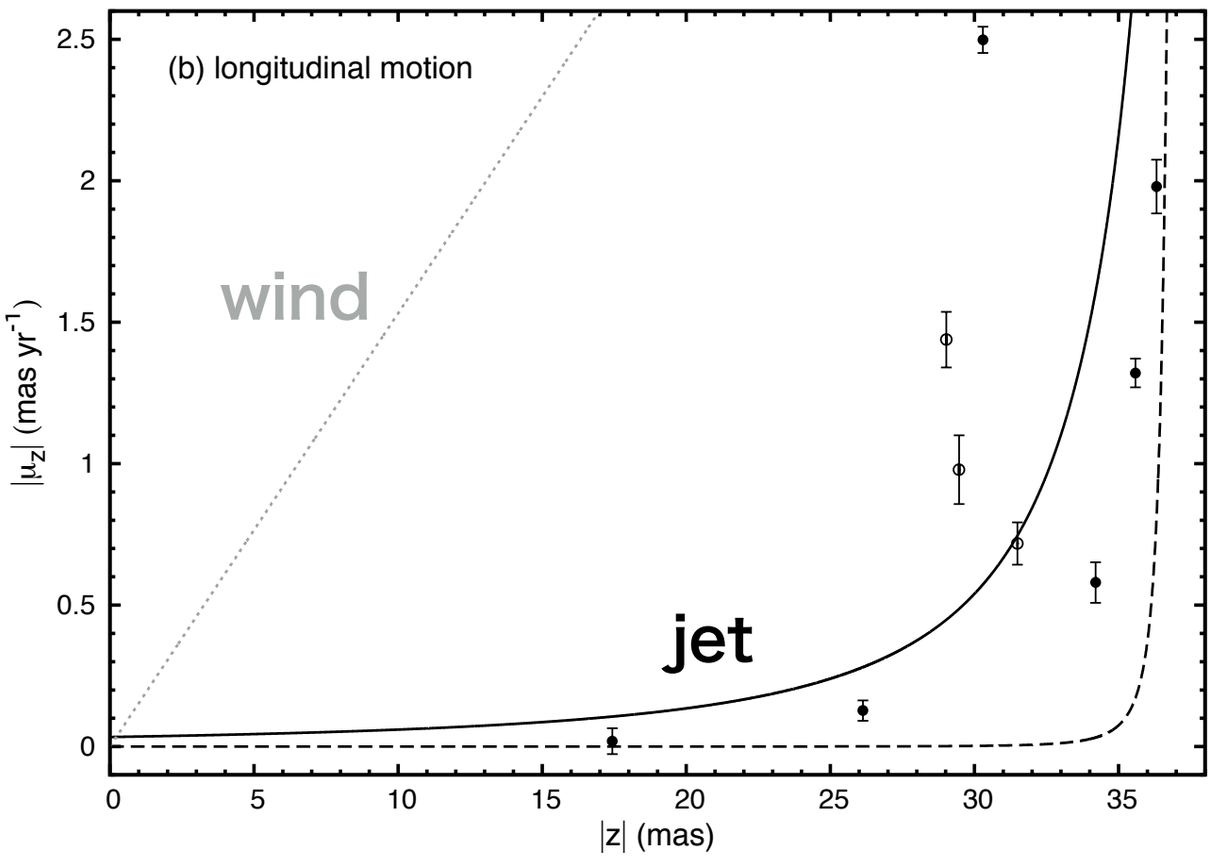
T_{kin} ~ 30 years

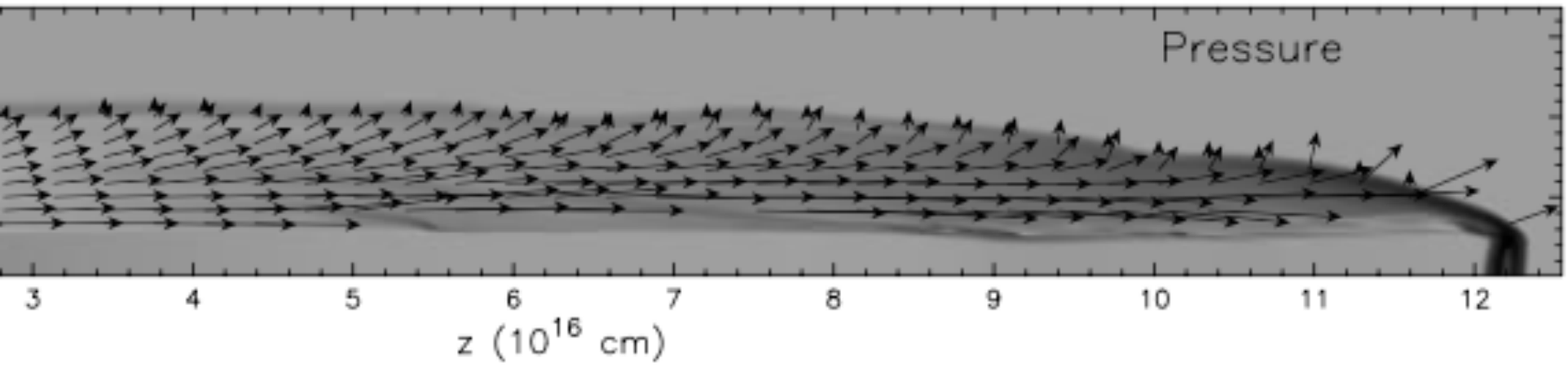
(at 10 kpc) $V_{exp,3D}$ ~ 200 km/s

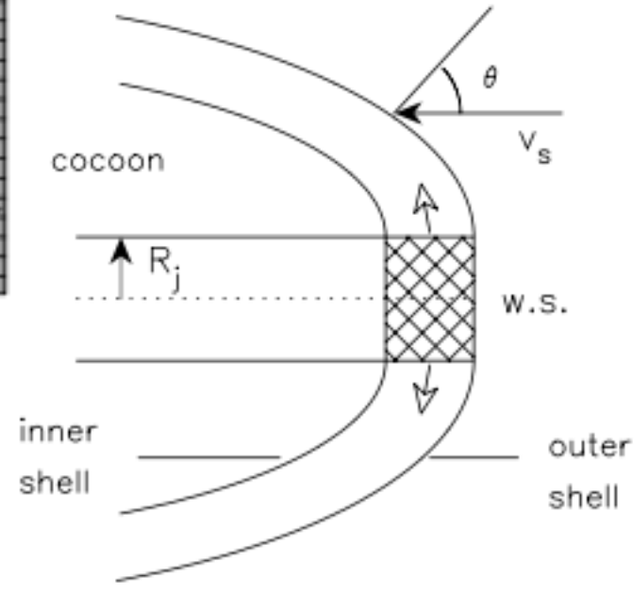
i ~ 75 deg

Ballistic bow shock model

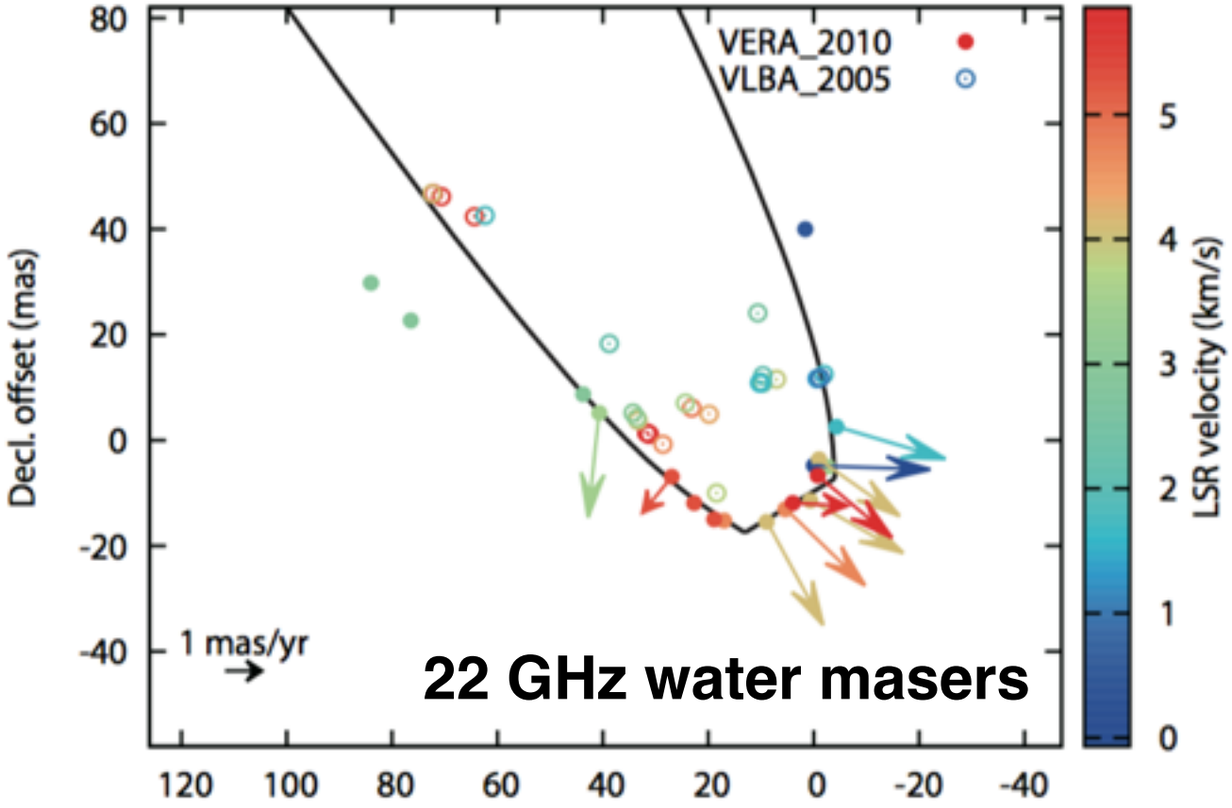




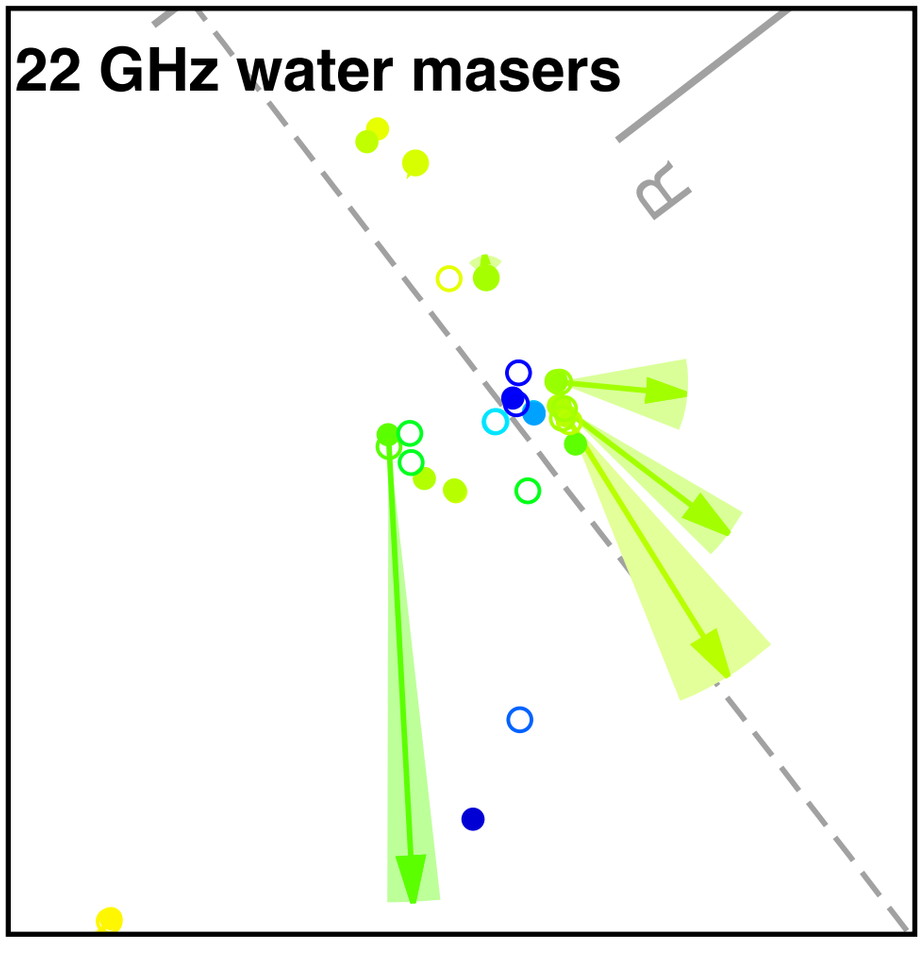


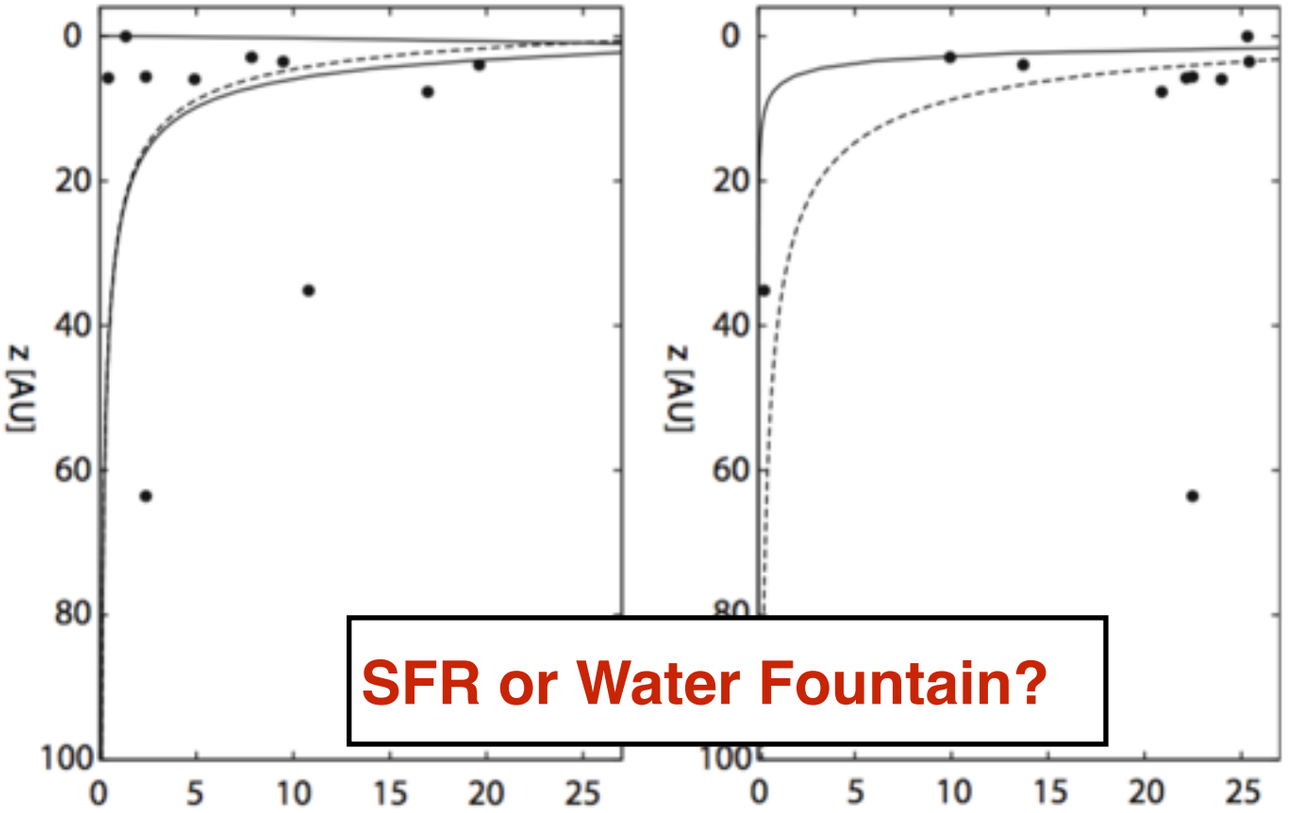


Jet-driven protostellar outflow shells:
Ostriker et al 2001 (model), Lee et al 2001 (simulation)



Burns et al. 2016

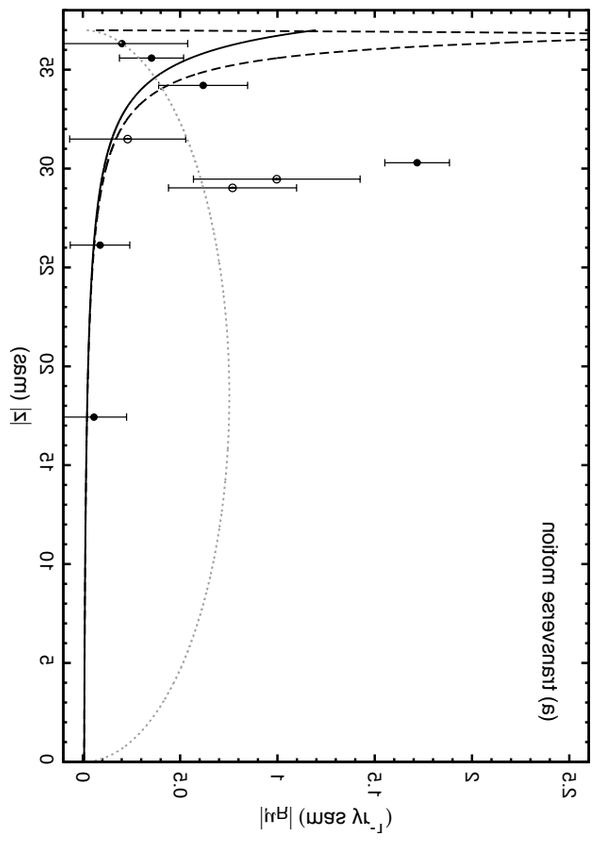


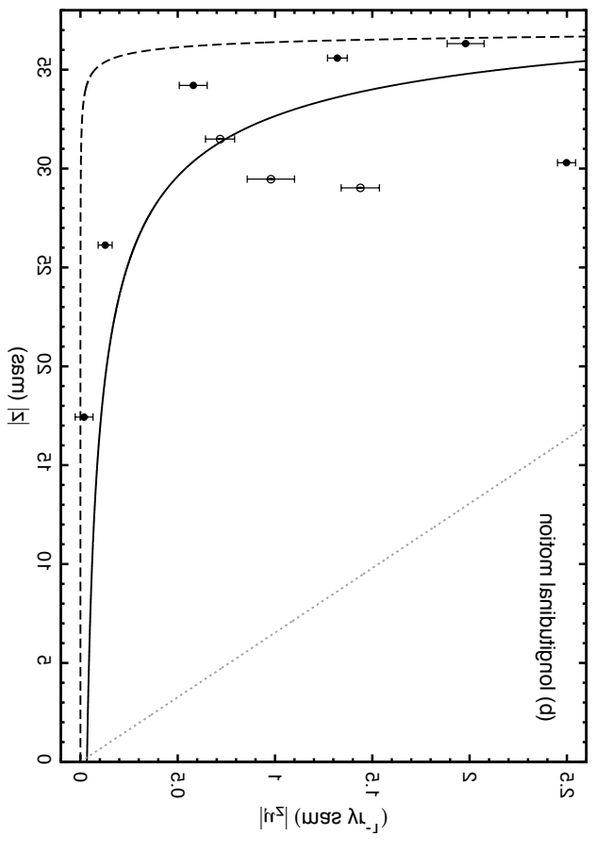


SFR or Water Fountain?

T_{kin} ~ 130 years

$V_{exp,3D}$ ~ 20 km/s





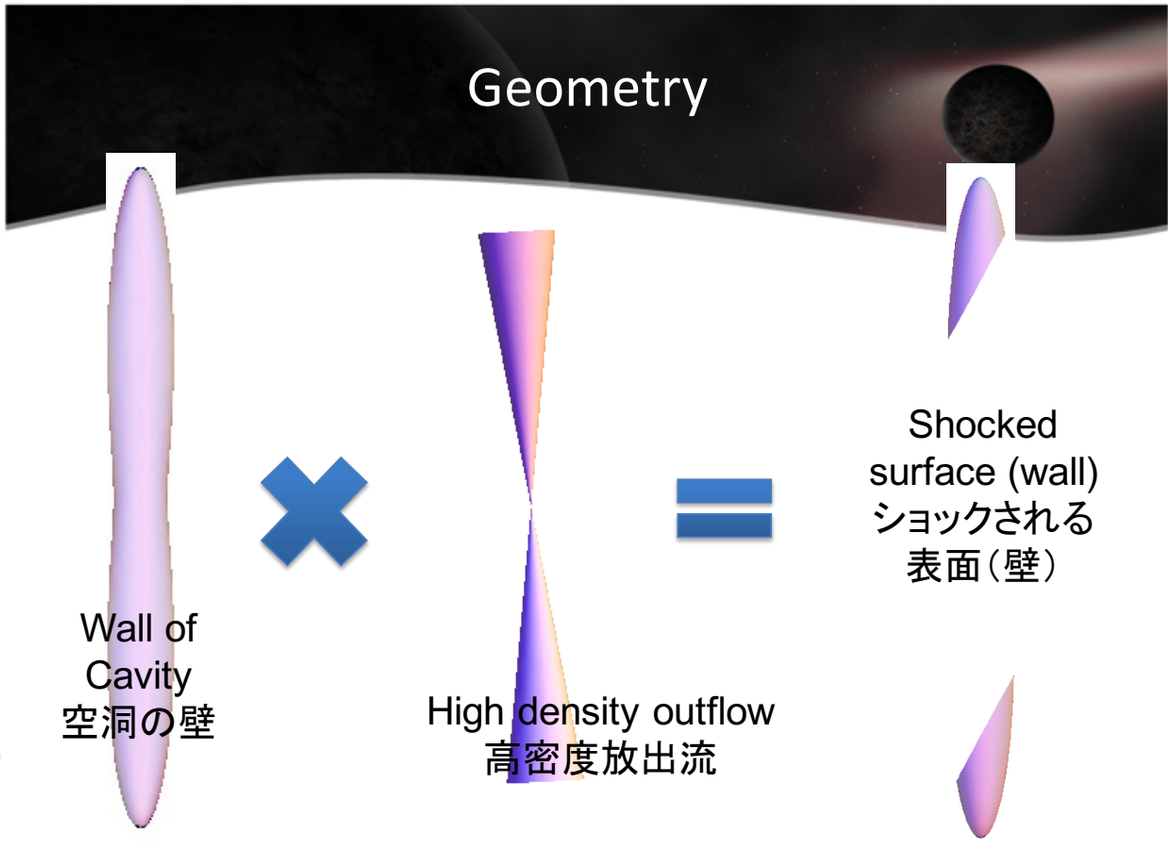
T_{kin} ~ 30 years

$V_{exp,3D}$ ~ 200 km/s

Water fountains outflows

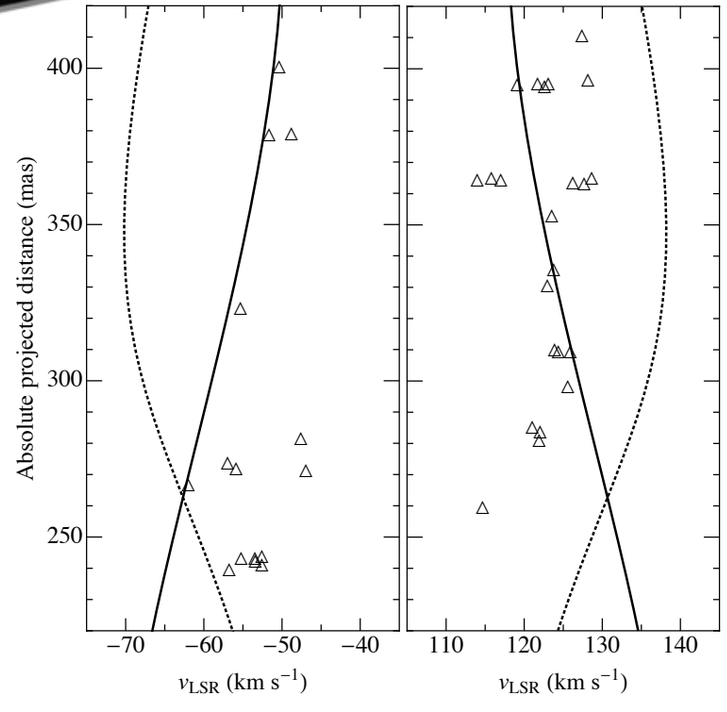
Two possible scenarios

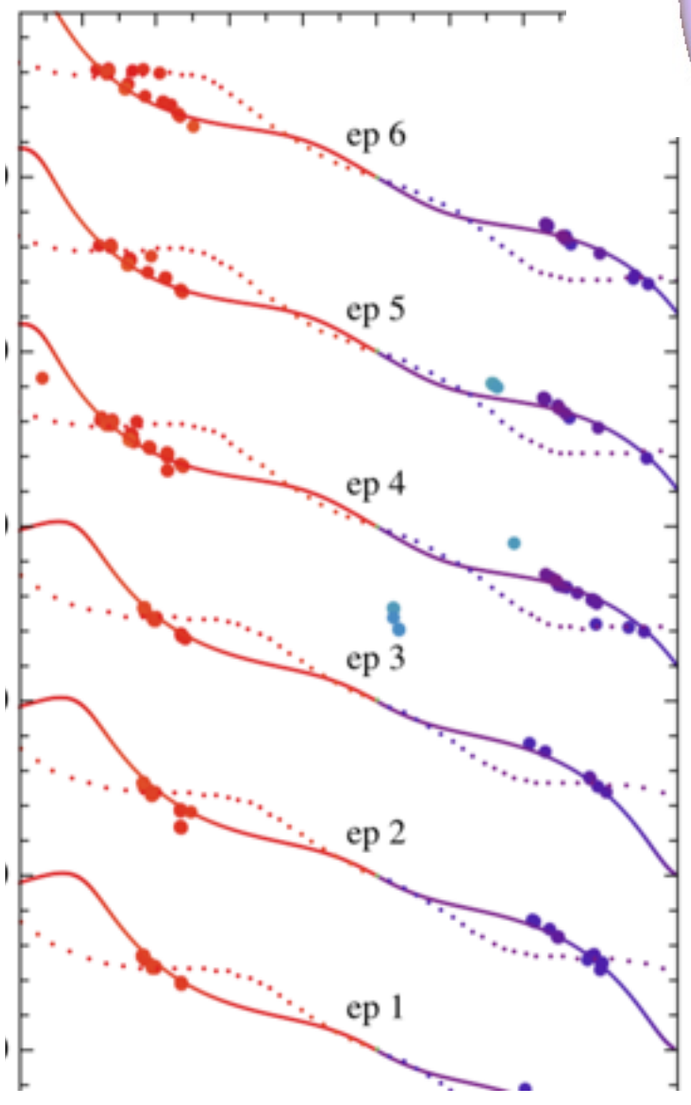
Cavity model
vs
precessing jet model

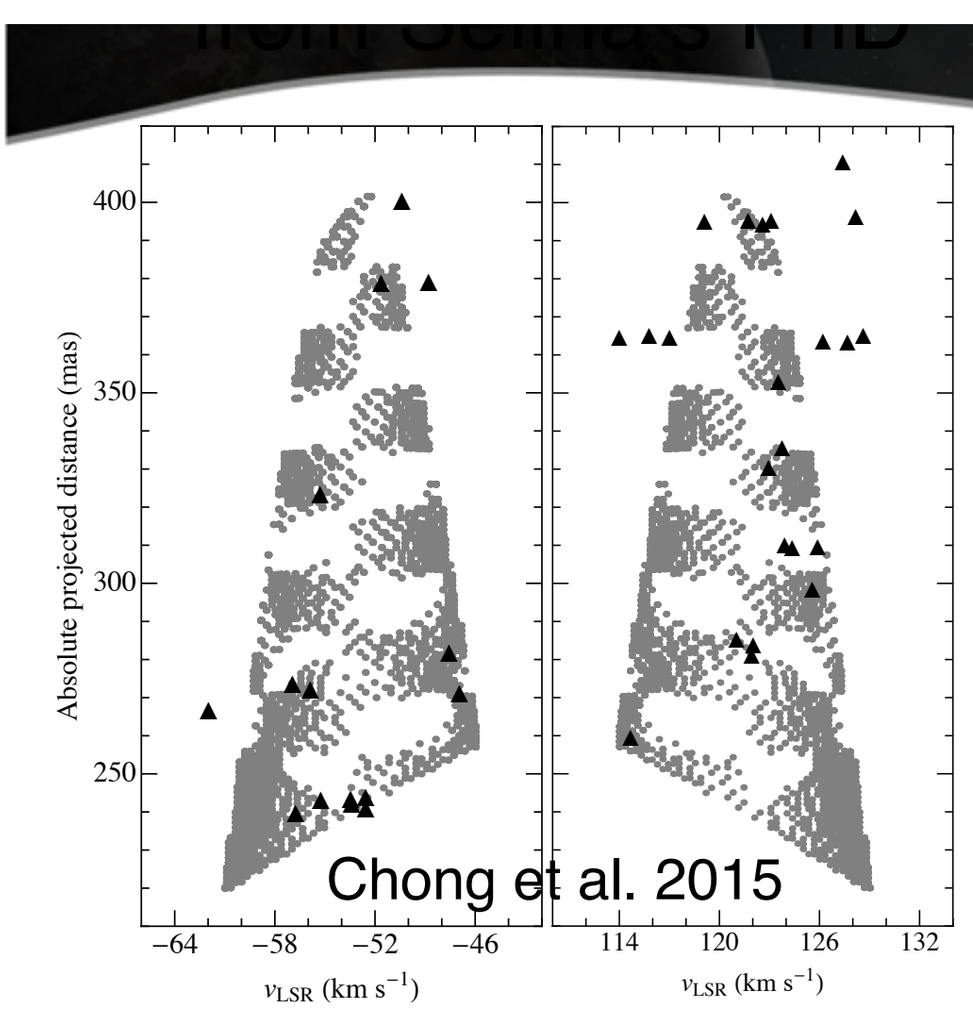


Precessing Jet Model
歳差ジェットモデル

?







Episodic event?

blue-shifted U shape

October, 2008

January, 2009

March, 2009

May, 2009

July, 2009

September, 2009

Flux density (Jy)

LSR velocity (km s^{-1})

So is IRAS 18113 a hot water fountain?

collimated outflow?	**definitely**
shocked surface?	**definitely**
episodic outflows?	**maybe**

ALMA will help: mapping the 321 GHz H_2O masers (Grade "C" proposal, PI: A. Perez-Sanchez)

Now some marketing and community notice…