Stellar Masers: An Observational Perspective

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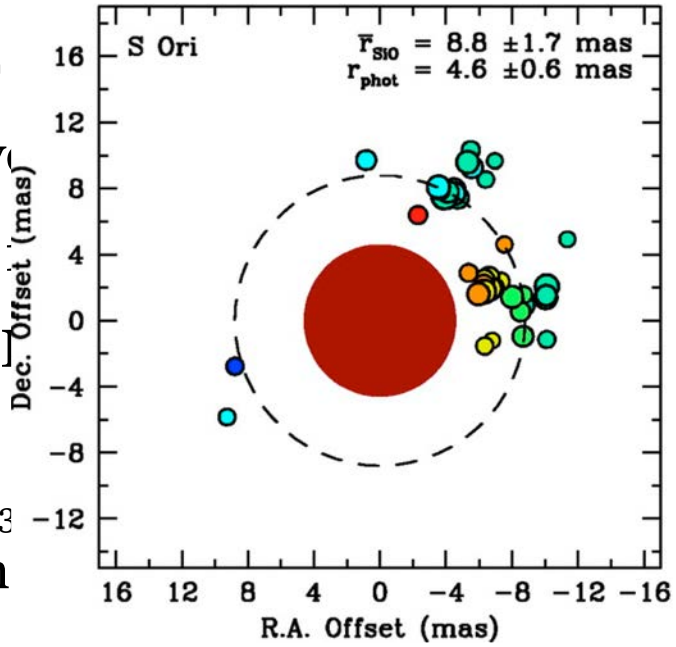
(retired from
Nobeyama, NAOJ)

Haystack workshop
Oct. 4, 2012

Stellar Masers: evolved stars (mainly AGB stars and Red Super Giants)

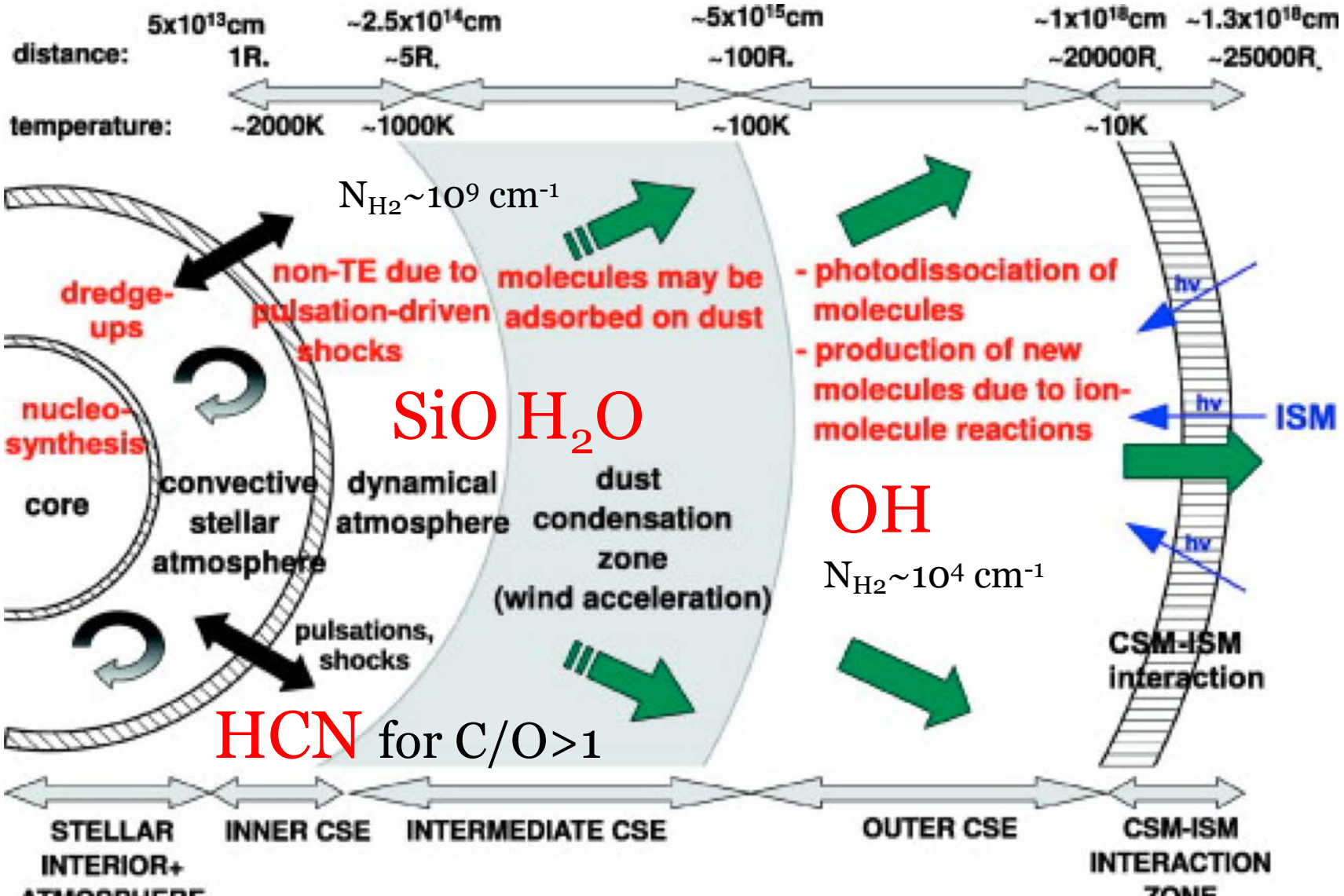
- O-rich: OH 1612, 1665, 1667 MHz, + other excited lines
- H_2O 22.235 GHz + many other lines
- SiO 43.122, 42.821, 86.234 GHz
- C-Rich: HCN 86.1, 181.... All v
- SiS 18.1 GHz +other in IRC+
- CS Highberger et al. 2008 in I
- Never detected in stars : CH_3OH/H2CO/NH_3 (Hakobian

Boboltz 2005



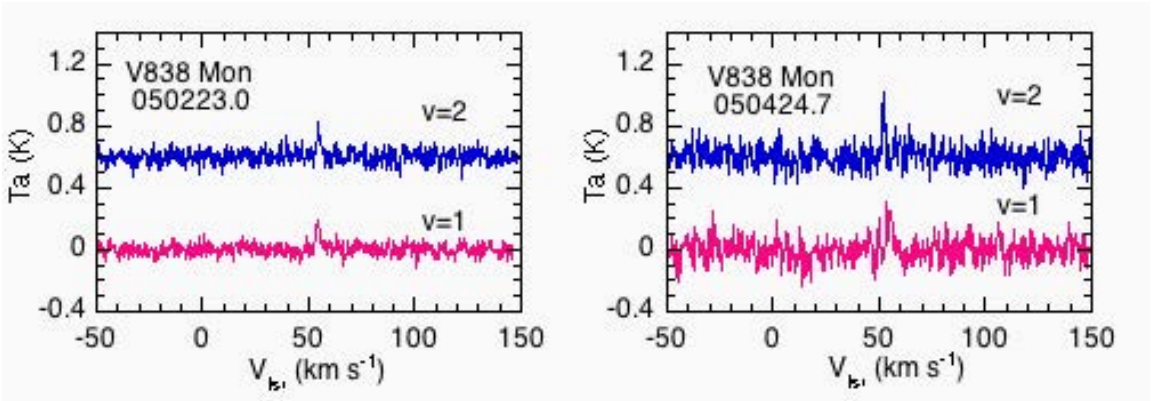
Physical conditions

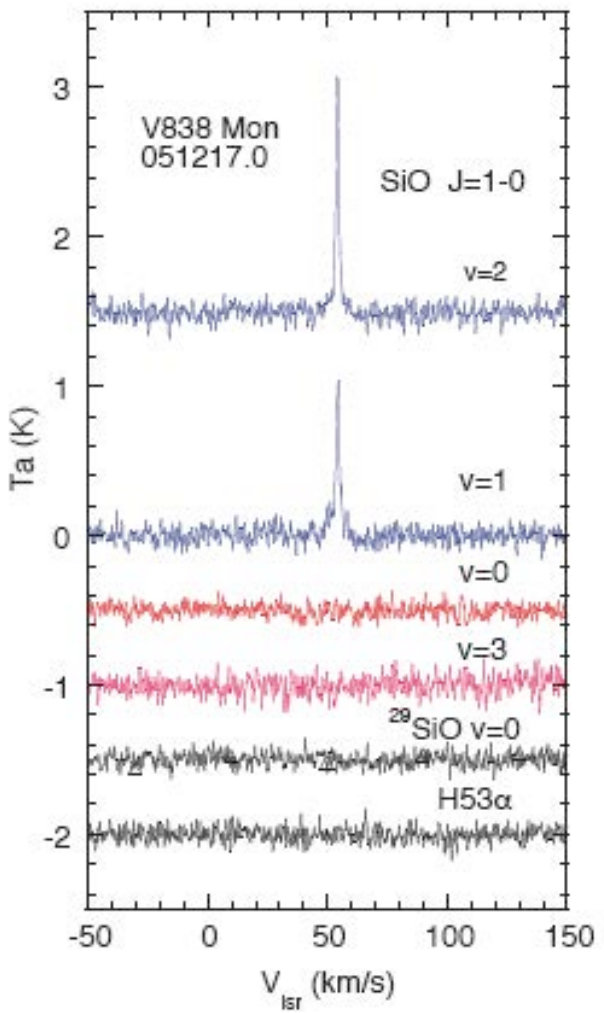
Decin2012



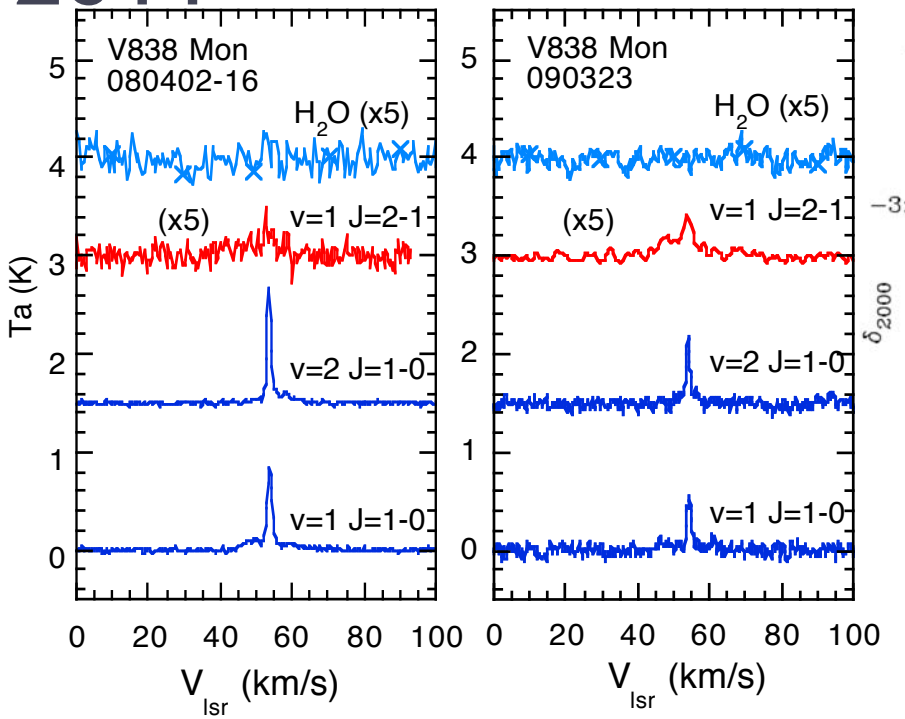
Extreme cases

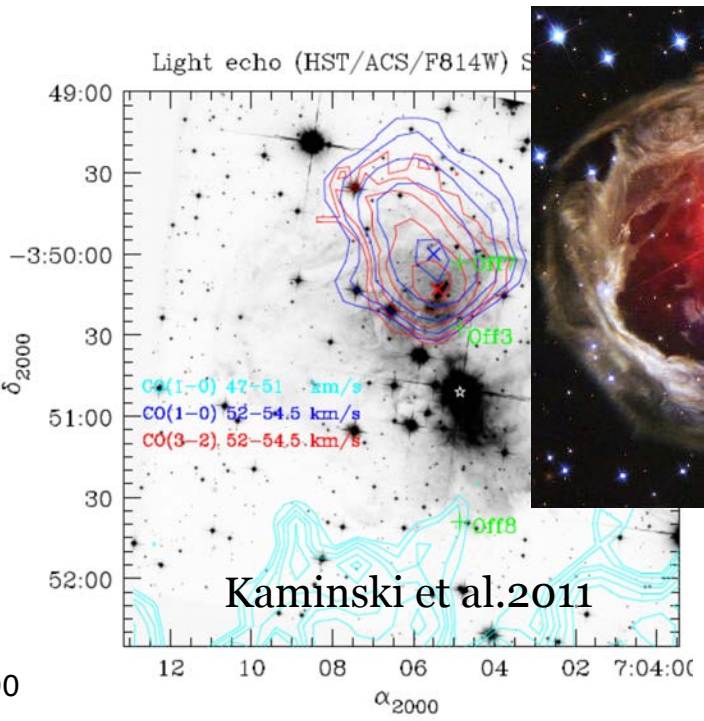
- Merged star (red nova): V838 Mon (SiO)
- Classical Nova with Gamma ray :
- Post-AGB: Water fountains (W43A
  and Planetary Neb: K 3-35 (Miranda et al. 20



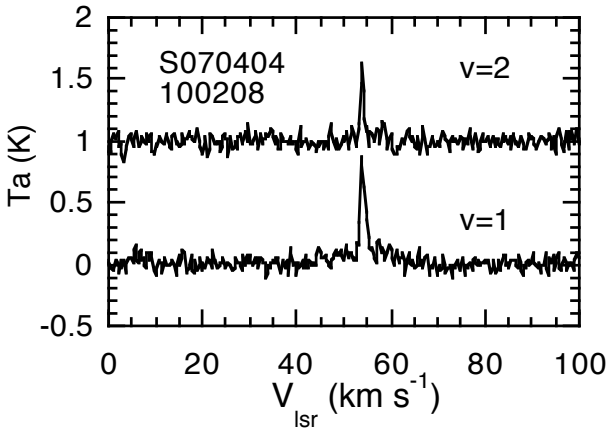


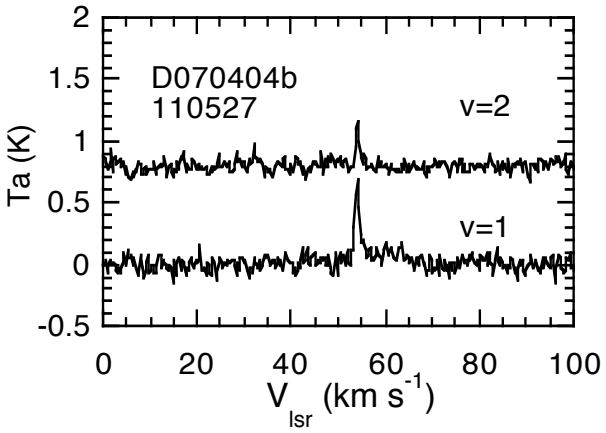
V838 Mon monitoring 2008-2011





Kaminski et al.2011



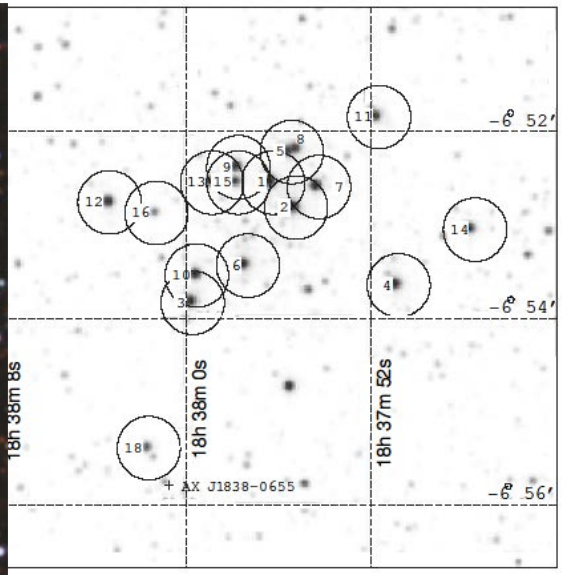


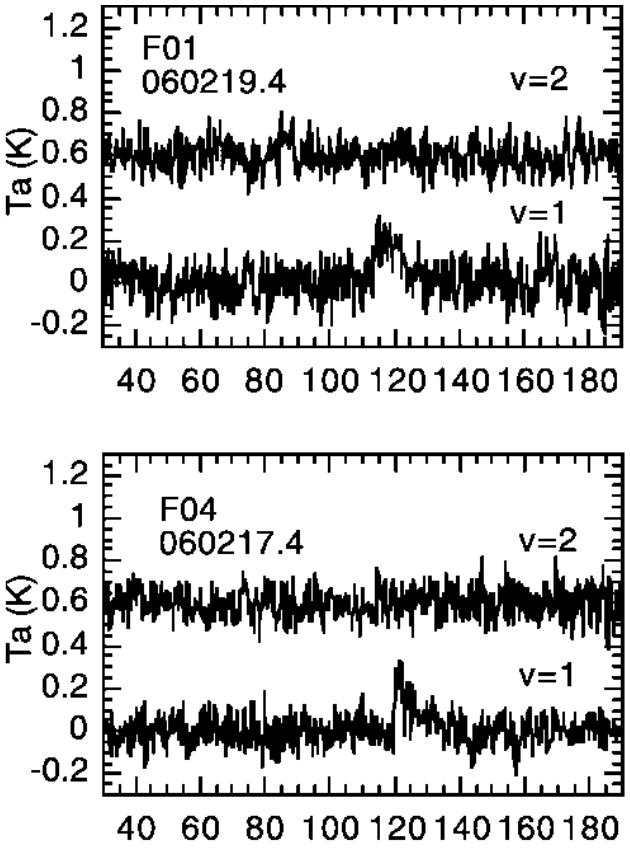
Two MS stars merged
H2O never detected

How long it continues?

Cluster Environment

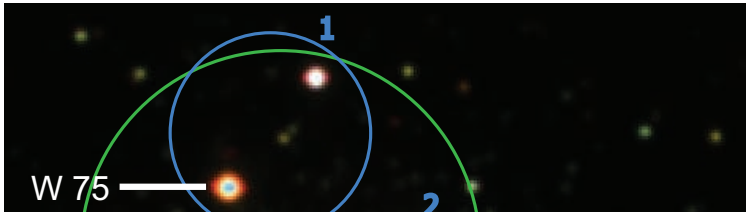
- Massive young star clusters : RSGC 1 (14),
  RSGC2 (20) ; age ~10—15 Myr
  D. Figer+ 2006, Nakashima+2006,
  Verheren 2012
- SiO obs. give rad. velocity + vel. dispersion

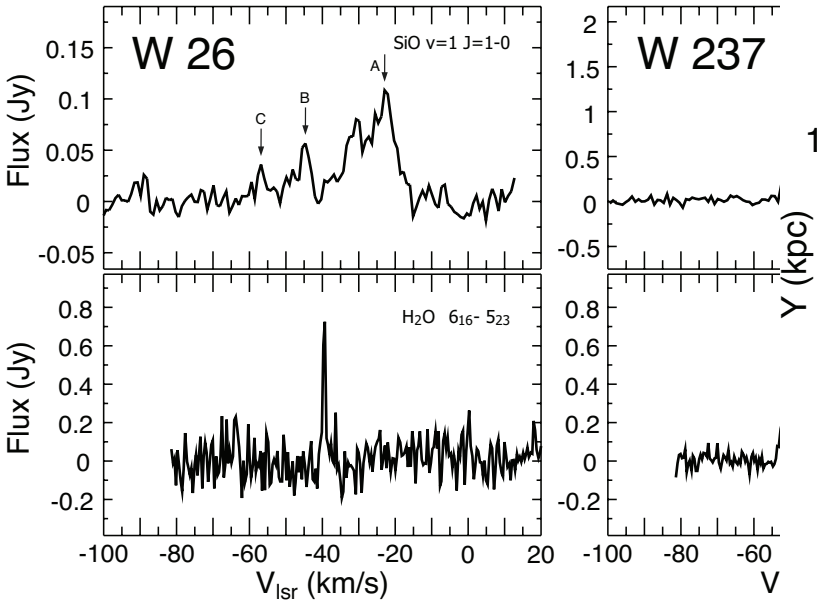


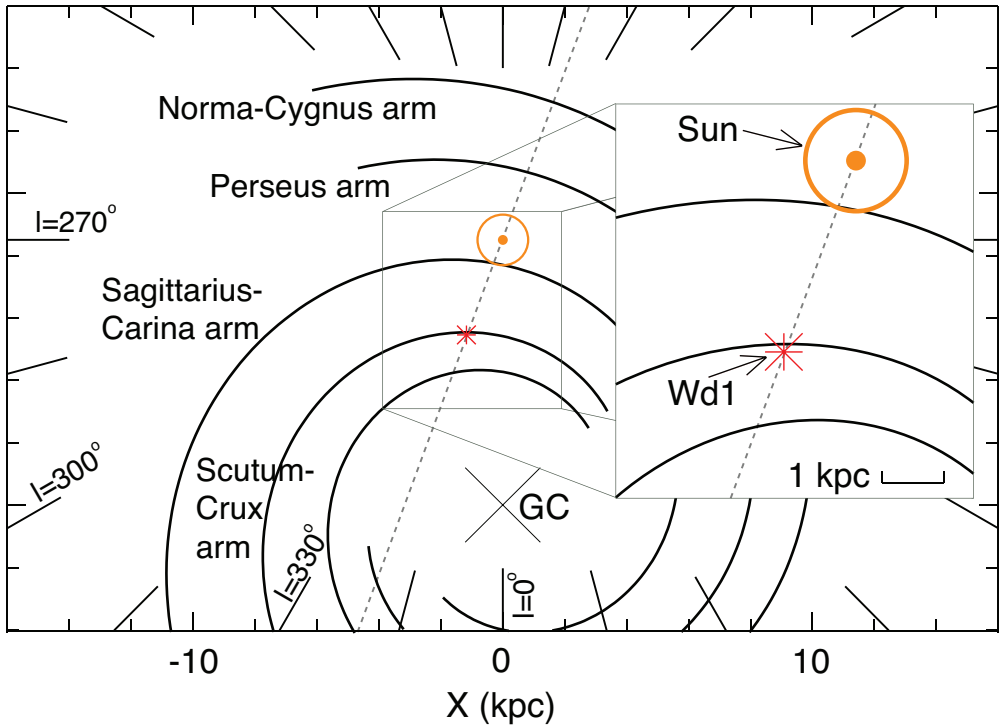


Red Supergiants in Westerlund 1

- Fok et al. 2012, ApJ (in press)
- Super star cluster







No CO associated with

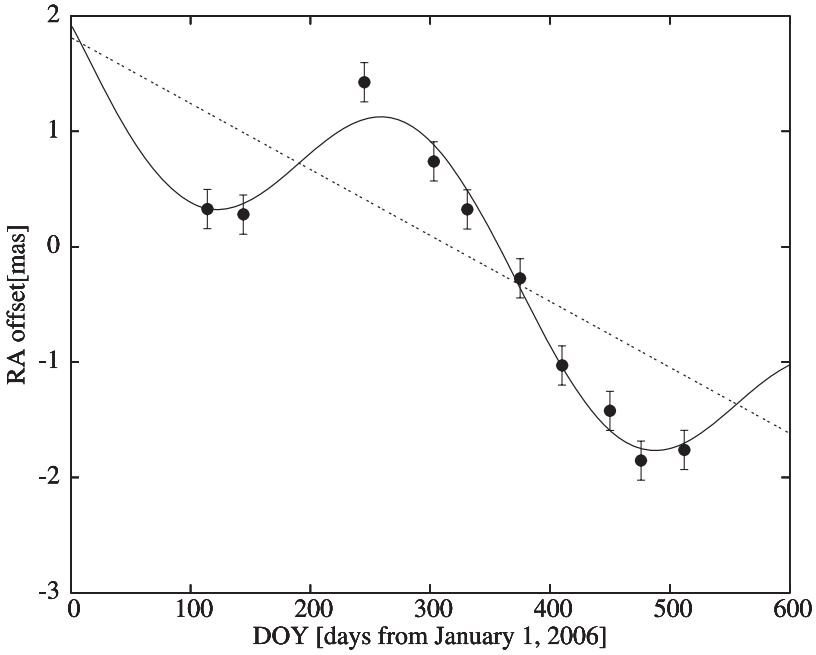
Difference from typical red supergiants

- VY CMa H2O masers at 22 GHz (Choi et al. 2008)
- Proper motion measurement with VERA

Ori KL, W51N, SgrB2IRs5,
LMC SiO source = merged star?

Parameter	Value
Parallax	0.88 ± 0.08 mas
Distance	$1.14^{+0.11}_{-0.09}$ kpc
Luminosity	$(3 \pm 0.5) \times 10^5 \, L_\odot$
Mass	$25 \, M_\odot$
Temperature	3650 ± 25 K

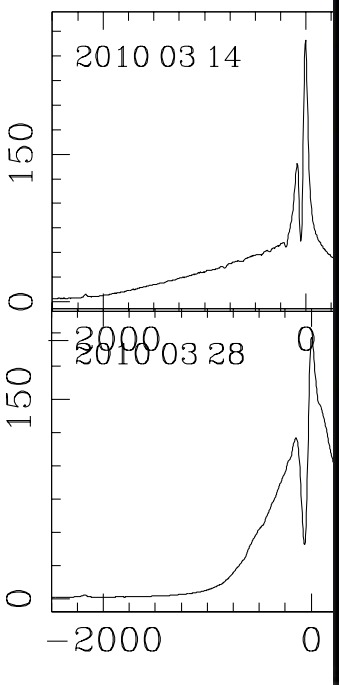
p(RA)= -2.09±-.16 mas/yr
p(dec)= 1.02±0.61 mas/yr

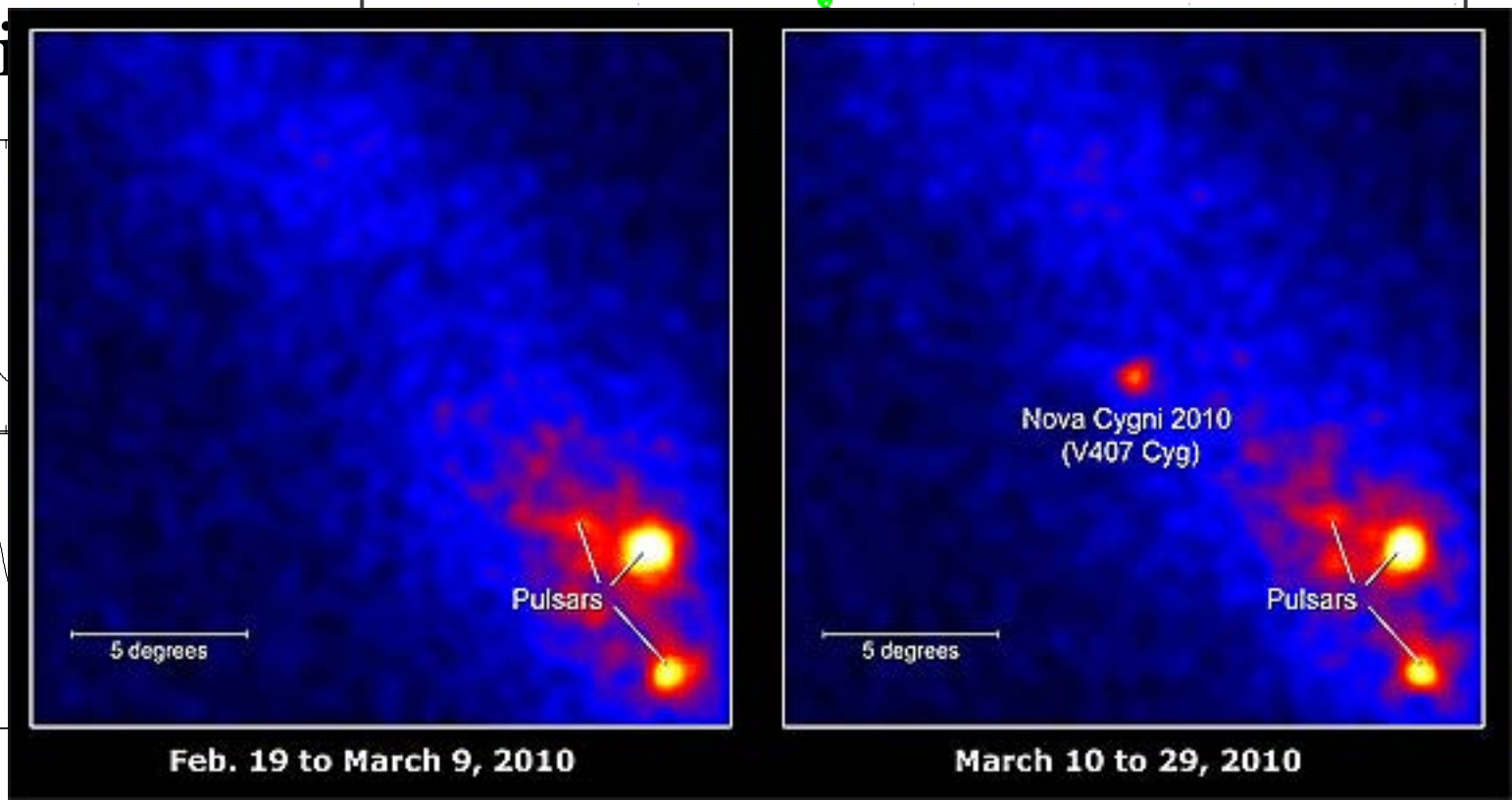


Choi et al. 2008

V407 Cyg Nova outburst 2010/03/11 with concurrent c-ray emission

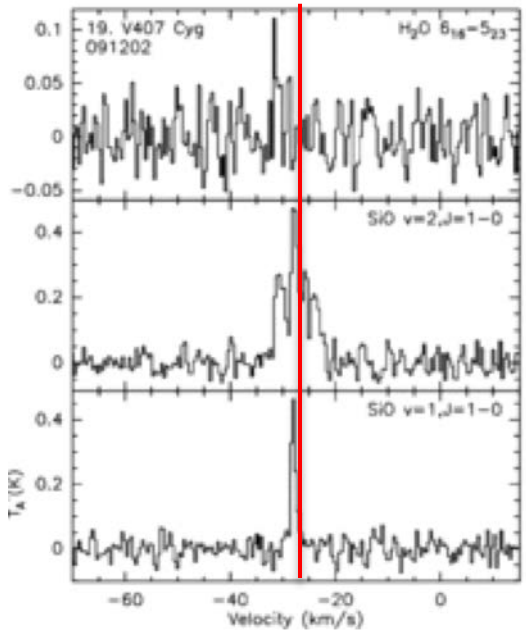
- Shock V~3000km/s
- Munari



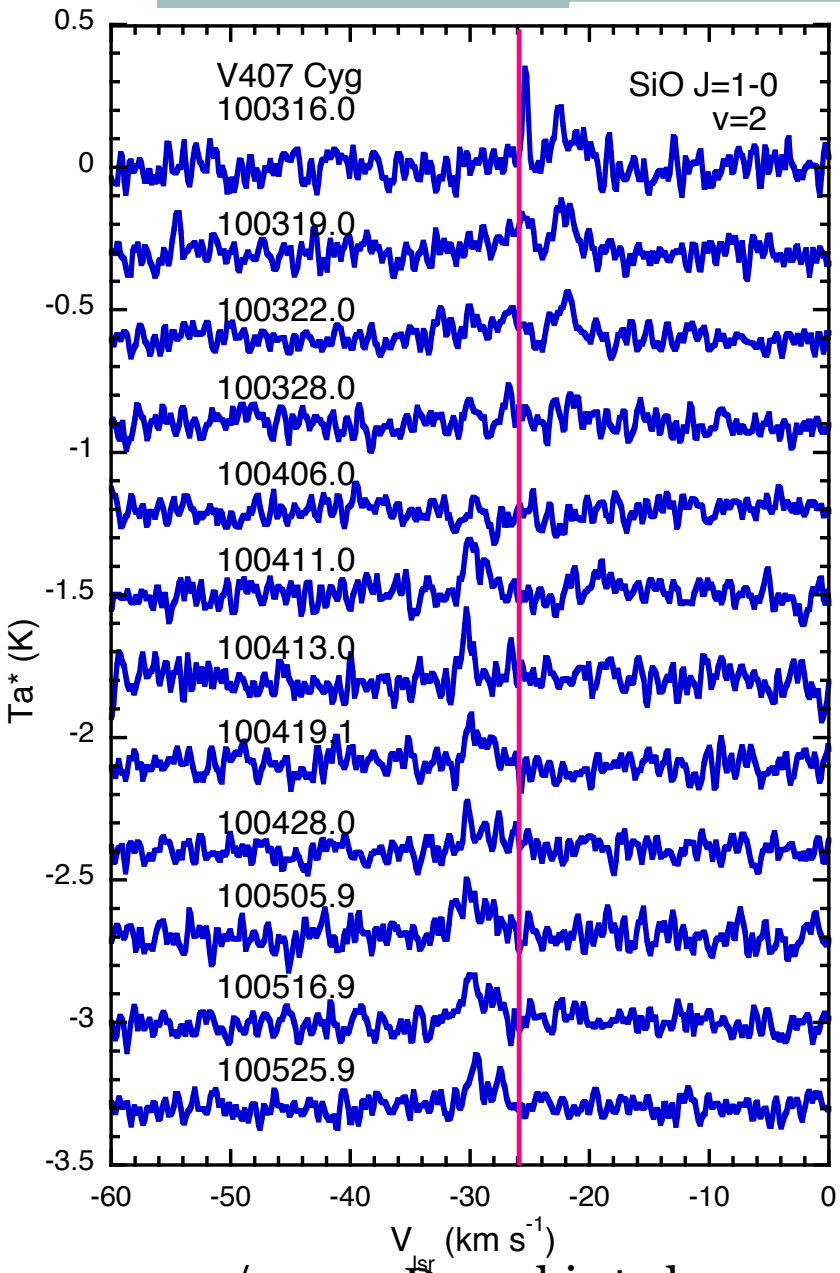


Observations by SiO J=1-0 v=1,2

- Only v=2, but no v=1
- First 2 weaks V_{lsr}>-26 km/s
- Then V_{lsr}<-26 km/s

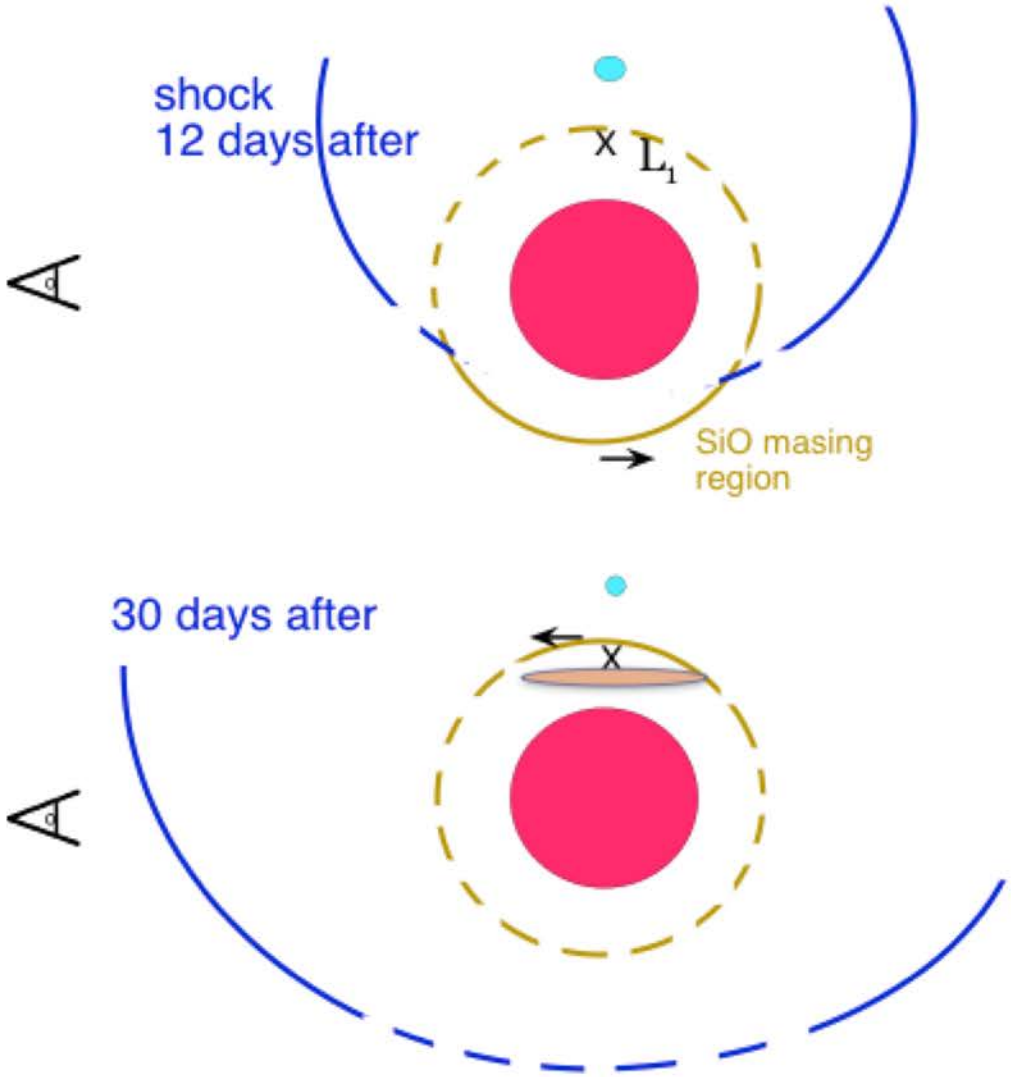


2009/12/02 Cho et al. 2011



2010/03-05 Deguchi et al. 2011

Interpretation



Burst V~3000 km/s

- 4 days ~ 1 10^{14}cm
- 12 days ~3 10^{14}cm
- 30 days 8 10^{14}cm

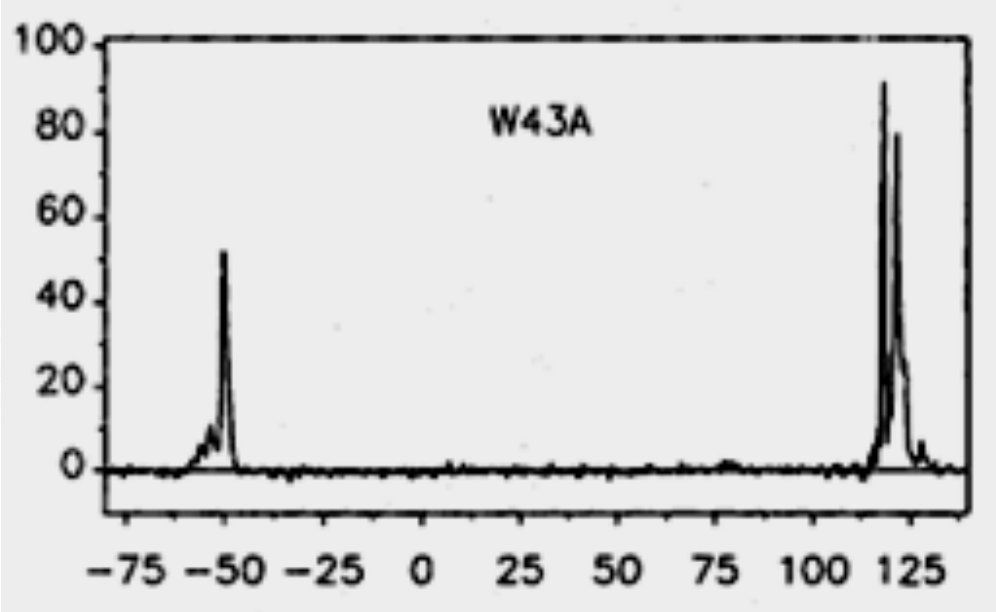
- R_{mira} ~ 3 10^{13} cm
- D_{wd} ~ 10^{14} cm
- $V_{cool\ wind}$ ~20 km/s
- x 30 d = 5 10^{12} cm

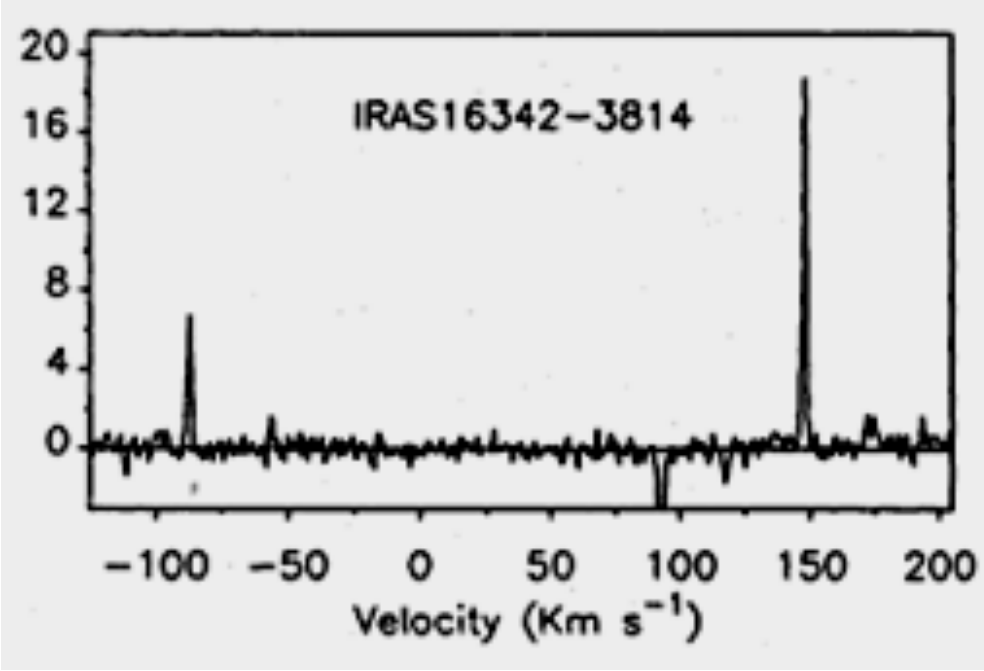
- $\tau_{dust}=4\ 10^{-21} N_{H2} cm^{-2}$

- → 10^{9} cm^{-3} 10^{12} cm

Water fountains
(V_e>100 km/s)

- W43A
- IRAS 16342-3814
- high $^{13}CO/^{12}CO$
- J=2-1 & 3-2
- Hot-Bottom Burning
- IRAS 18286-0959

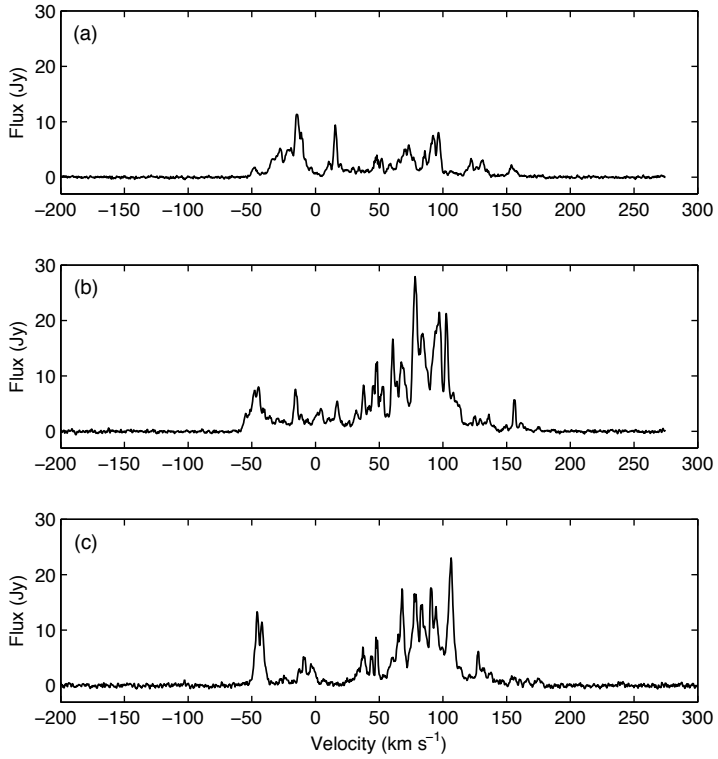


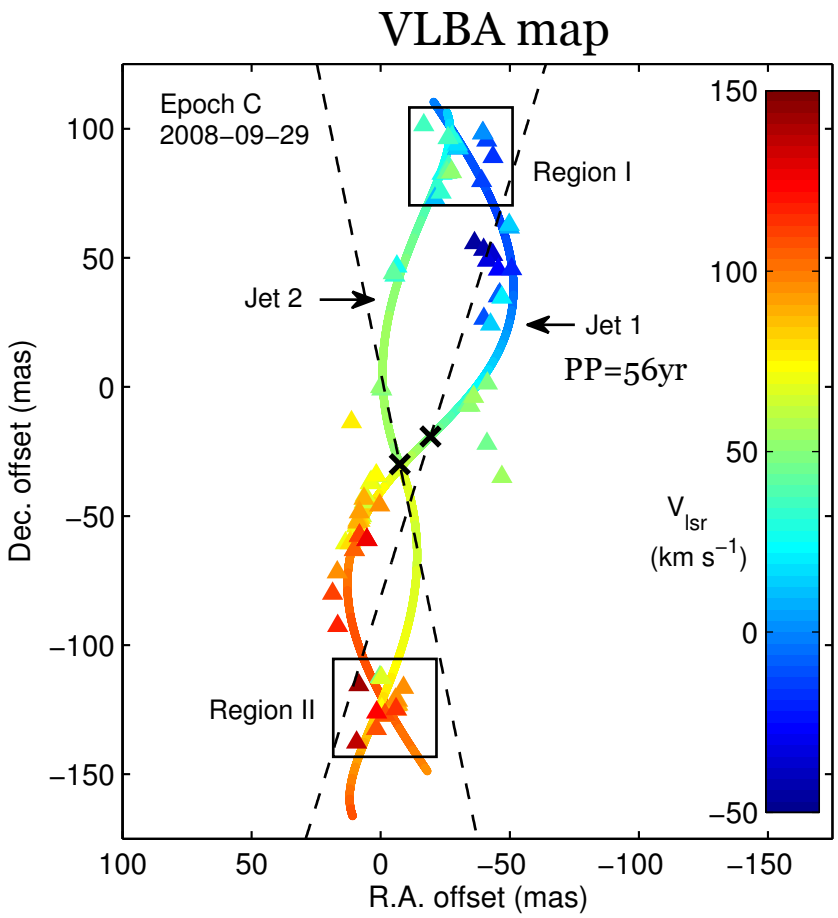


Water fountain jet

IRAS 18286-0959 Yung et al. 2011, ApJ, 741, 94

- Binary geometry ?
- double helix model



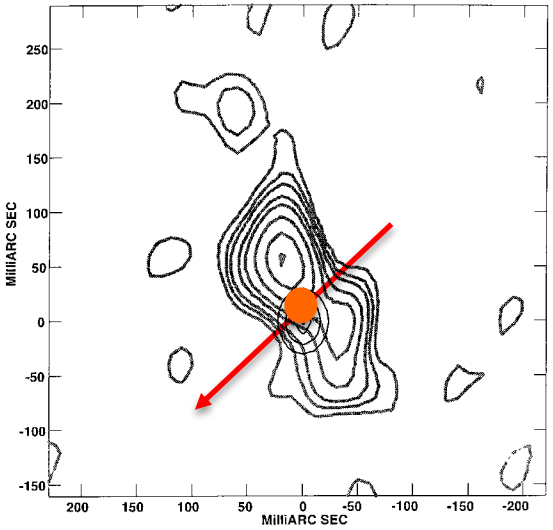


R Aqr (symbiotic star)

- P_{mira}=387 d, P_{orbit}=44 yr

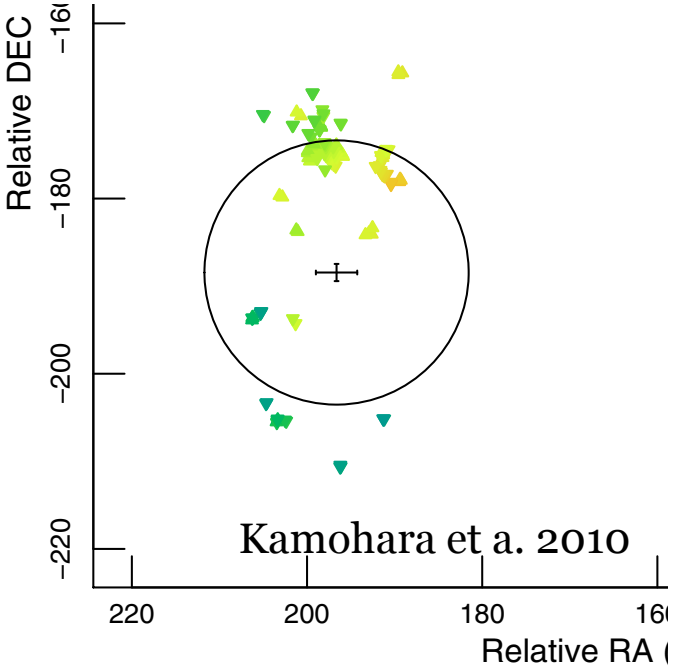
- D=214^{+45}_{-32} pc (VERA: Kamohara et al. 2010)
- Proper motion 45 mas y^{-1} → V=~150 km s^{-1}

- dM/dt~9x10^{-6} $M_\odot$ y^{-1} (Bujarrabal et al. 2010)
- Jet mass (Hollis)= 3 10^{-5} $M_\odot$ (episod. or contin.)



Hollis et al. 1997 scale: 400 mas

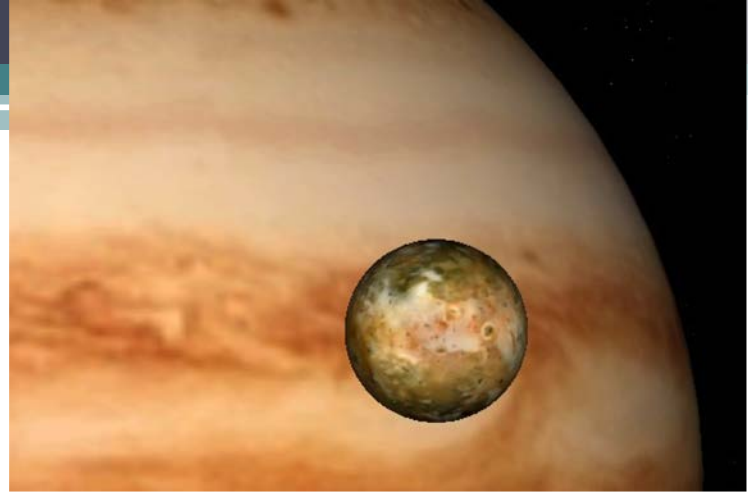
AAT scale 3'



Summary

- Evolved star masers are useful tools to explore the circumstellar envelopes of stars as well as star clusters and the Milkyway Galaxy.
- Binary/multiple-star nature produces interesting distortion to stellar evolution of these stars.
- Maser observations can offer a bridge of understanding between binary and merger phenomena.

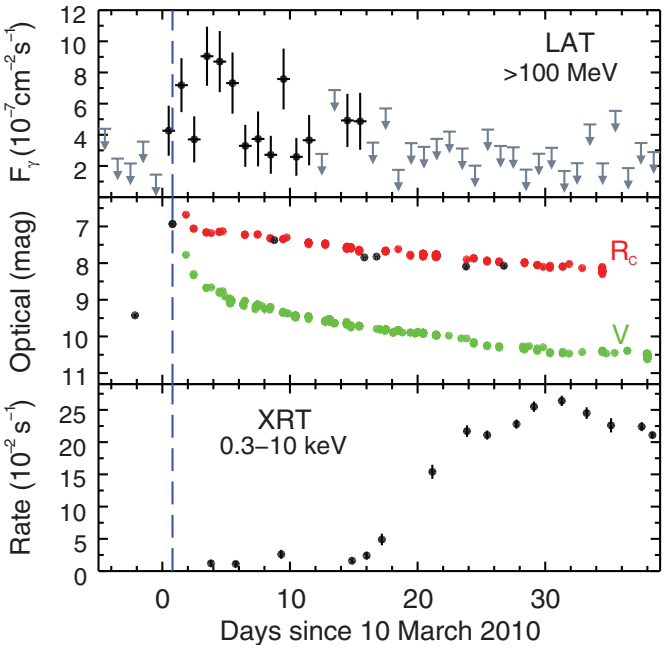
Future prospects

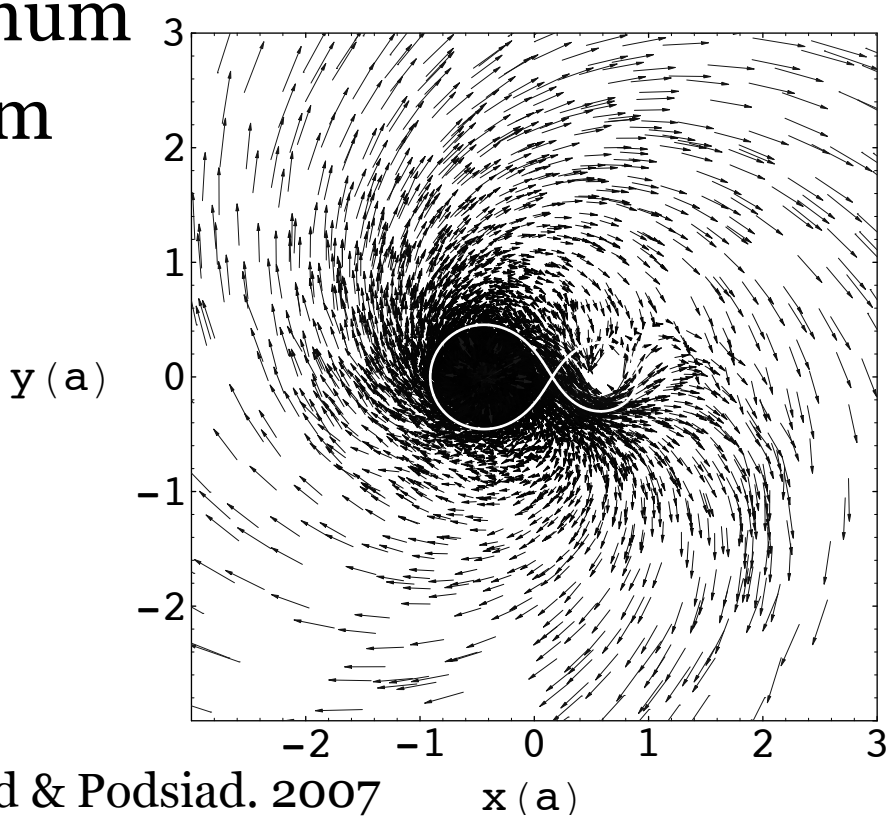


- ALMA --- submillimeter wave masers
  maser star positions—Astrometry
  +CALMA & SMA (VLBI)
- SKA ? OH/H2O CH3OH(not in stars)
  electron-cyclotron masers?
- Atomic line masers ? (or lasers in shock?)
- nova & merged stars (+water fountains)
- embedded star clusters
- RSG + Blackhole

Binary stars and masers

- V407 Cyg (symbiotic star)
- M6III (P=745d) +WD (orbital P~43yr ?)
- SiO Masers found 2005 by Deguchi
- 2010 Feb. I-band maximum
- 2011 May near minimum





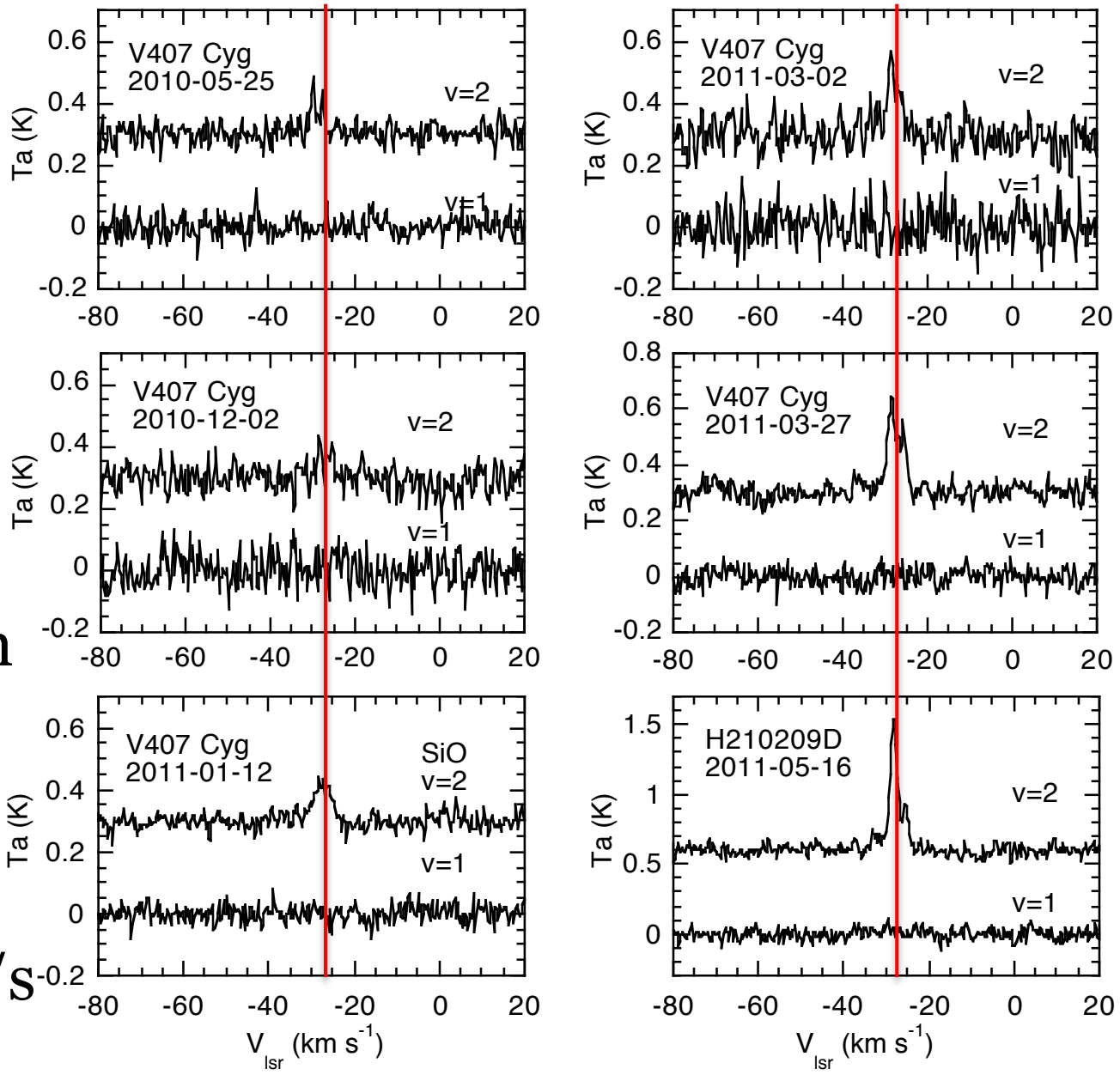
Mohamed & Podsiad. 2007

2010/05 -2011/05

- v=2 became very strong
- But not v=1

- v=1 emission outside need time

Stable -28 km/s



Galactic dynamics

- Radial velocities
- Proper motions (VLBI)
- How about optical proper motion data ?
- Hipparcos ~ 1 mas/yr
  optically faint, light variation
- PPMXL ~ 5 mas/yr