TRANSITION OF THE OUTFLOW AND ASSOCIATED EXPANDING H2O MASER SHELL IN THE MASSIVE STAR-FORMING REGION W75N

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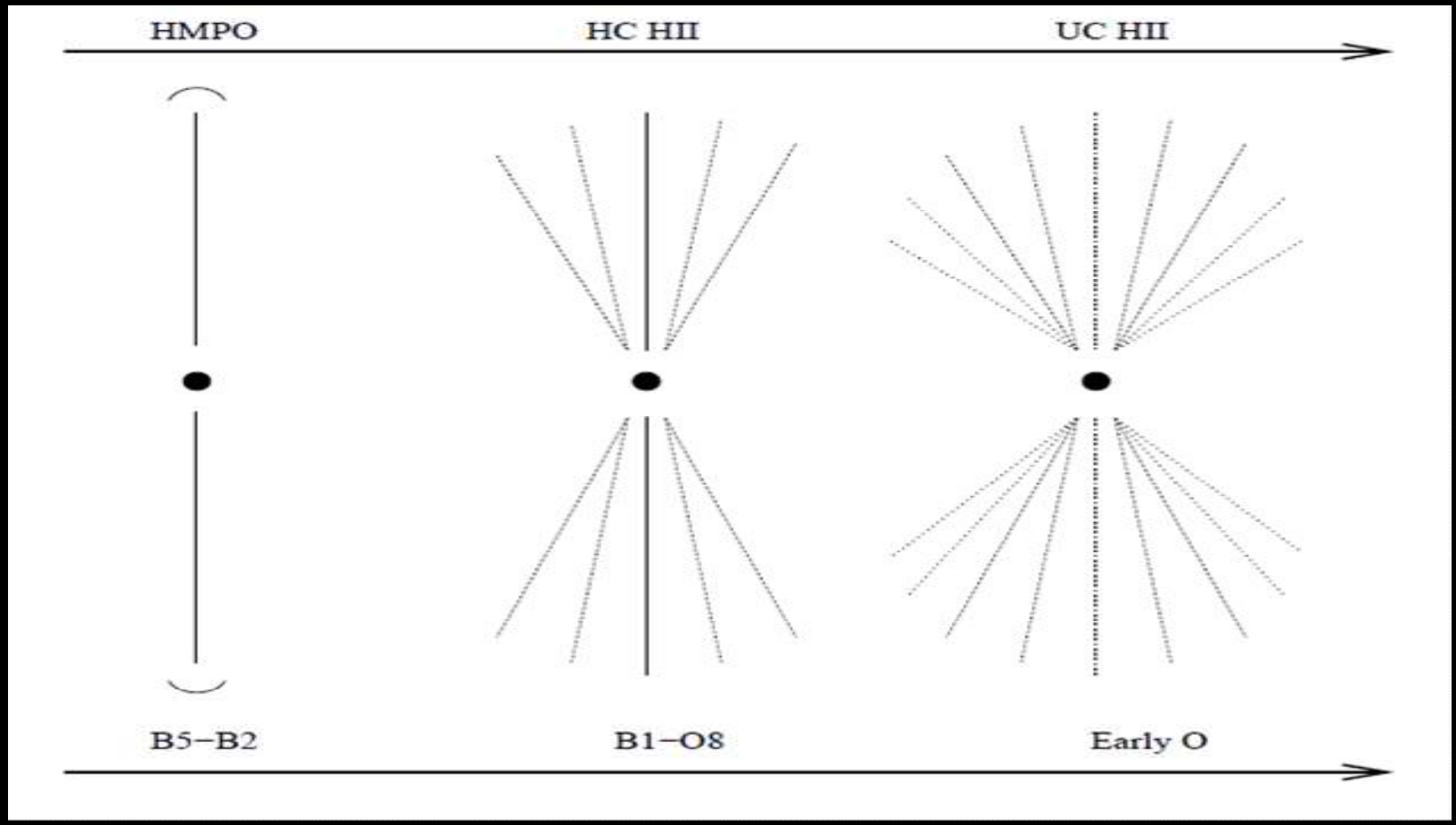
EVOLUTIONARY OUTFLOW HYPOTHESIS I : OBSERVATION

FROM COLLIMATED TO WIND-LIKE



Beuther and Shephered (2005)

EVOLUTIONARY OUTFLOW HYPOTHESIS II: MHD SIMULATION
WIND-LIKE TO COLLIMATED

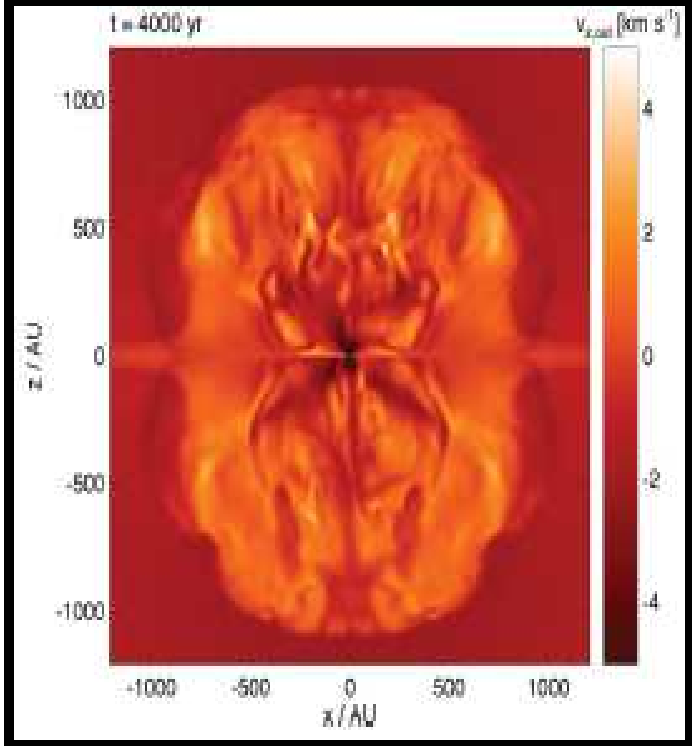
Time →

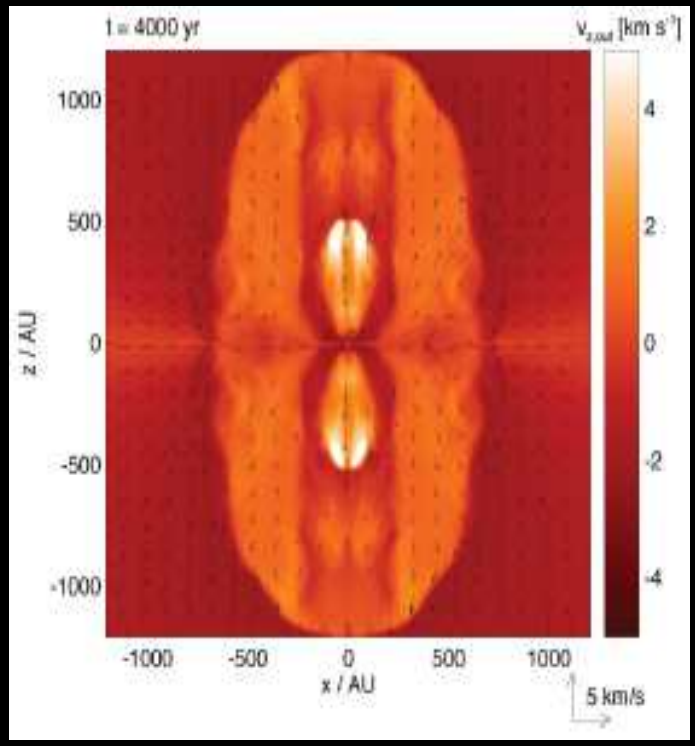
Magnetic field strength

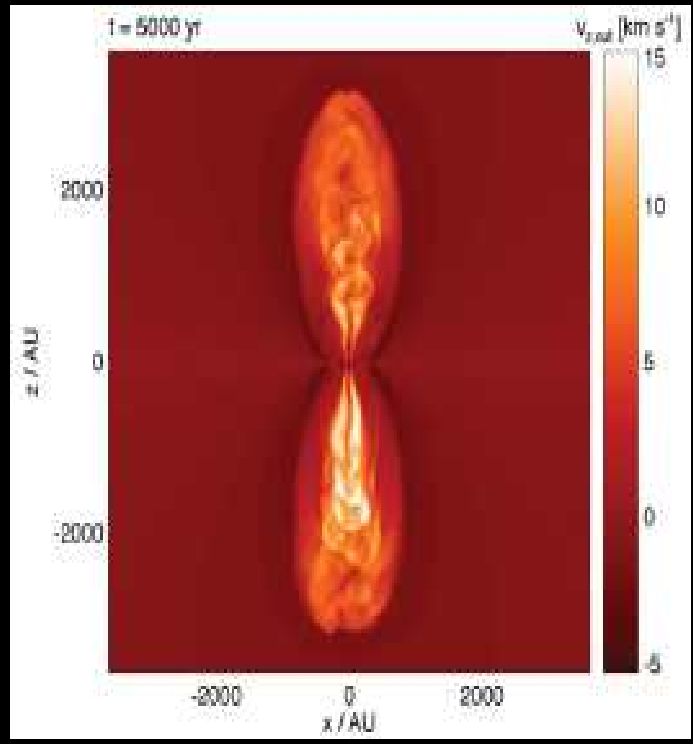
Strong → weak

Outflow morphology

less collimation → collimated







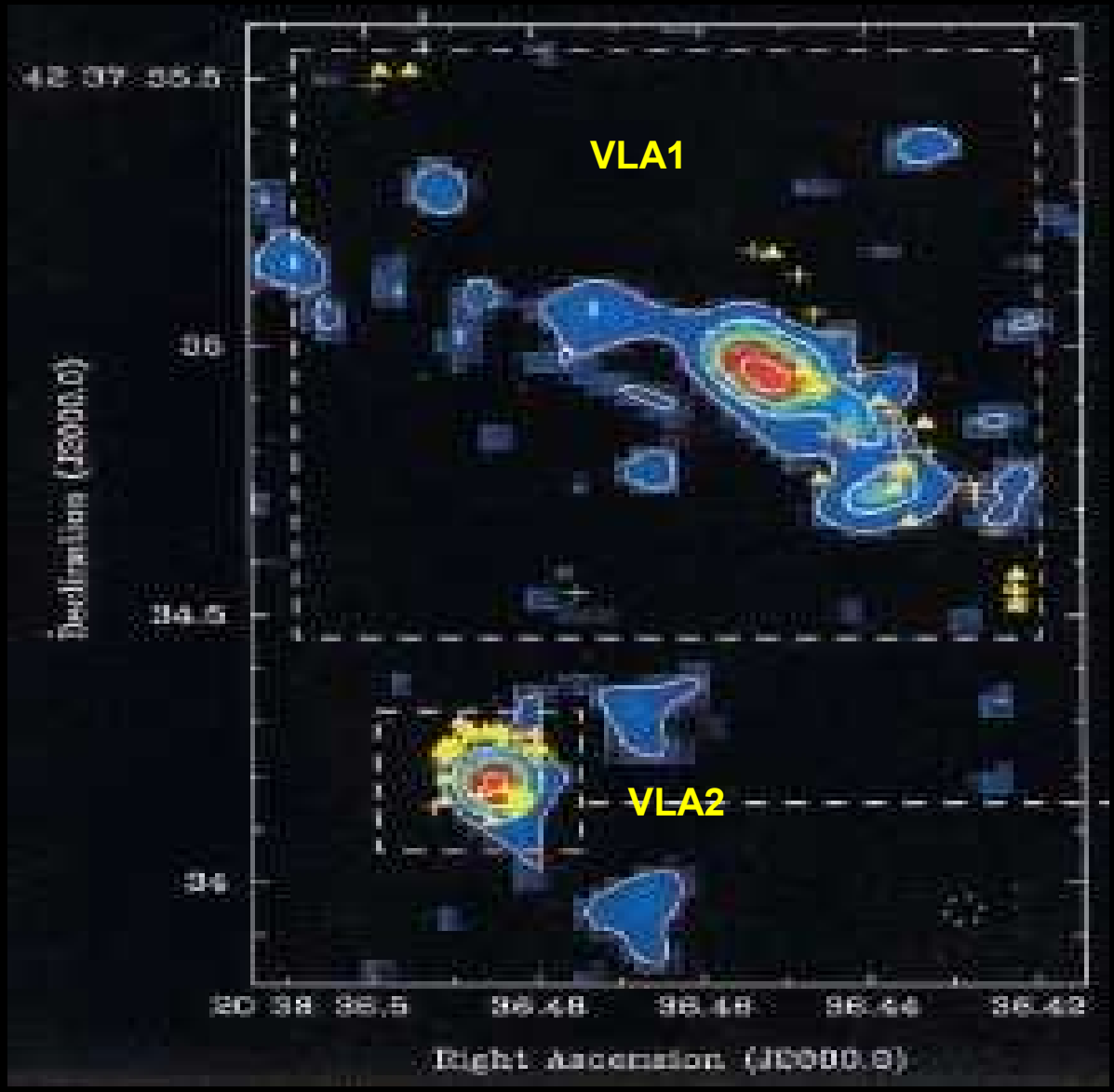
BIPOLAR-LIKE AND WIND-LIKE OUTFLOWS: WHICH COMES FIRST IN THE VERY EARLY PHASE OF MASSIVE STAR FORMATON ?

H2O MASER

IN STAR FORMATION REGION

- The initial stage is embedded by a dense gas and dust envelope.
- H2O maser is an indicator in the very early stage.
- Benefits of Maser Observation with VLBI:
  Kinematics of outflow and Keplerian disk
  Various configuration near HII region

DISTRIBUTION OF H2O MASER IN W75N

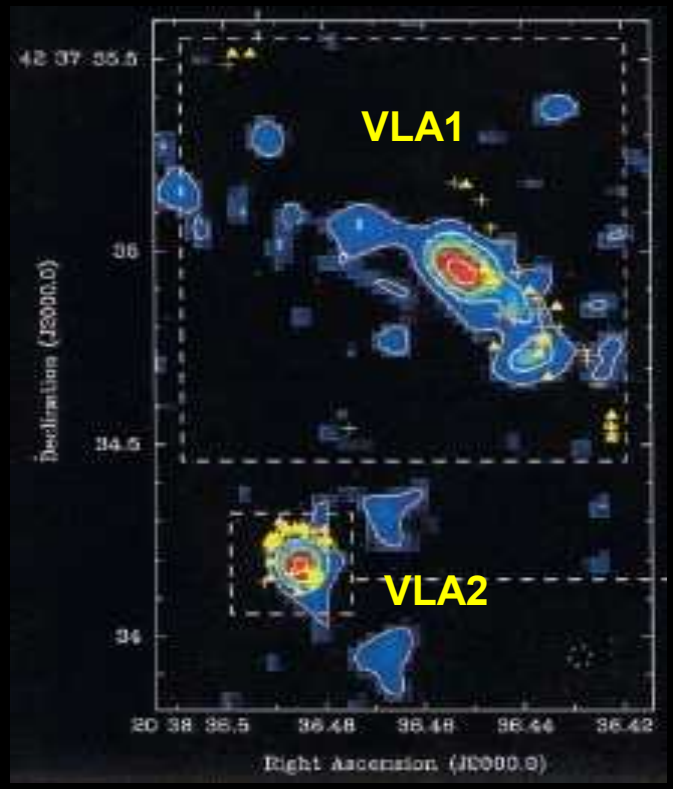


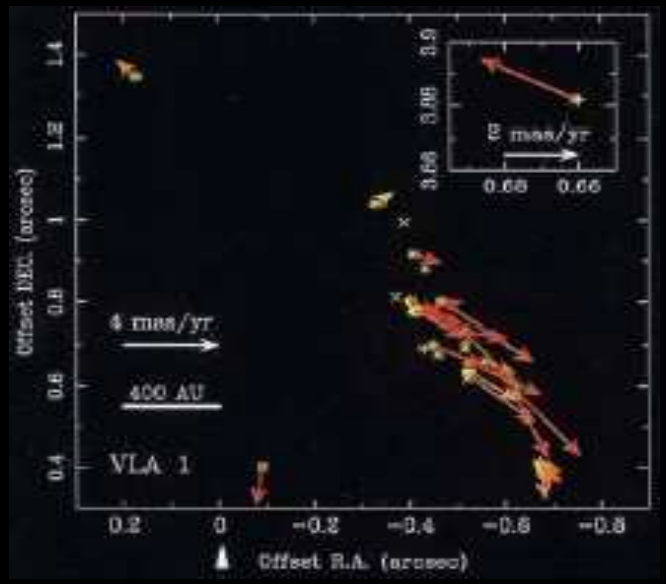
(Torrelles et al. 2003)

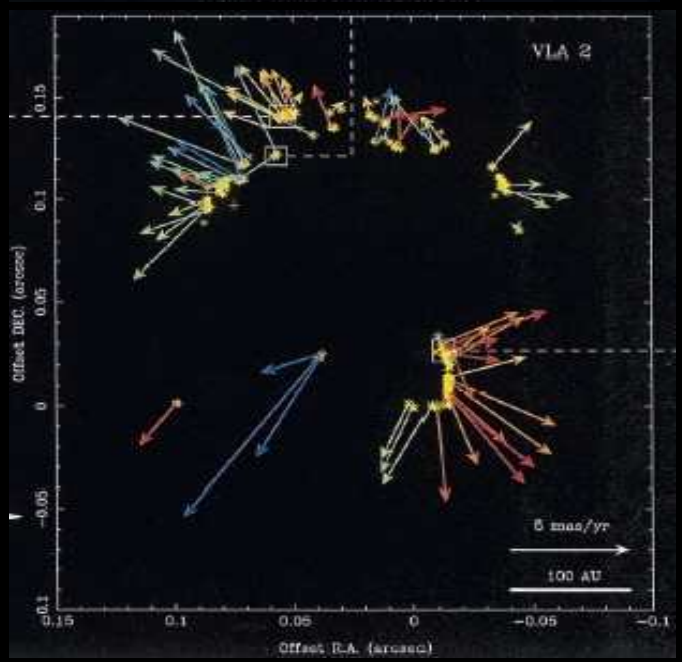
OBSERVATION FOR WATER MASER USING VLBI

	year	Telescope	epoch	poolarization	Reference
1st	1999	VLBA	multi	X	Torrelles et al 2005
2nd	2005	VLBA	single	O	Surcis et al 2011
3rd	2007	VERA	multi	X	Kim et al 2013
4th	2012	VLBA	single	O	Surcis et al 2014

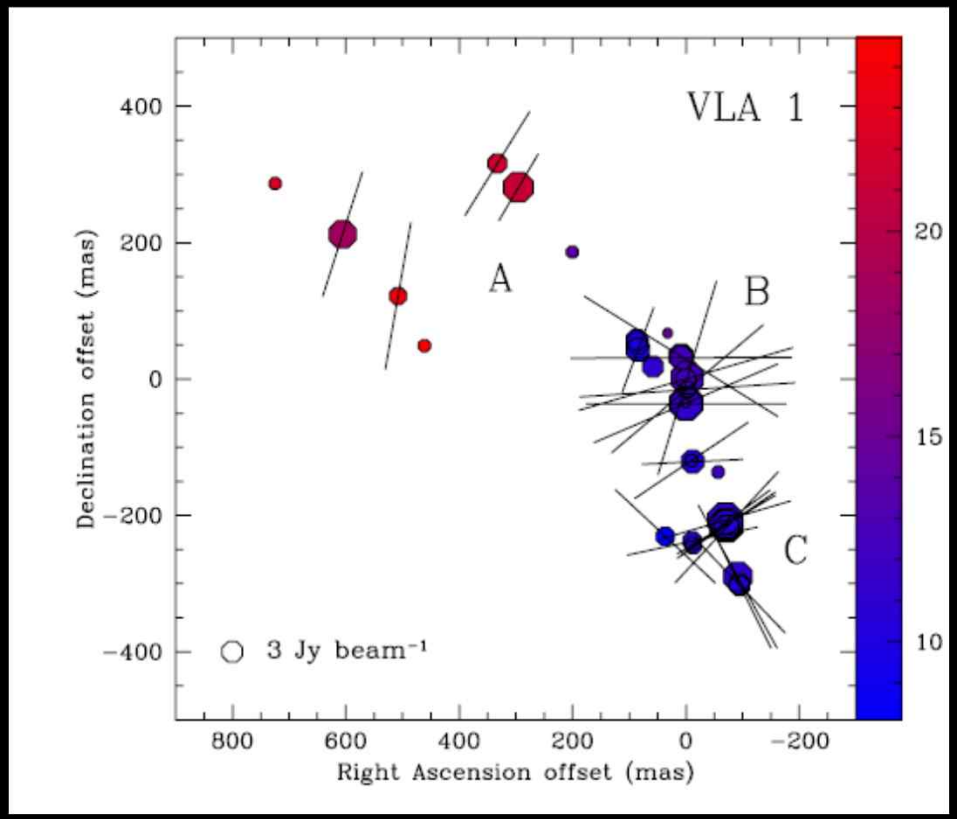
	year	Telescope	epoch	poolarization	Reference
1st	1999	VLBA	multi	X	Torrelles et al 2005

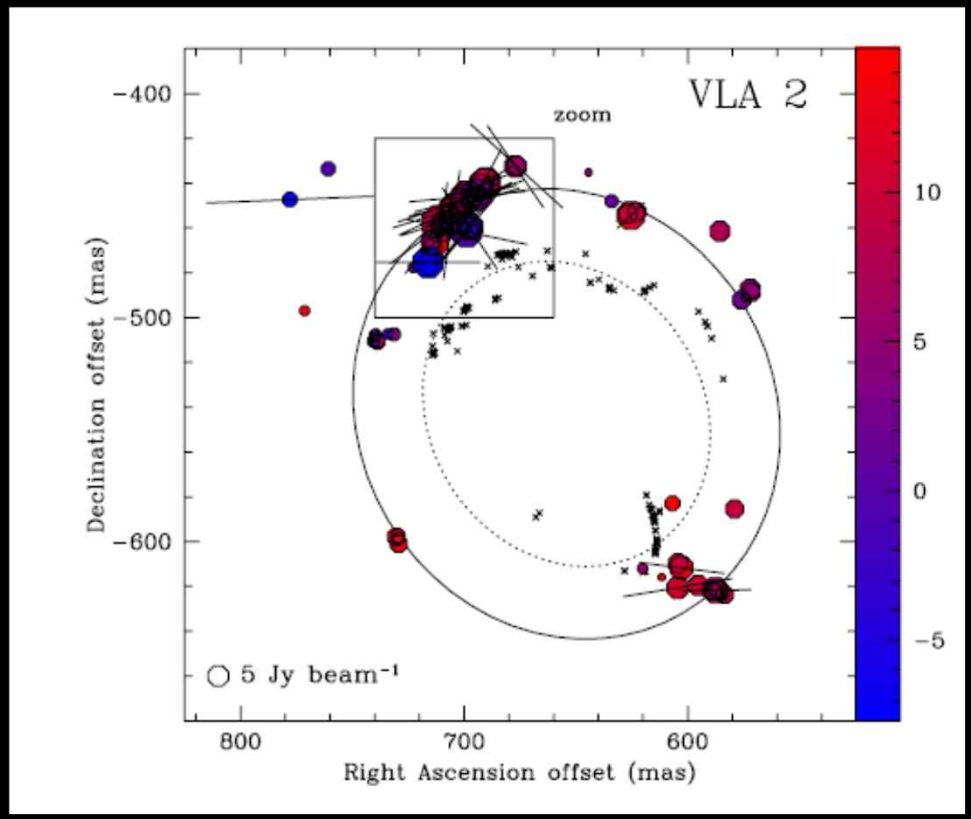




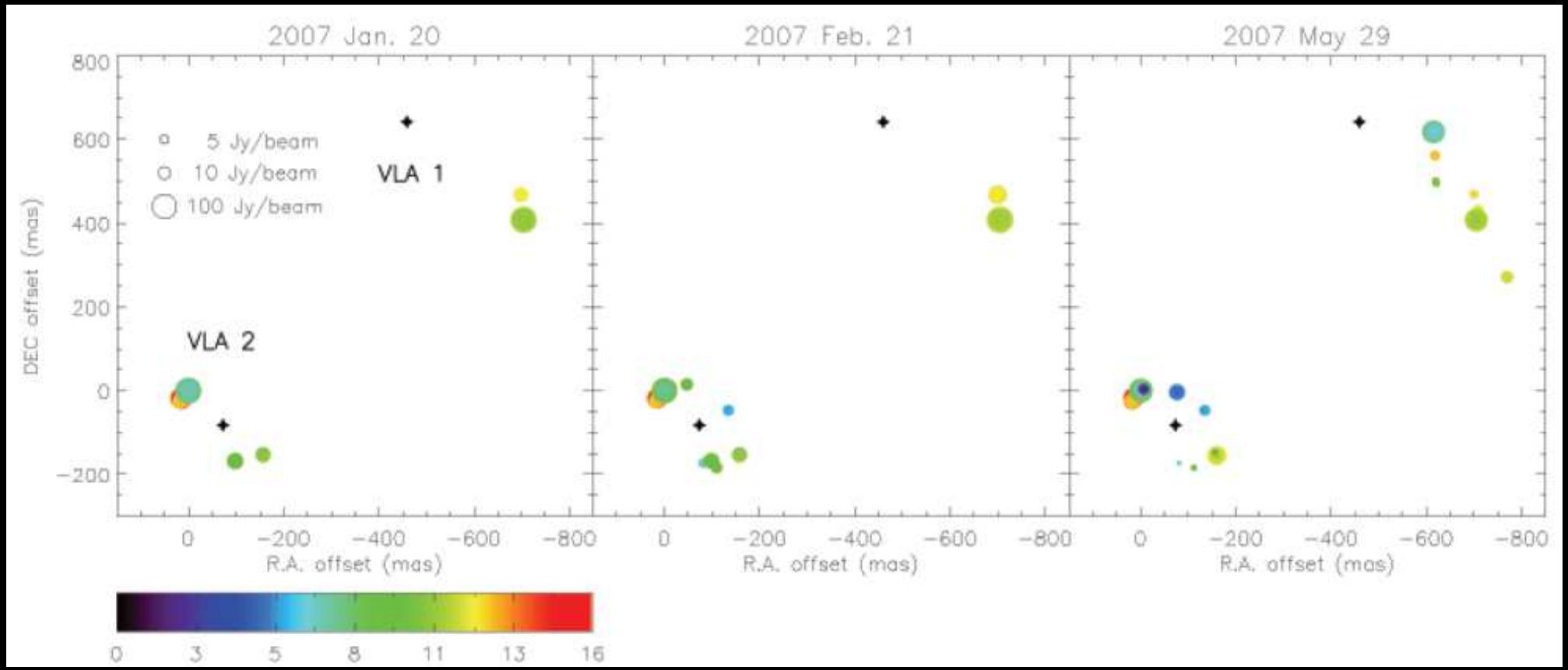


	year	Telescope	epoch	poolarization	Reference
2nd	2005	VLBA	single	O	Surcis et al 2011

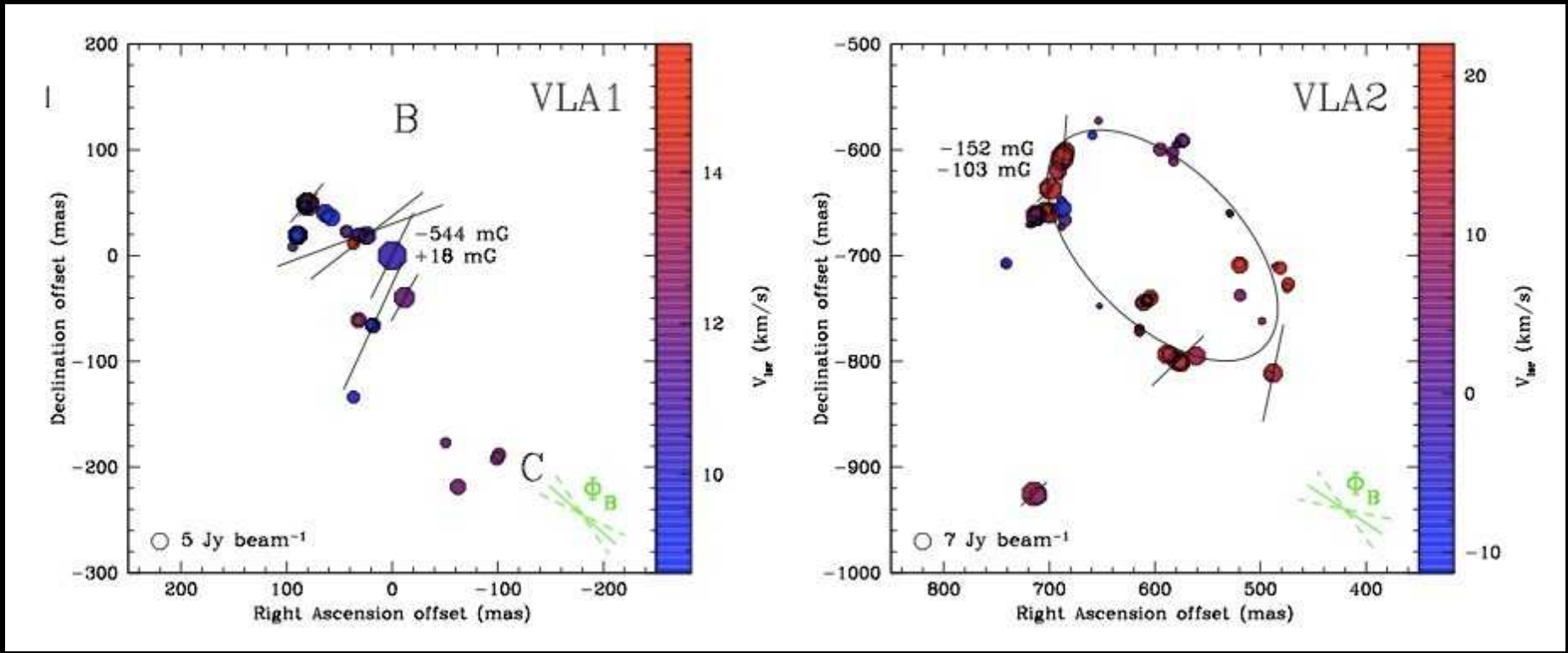




	year	Telescope	epoch	poolarization	Reference
3rd	2007	VERA	multi	X	Kim et al 2013

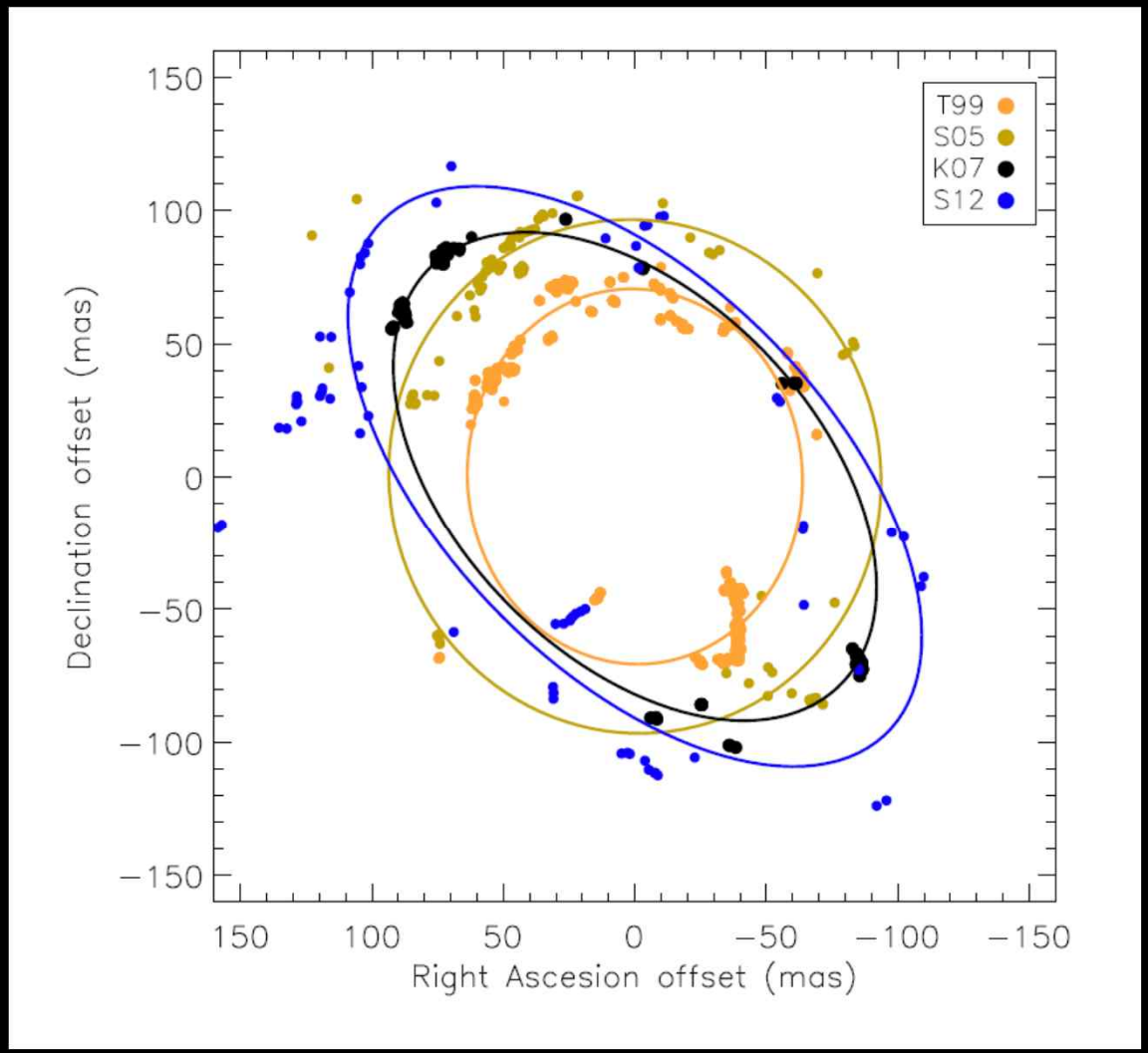


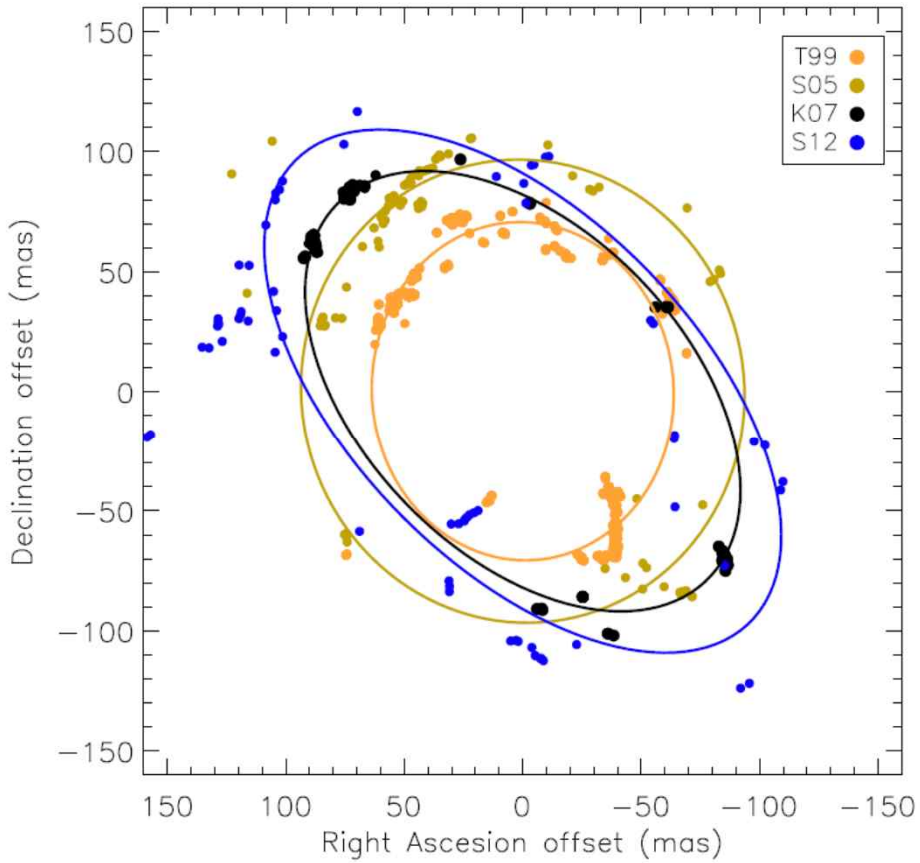
	year	Telescope	epoch	poolarization	Reference
4th	2012	VLBA	single	O	Surcis et al 2014



I. MASER SPOT CONFIGURATION IN VLA2

H2O MASERS IN VLA 2 REGION: ELLIPTICAL MODEL FIT FOR EXPANDING SHELL



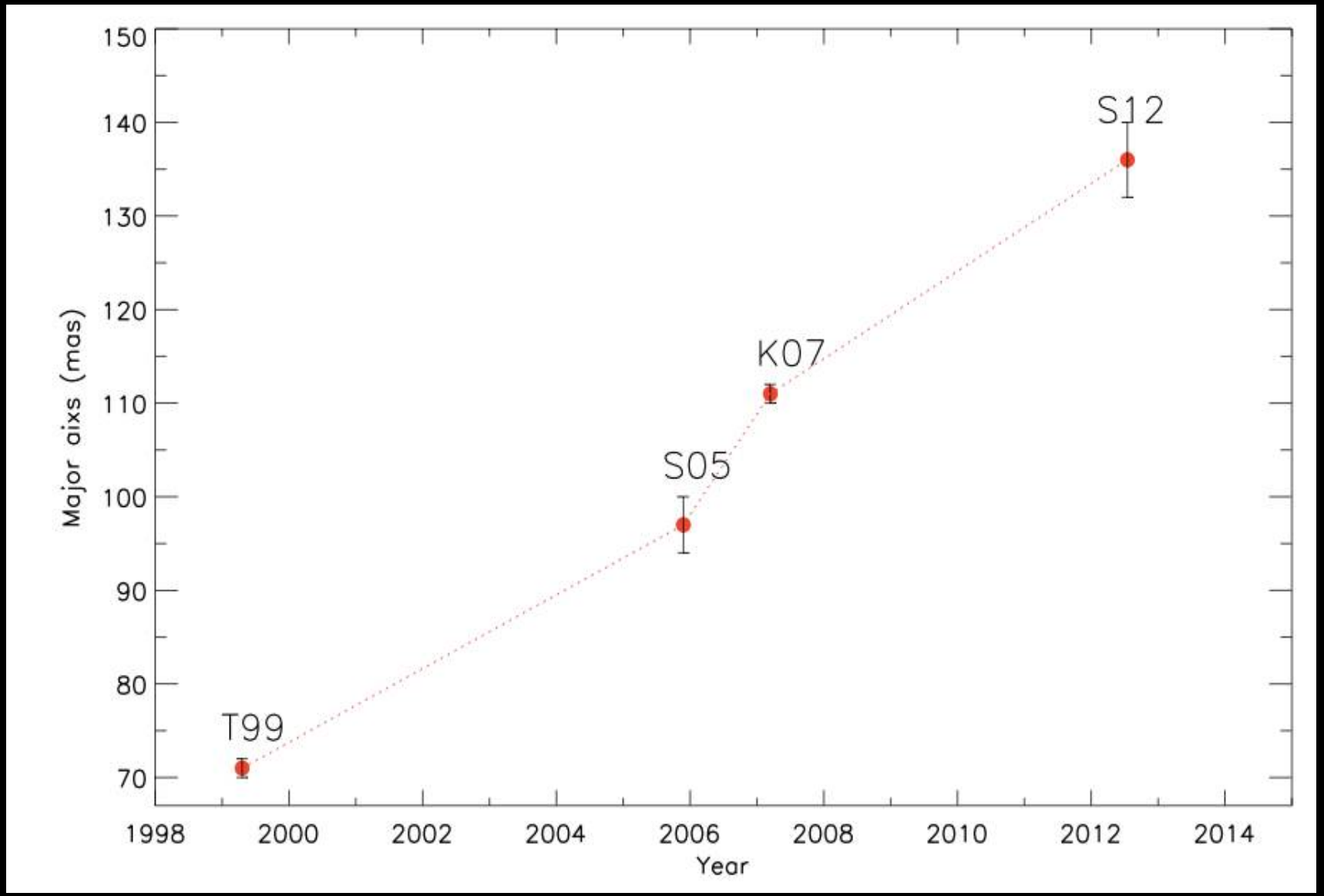


H2O MASERS IN VLA 2 REGION: ELLIPTICAL MODEL FIT FOR EXPANDING SHELL

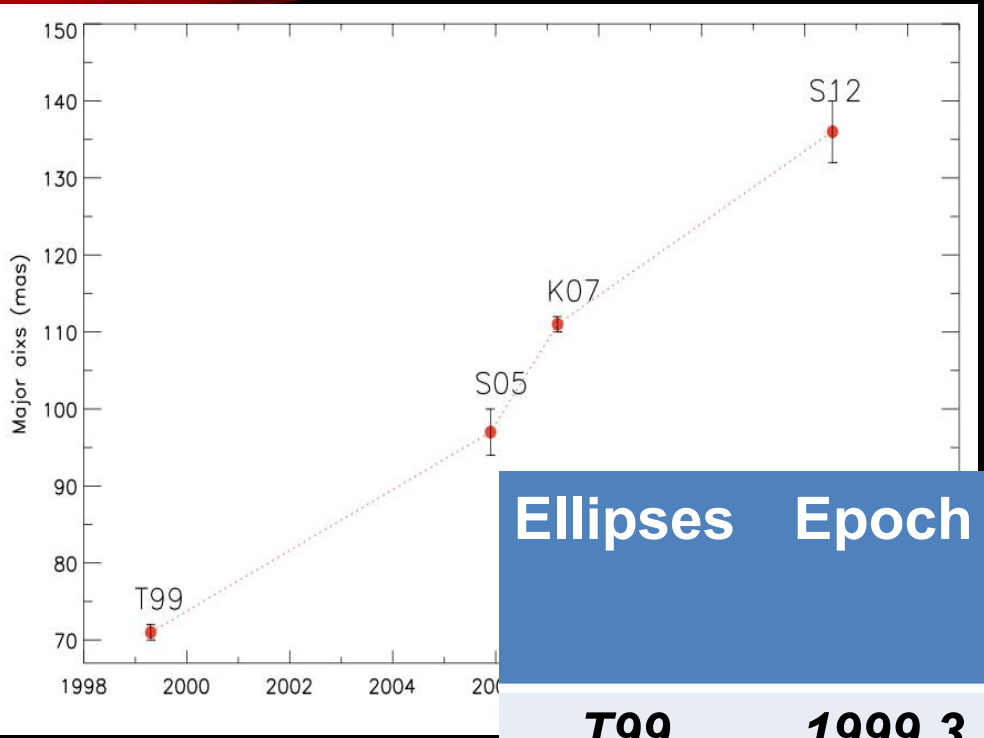
To our surprise, the shell has become more eccentric, giving us a hint that the outflow has evolved from wind-like to more elongated.

Ellipses	Epoch	a (mas)	b (mas)	b/a	PA (°)
T99	*1999.3*	*71±1*	*64±1*	*~0.90*	*5±3*
S05	*2005.9*	*97±3*	*93±2*	*~0.96*	*15±45*
K07	*2007.2*	*111±1*	*68±1*	*~0.61*	*45±1*
S12	*2012.5*	*136±4*	*73±2*	*~0.54*	*45±2*

H2O MASERS IN VLA 2 REGION: ELLIPTICAL MODEL FIT EXPANDING SHELL



H2O MASERS IN VLA 2 REGION: ELLIPTICAL MODEL FIT EXPANDING SHELL



This means the shell has been accelerated between 2005 and 2007!

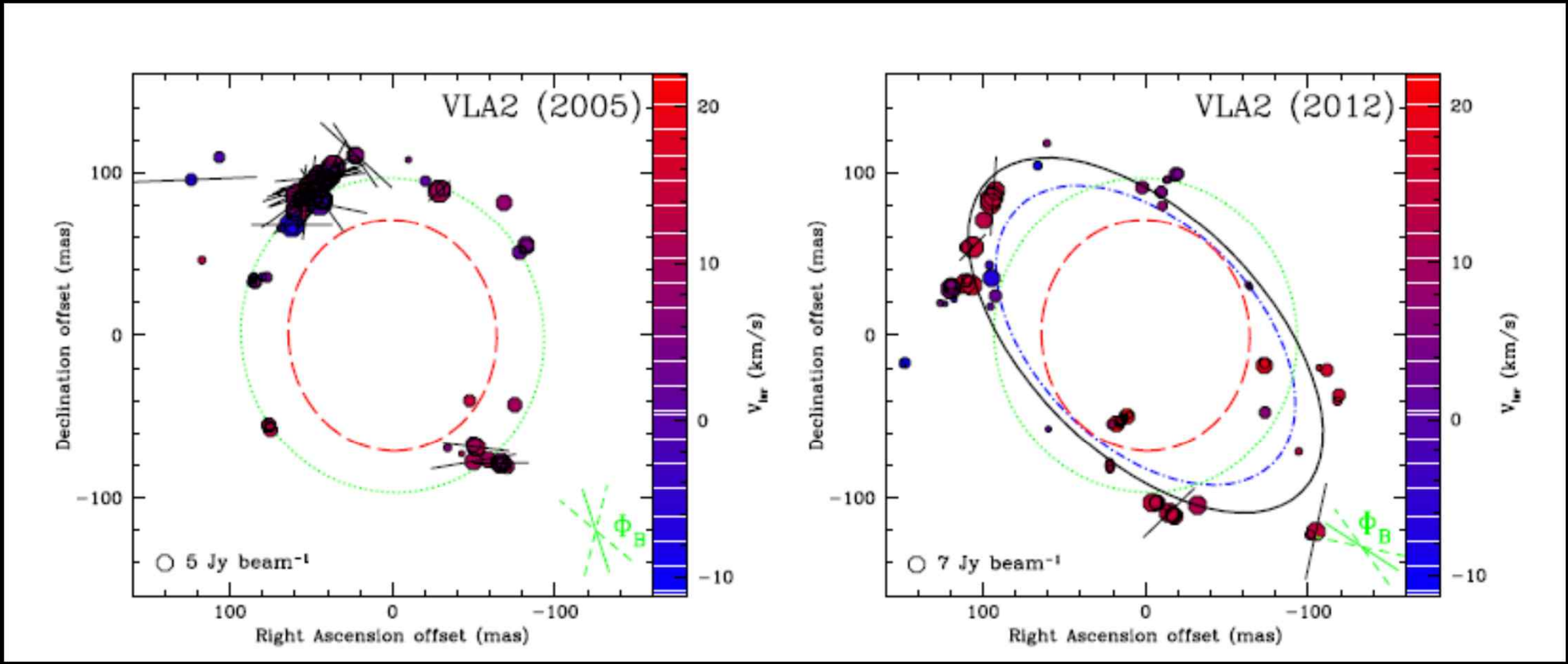
Ellipses	Epoch	Expansion Velocity	
		(mas /yr)	*(km/s)*
T99	*1999.3*		
S05	*2005.9*	T99–S05: **3.9 ± 0.8**	**25 ± 5**
K07	*2007.2*	S05–K07: **10.8 ± 3.1**	**67 ± 12**
S12	*2012.5*	K07-S12: **4.7 ± 0.8**	**29 ± 5**

II. MAGNETIC FIELD STRENGTH IN VLA2

2005 VS. 2012

Polarization observation in W75N - 2005 vs. 2012

Surcis et al (2014)



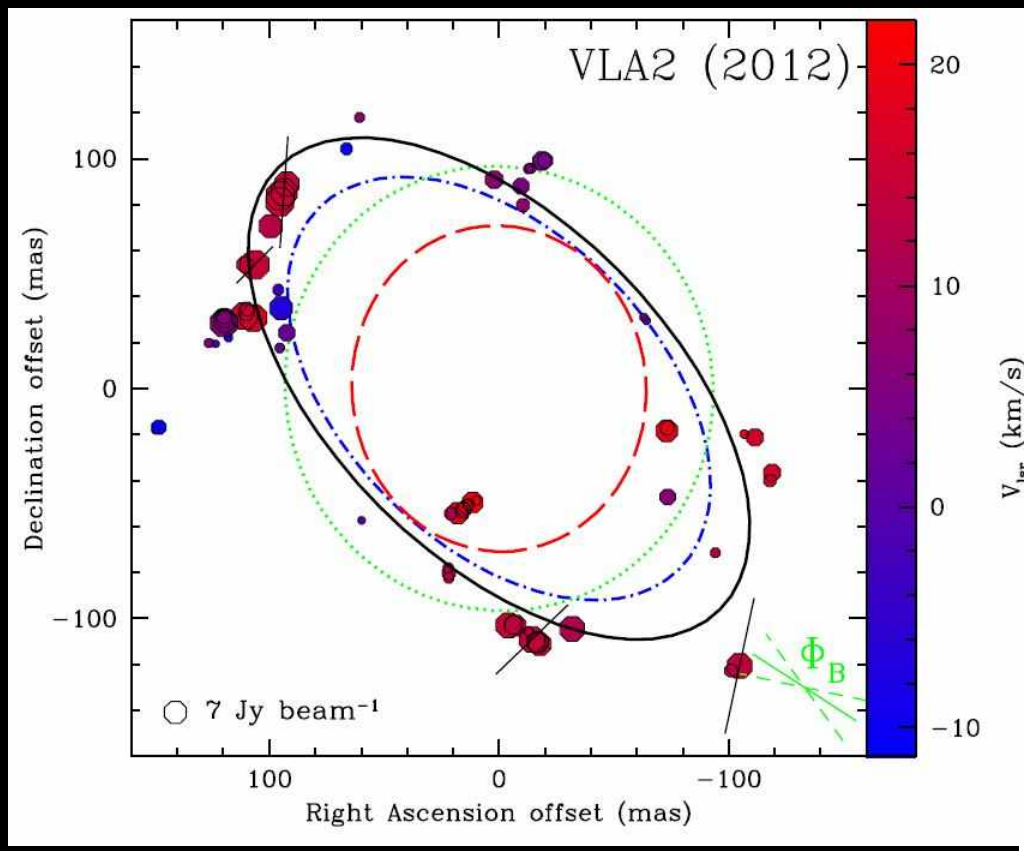
$$|\overline{B}|_{2005} = 345\ m\,G$$

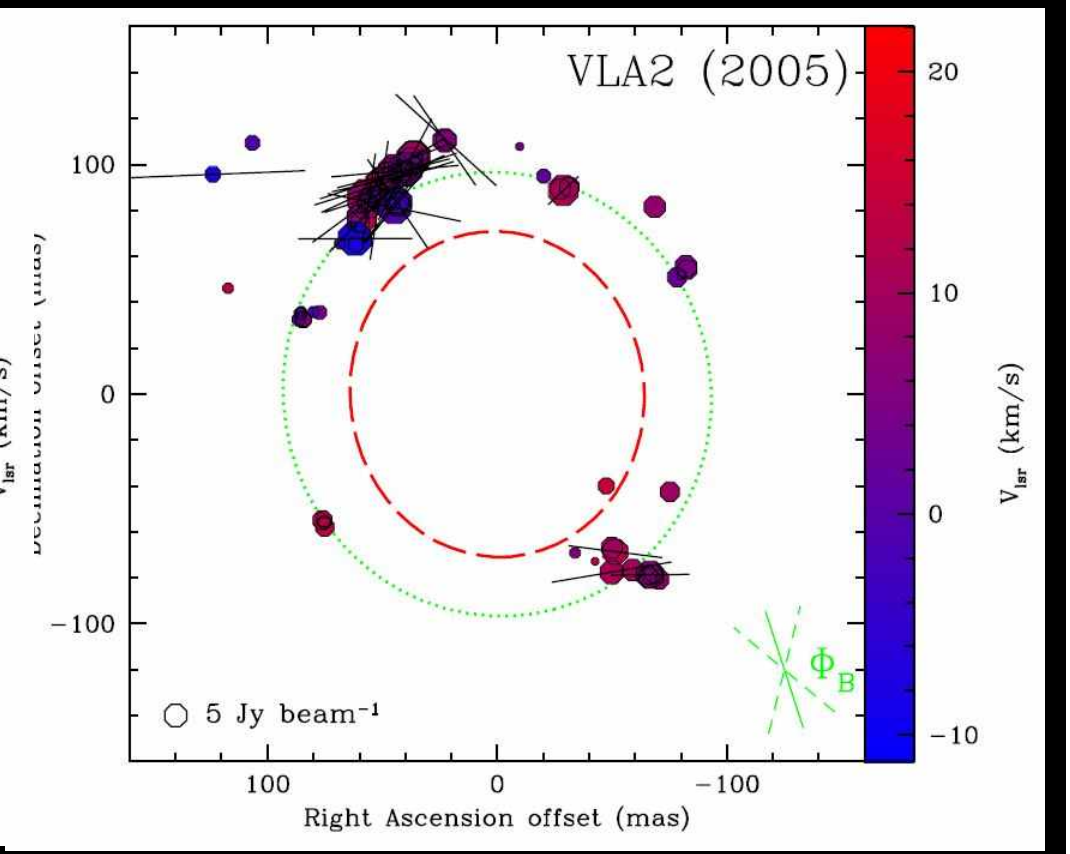
$$|\overline{B}|_{2012} = 128\ m\,G$$

The magnetic field in 2012 is one third of the magnetic field measured in 2005. It is coincided observations with simulation of Seifried et al (2012).

Orientation of Magnetic field in VLA2– 2005 vs. 2012

Surcis et al (2014)



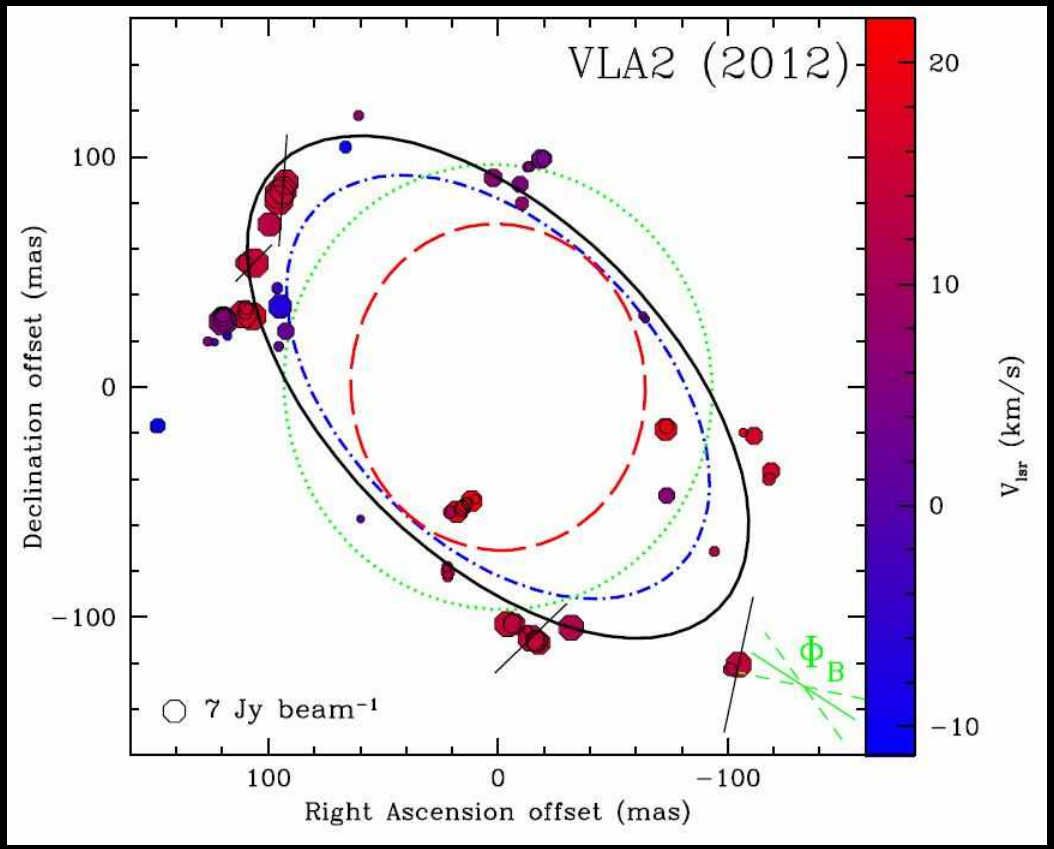


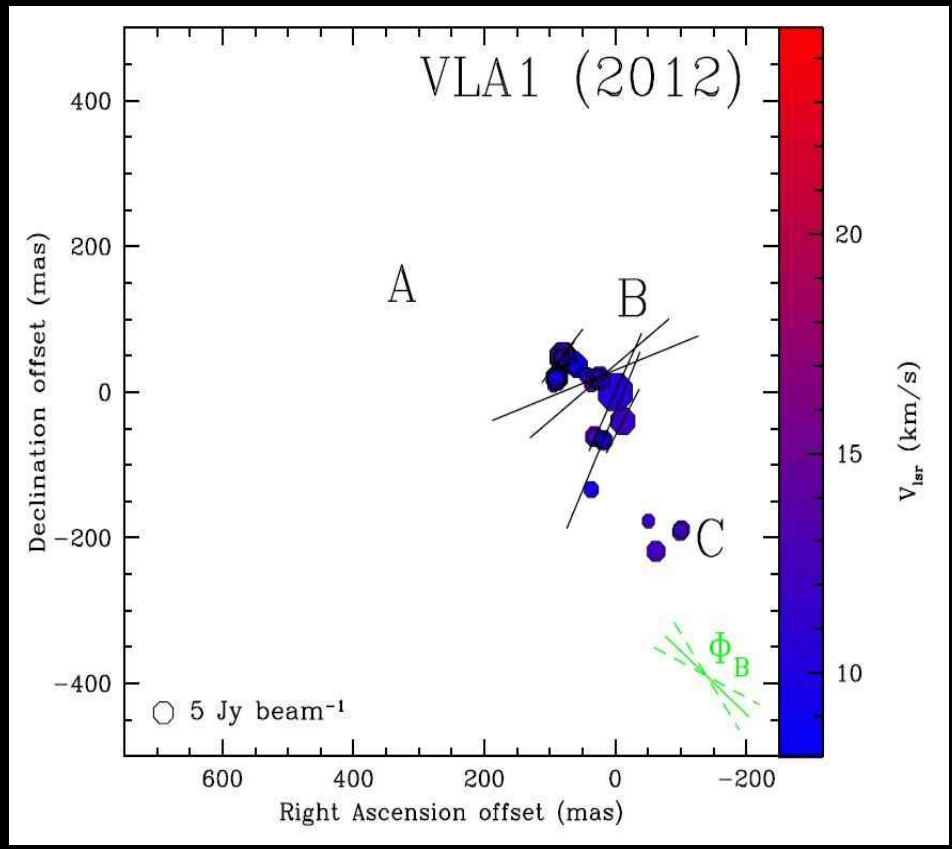
$$\Phi_{B,2012}^{VLA2} = +45^{\circ} \pm 2^{\circ}$$

$$\Phi_{B,2005}^{VLA2} = +23^{\circ} \pm 40^{\circ}$$

Orientation of Magnetic field in 2012– VLA1 vs. VLA2

Surcis et al (2014)





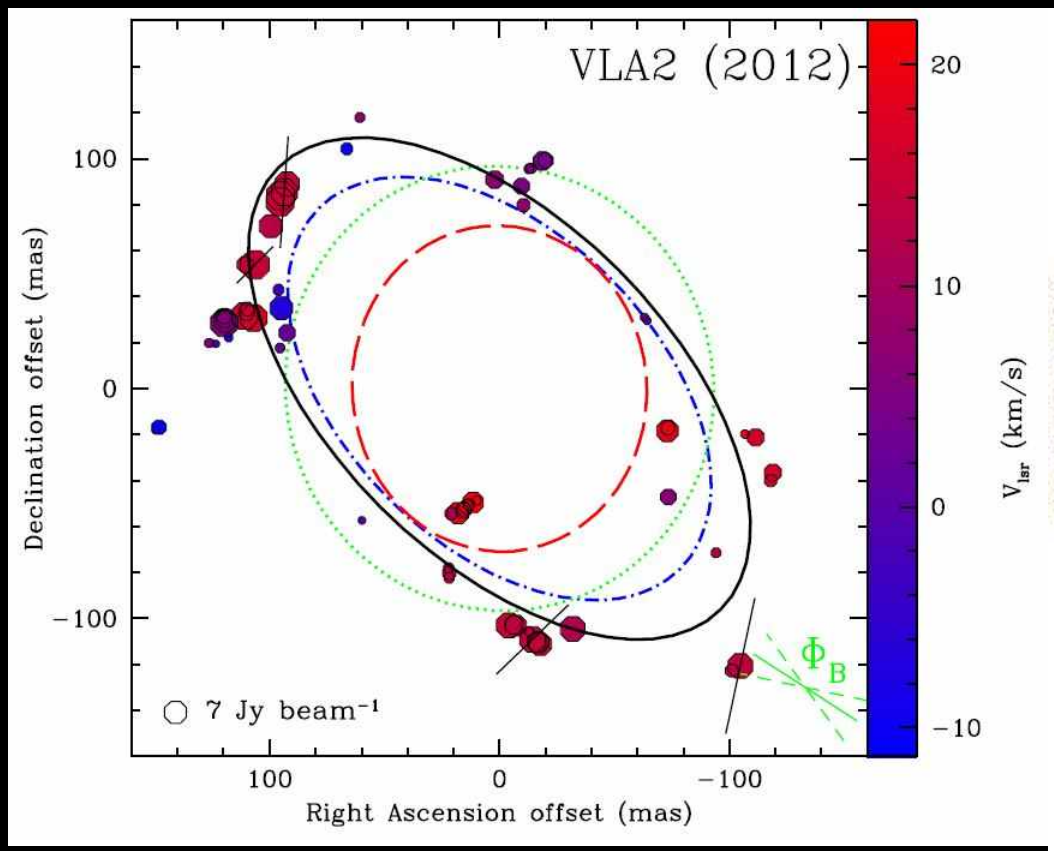
$$\Phi_{B,2012}^{VLA2} = +45^{\circ} \pm 2^{\circ}$$

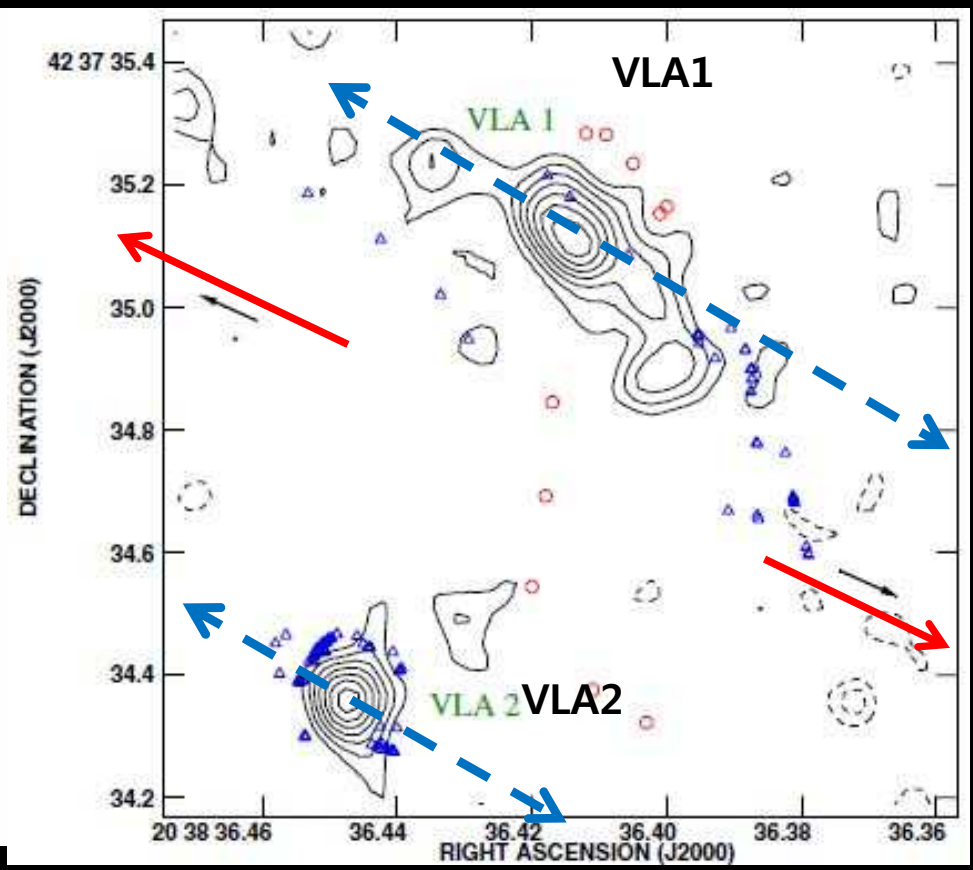
$$\Phi_{B,2012}^{VLA1} = +49^{\circ} \pm 15^{\circ}$$

Orientation of magnetic fields are +49 degree(VLA1) and +45 (VLA2)

Magnetic field aligned with the molecular outflow?

Surcis et al (2014)



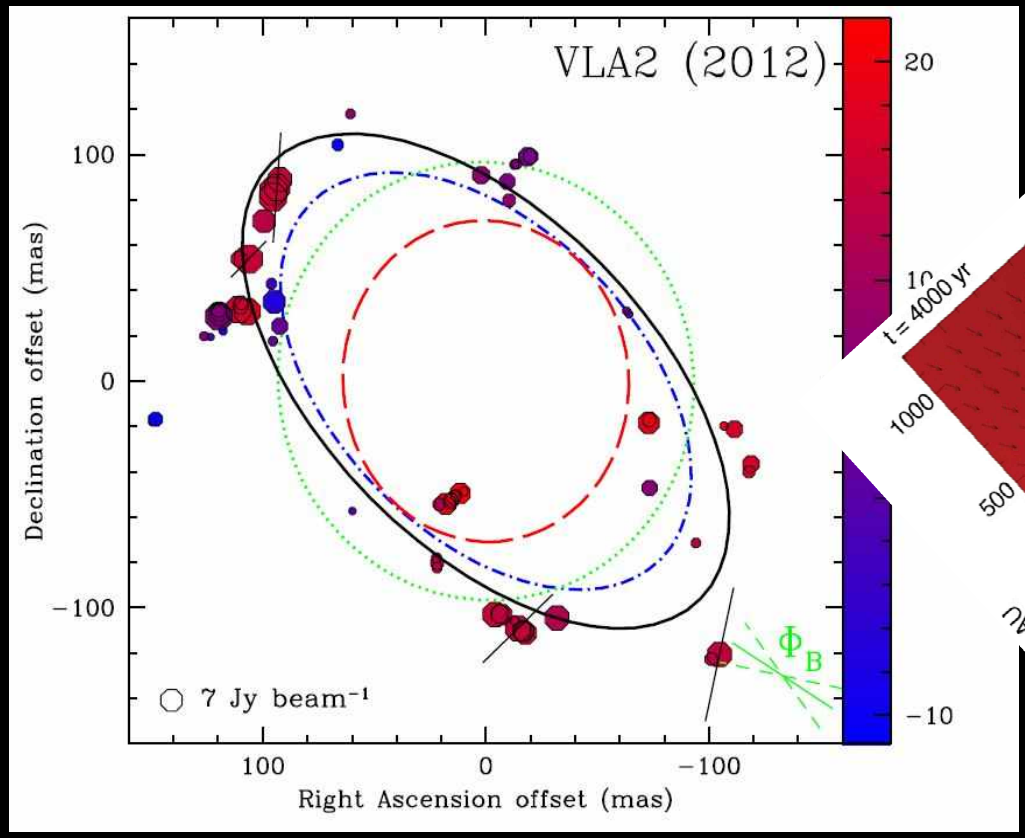


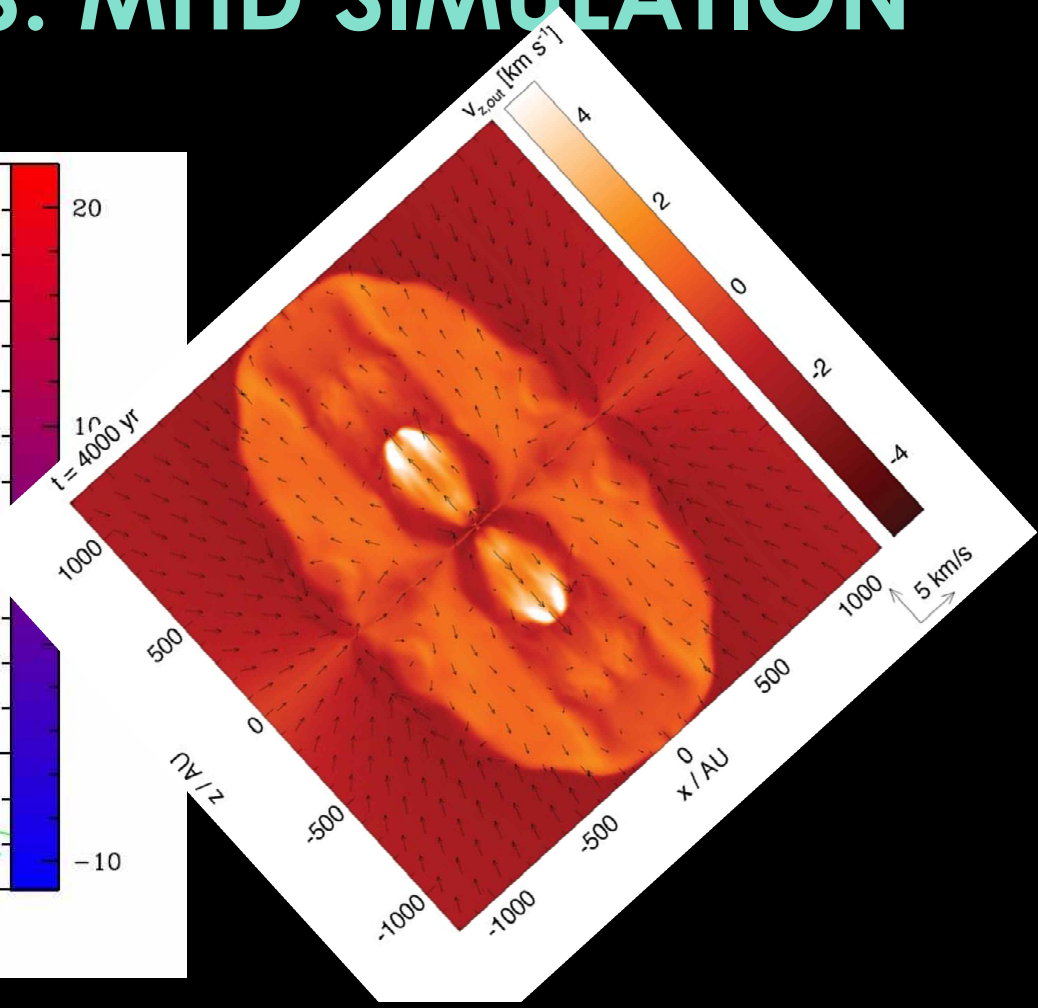
$$\Phi_{B,2012}^{VLA2} = +45^{\circ} \pm 2^{\circ}$$

SUMMARY: OBSERVATIONAL RESULTS

- In VLA1 region, it has been collimated outflow, and magnetic field strength is not so changed.
- In VLA2 region, the shell like structure has been expanded and had elongated for 13 years. the expansion velocity based on major axis size was increased between 2005 and 2007.
- In addition, the magnetic field strength on 2012 is deceased one third than 2005. And the orientation of magnetic field changed similar with VLA1.

OBSERVATION VS. MHD SIMULATION





- this result is consistent with the MHD simulation of Seifried et al.
- That is, more collimated outflow *can develop* in the *early* phase of the massive star formation, due to the built-up of Keplerian disk coupled with *weaker* magnetic field.

we are seeing such a dramatic evolution of outflow in real time, for the first time.

THANK YOU!

Follow-up observations

First, To trace of morphology for water maser in VLA2,

(1) VLA, VLBA and VERA observation was carried out in 2014.

(2) We performed the KaVA (Korea-Japan VLBI Array) observations in 2015A season.

Second, to monitoring of polarization for W75N,

EVN proposal has been accepted for the polarization mode over 6 years, 4 epochs spaced by 2 years. And, the 1st one was performed in 2014.