High Velocity Precessing Jets from the Water Fountain IRAS 18286−0959 Revealed by VLBA Observations

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We report the multi-epoch VLBA observations of 22.2 GHz water maser emission associated with the "water fountain" star IRAS 18286−0959. The detected maser emission are distributed in the velocity range from −50 km s^{-1} to 150 km s^{-1}. The spatial distribution of over 70% of the identified maser features is found to be highly collimated along a spiral jet (namely, jet 1) extended from southeast to northwest direction, and the rest of the features appear to trace another spiral jet (jet 2) with a different orientation. The two jets form a "double-helix" pattern which lies across ~200 milliarcseconds (mas). The maser features are reasonably fit by a model consisting of two precessing jets. The velocities of jet 1 and jet 2 are derived to be 138 km s^{-1} and 99 km s^{-1}, respectively. The precession period of jet 1 is about 56 years, and for jet 2 it is about 73 years. We propose that the appearance of two jets observed are the result of a single driving source with significant proper motion.

Introduction and VLBA Observations

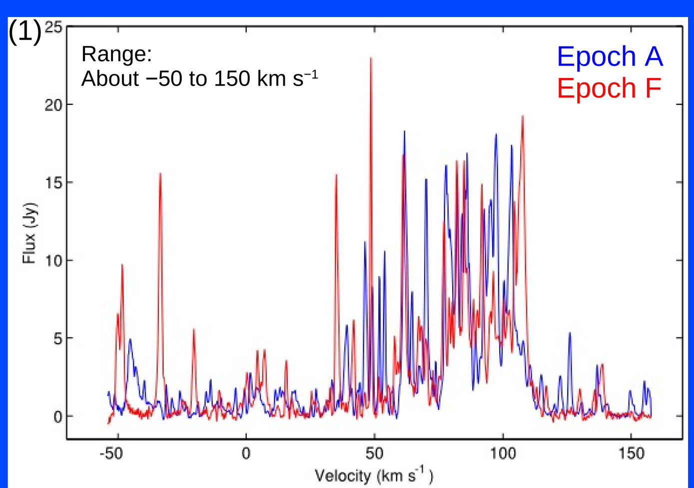
IRAS 18286−0959 is a water fountain which exhibits a fast and collimated molecular outflow that is traced by water maser mission. From the view point of stellar evolution, this type of object is in the transition phase from an asymptotic giant branch (AGB) star to the central star of a planetary nebula. Therefore the high velocity outflow originated from a water fountain is closely related to the shaping of a planetary nebula.

The water maser emission of IRAS 18286−0959 was first detected by using the NRO 45m telescope (*Deguchi et al. 2007, ApJ, 664, 1130*). The first VLBA observation on this object was done shortly after its discovery (*Imai 2007, IAU Symp. 242, 279*) and over 100 maser features were identified. In this poster we are presenting the new multi-epoch VLBA observations together with a suggested precession model.

The new VLBA observations of IRAS 18286−0959 were made at six epochs (namely epoch A to F) spanning the period from 2008 April 21 to 2009 May 19 (BI 37). The total integration time for the target was about 80 minutes. The NRAO's AIPS package and MIRIAD were used for visibility data calibration and image cube synthesis respectively.

Water Maser Spectra

(1)



Spiky profile! Different from other water fountains like W43A, IRAS 19134+2131, IRAS 16342−3814 * or IRAS 16552−3050 **

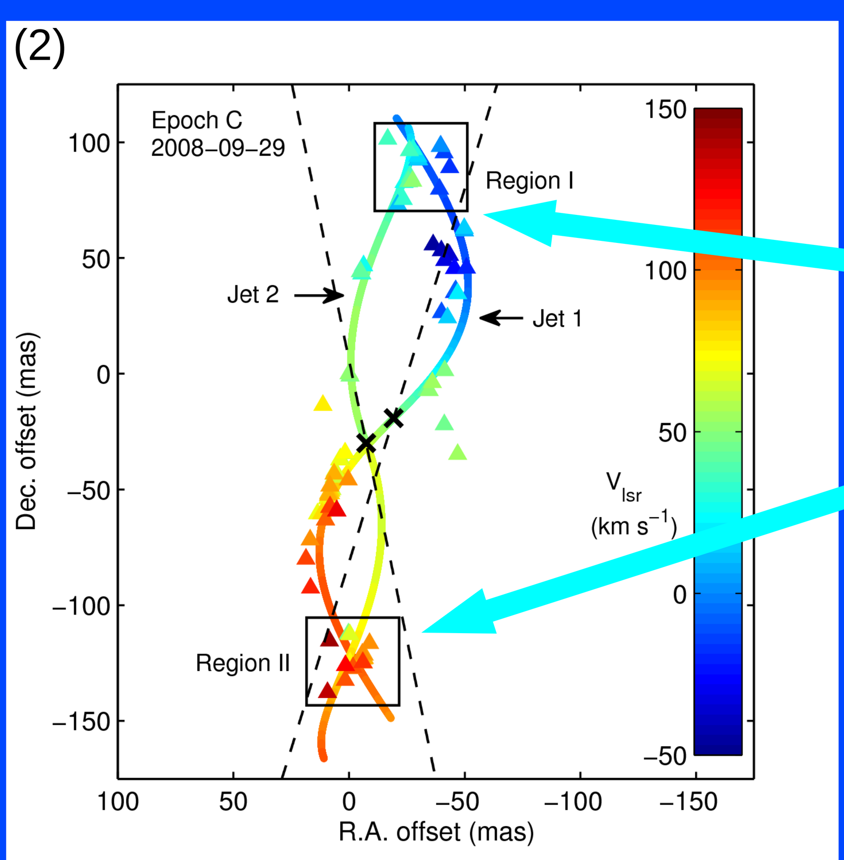
Figure 1 represents significant changing in the profile within 1 year, between epoch A (2008 April 21) and F (2009 May 19).

(*) *Likkel et al. 1992, A&A, 256, 58*
(**) *Suarez et al. 2008, ApJ, 689, 430*

Precession Model

The spatial position of each maser feature is obtained by doing a 2D Gaussian fitting at the channel where the maximum flux of each feature is found. Around 40 to 140 features are identified in each epoch. Figure 2 shows epoch C as an example.

(2)



The two apparent jet engines are separated by ~16 mas.

Features with different line-of-sight velocities (nearly over 50 km s^{-1}) visually overlapping at both northern and southern ends of the structure in all epochs.

Over 70% of the maser features are found on a highly collimated spiral jet (jet 1) and the rest of the features appear to trace out another spiral jet (jet 2) with a different orientation.

Jet Kinematics:

	Jet 1	Jet 2
Goodness of fit, R^2	0.86	0.73
Precession Period (years)	56.03	73.32
Precession Angle (degrees)	28.04	18.91
Jet Velocity (km s^{-1})	138	99

Jet axes:

Position Angle (degrees)	-17.22	11.7
Angle out of sky-plane (degrees)	-2.13	21.69

Position Angle: From north to east of the jet axis.
Angle out of sky-plane: Positive value means the northern end is pointing out from the sky-plane.

Proper Motions and Comparison with Model

(3a) (3b)

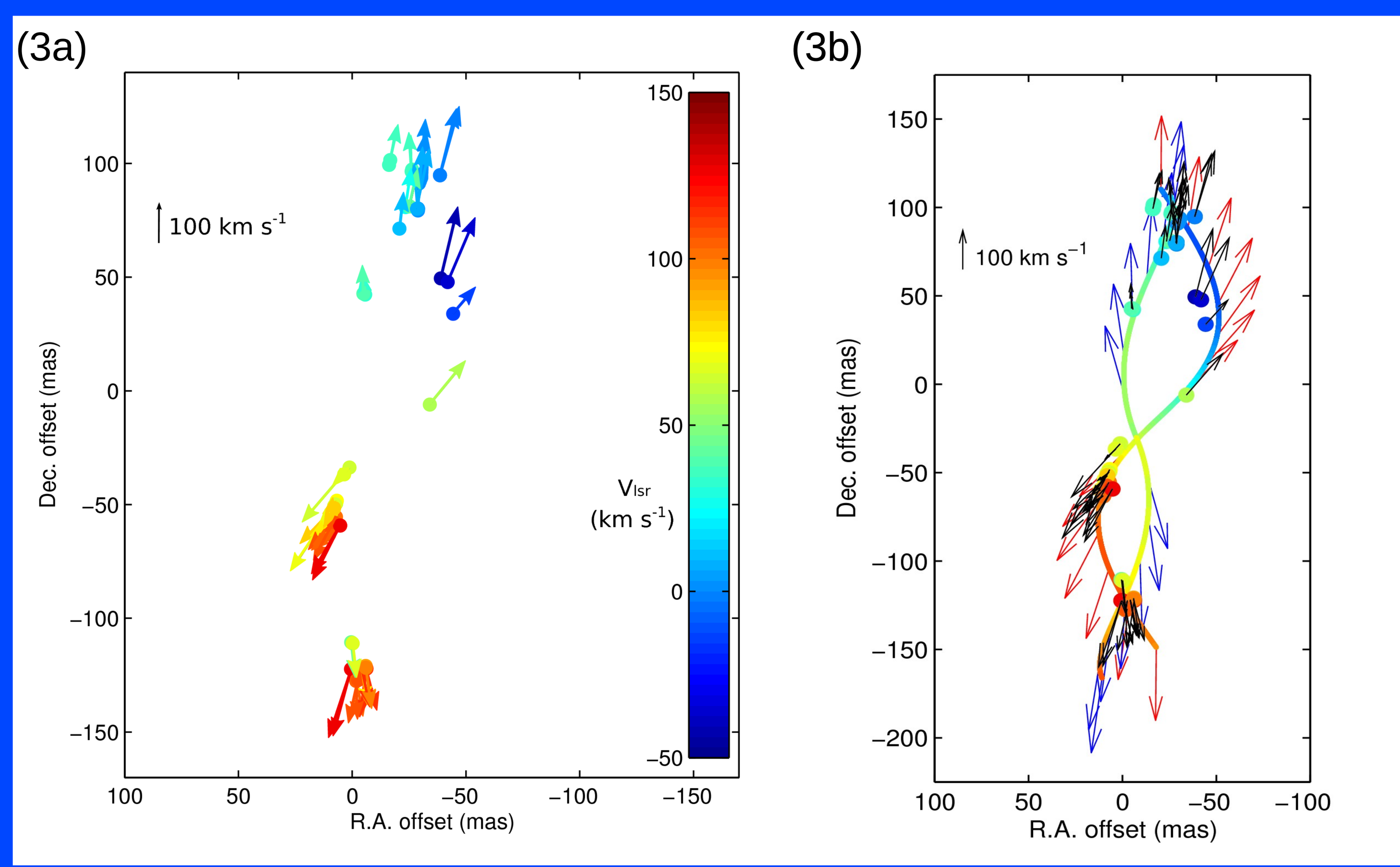


Figure 3a: Proper motions of 54 water maser features which can be traced out in any 3 consecutive epochs are shown.

Maser features from the same driving source should originated from the same point. Here the velocity vectors can be divided into two groups, and the two groups converge to different origins.

A single jet is difficult to explain the deviation of vector direction and the overlapping of maser features with different line-of-sight velocity as shown in figure 2.

The double-jet model becomes more favorable!

Proof! In figure 3b:
Black arrows: Observed proper motions
Red and blue arrows: Model predicted proper motions for jet 1 and jet 2.
The observed and predicted directions, do match with each other!

Discussion

IRAS 18286−0959 is about 4.0 kpc apart from us according to an annual parallex analysis (*Imai et al., in preparation*). The visual distance between the two apparent dynamical centers will be about (and at least) 64 AU at 4.0 kpc.

We propose that the "two" jets are actually formed by one single source but at different instants, and the source itself has a secular motion across the sky, from the position of jet 2's driving source to that of jet 1. This argument can explain why jet 2 has almost no maser spots along the jet path other than at its tips. If the outflow is episodic such that it will stop and resume after some time, the maser spots at the tips of jet 2 mark the end of the previous ejection. The estimated "age" of this jet (~30 years) then reveals the time passed since this ejection. Jet 1 has a dynamical age of ~19 years, which means at least 19 years ago the driving source was located at (or very near to) the current position, which is the fitted center of jet 1. In that case the driving source has taken less than 11 years to travel 64AU (if only the 2D motion is considered), and its secular motion velocity is estimated to be ~27 km s^{-1}, if constant.

A detailed report on the current project will be given in *Yung et al. (2010, ApJ, submitted)*.

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