Modeling the circumstellar structure of Water Fountain evolved sources

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Abstract

We report 1mm and 3mm observations, carried out with IRAM 30m telescope and the Australia Telescope of Compact Array (ATCA), respectivelly, of 11 of the 14 candidate “water-fountain” evolved stars reported to date. Using these data, together with observations at shorter wavelengths taken from the literature, we built the spectral energy distribution (SED) between 0.8-3300 microns of these sources. The broadband SEDs are fitted with radiative transfer models which include a star, a circumstellar disk or toroid, and an expanding shell. The modeling of the sources allows us to estimate physical parameters of the components such as luminosities, masses, sizes, dust grain properties, and geometry. Our models indicate in order to fit mm wavelenghts data we required massive (of the order of $2M_{sun}$) disks and envelopes.

Observations

IRAM - 30m: 1 mm (8 of 14 candidates)
ATCA: 3 mm, 3.3 mm (5 of 14 candidates)

Water – Fountain sources

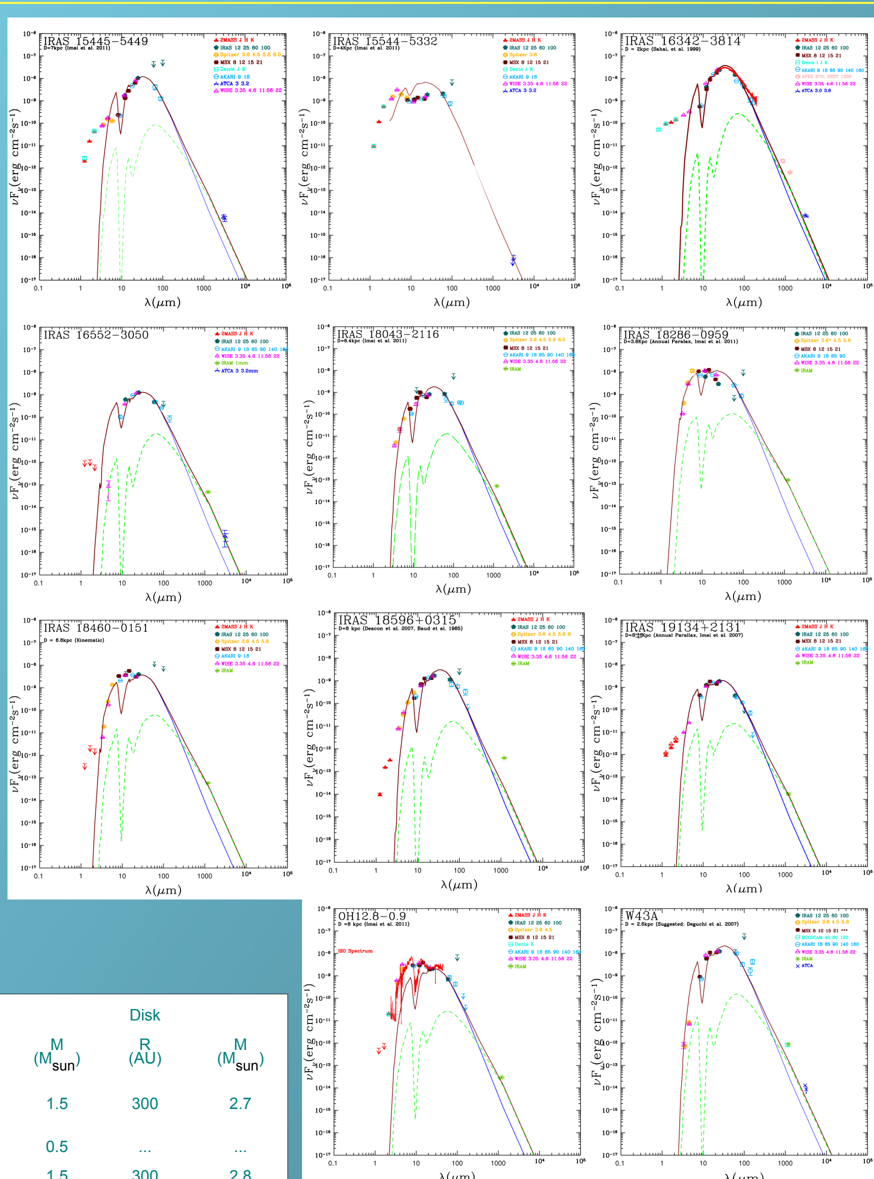
These sources are late asymptotic giant branch (AGB) or post-AGB stars. They show high-velocity water maser emission greater than 50km/s. This emission traces highly collimated mass-loss with very short dynamical scales (<100yr; Sahai, et al. 2005, Imai, et al. 2007). It presents one of the first manifestation of collimated mass-loss in evolved stars. Optical and MIR images (Lagadec, et al 2011) of these sources show a bipolar structure with a dark equatorial waist (most likely tracing a disk or a torus). These features are surrounded by extended and optically thick dusty envelope, whose emission dominates the FIR wavelength range.

Models

We use new radiative transfer models that include a central star, a spherical *expanding* envelope (with bipolar cavities), and a circumstellar disk (based on models by Kenyon et al. 1993; and D'Alessio et al. 2006). The grain composition of the envelope is similar to that assumed for the disk. The disk model takes into account grains as large as 1mm in the midplane. Model-fitting allowed us to obtain fundamental physical parameters which are listed in the table below.

Conclusion

In order to fit the millimeter wavelength data we require massive envelopes (usually of the order of $2M_{sun}$). The masses of the disks are also high, and in some cases very high ($>>2M_{sun}$). In order to fit the peak of the SED we require luminosities in the range 4000-7500L_{sun}, indicating that the progenitor of these sources was a relatively massive star.



NAME	L (L_{sun})	I (deg)	Routt (AU)	ρx10^{-5} (g/cm^3)	M (M_{sun})	R (AU)	M (M_{sun})
	Envelope					Disk	
IRAS 15445-5449	60 00	70	10000	2.7	1.5	300	2.7
IRAS 15544-5332	4000	20	10000	1.0	0.5	...	...
IRAS 16342-3814	6000	70	10000	2.7	1.5	300	2.8
IRAS 16552-3050	6000	30	10000	2.7	1.4	300	2.6
IRAS 18043-2116	6000	70	10000	2.7	1.5	300	2.7
IRAS 18286-0959	7500	70	10000	1.0	0.5	300	2.7
IRAS 18460-0151	7500	40	10000	2.0	1.1	350	3.9
IRAS 18596-0315	6000	70	10000	2.7	1.5	300	2.7
IRAS19134+2131	6000	85	10000	1.5	0.8	300	2.7
W43A	6000	70	10000	2.7	1.5	300	2.7
OH12.8	6000	70	10000	1.5	0.8	350	3.1

References

Kenyon, Calvet & Hartmann, 1993
D'Alessio, et al. 2006
Imai, et al. 2007
Lagadec, et al. 2011
Sahai, et al. 2005