SMA Imaging of the HRL Masers in MWC349A

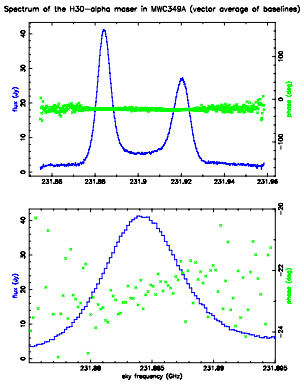
Jonathan Weintroub[1], James Moran[1], Ramprasad Rao[2], Hiroko Shinnaga[3], David Wilner[1] & Ken Young[1]

[1]*Harvard-Smithsonian Center for Astrophysics, 60 Garden Street, Cambridge, MA 02138 USA* email contact: jweintroub@cfa.harvard.edu

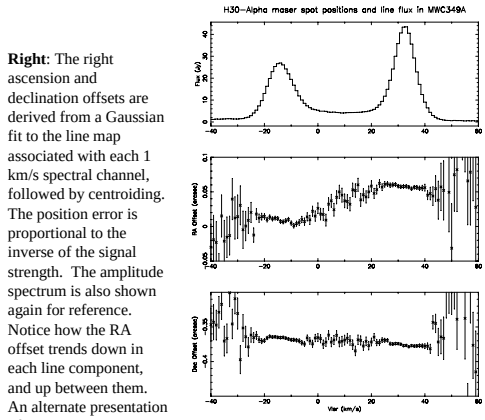
[2] *Academia Sinica Institute of Astronomy & Astrophysics, 645 North A'ohoku Place, Hilo, HI 96720*

[3]*Caltech Submillimeter Observatory, 111 Nowelo Street, Hilo, HI 96720*

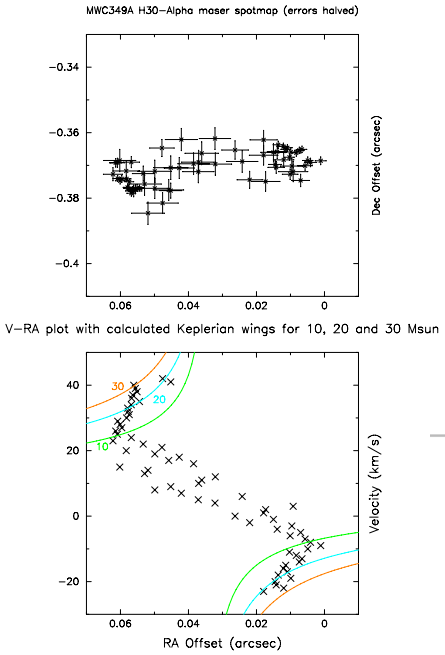
Abstract: In September 2004 and September 2005 we used the SMA in an extended configuration to map the hydrogen recombination line (HRL) maser spots that originate in the envelope of the peculiar star MWC349A. H30 Alpha (231.9 GHz), H26 Alpha (353.6 GHz) and H21 Alpha (662.4 GHz) data were acquired. We measured spot positions in the line over a 100 km/s velocity range with 1 km/s spectral resolution. The positions of the maser spots can be traced continuously from the extremes of the red- and blue-shifted peaks of the spectrum. The position-velocity relationship is quite remarkable, and reminiscent of that of NGC4258. The masers appear to trace a nearly edge-on disk like structure in approximate Kelperian rotation. However the "wings" of the position-velocity plot are much too steep for a simple Keplerian prescription to be correct. We suggest that the high velocity masers may trace spiral density arms in Keplerian rotation. The rapid change of azimuthal angle with radius, characteristic of a spiral, leads to the steep rotation curve. (The maser data presented here are from the H30 Alpha observations only.)



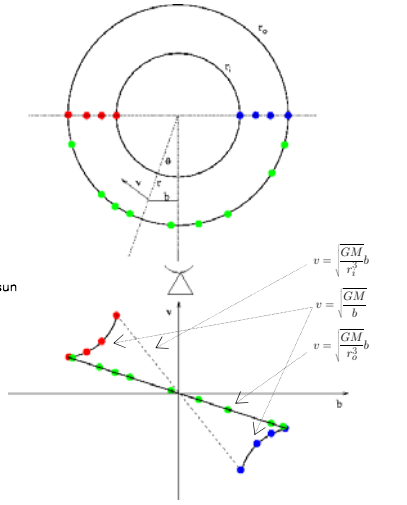
Left: The vector averaged visibility data of all baselines from the 12 September 2004 observations of the H30 Alpha line. Passband, gain and flux calibrations have been applied. The bottom panel shows a detail of the visibility spectrum in the redshifted component. The scatter in the phase is small because of the high SNR in the line, and because of the spectral components are in close angular proximity.



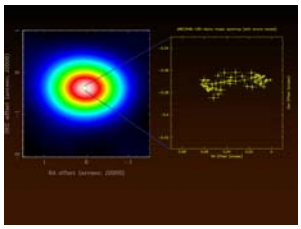
Right: The right ascension and declination offsets are derived from a Gaussian fit to the line map associated with each 1 km/s spectral channel, followed by centroiding. The position error is proportional to the inverse of the signal strength. The amplitude spectrum is also shown again for reference. Notice how the RA offset trends down in each line component, and up between them. An alternate presentation of this is the velocity-RA plot shown above right.



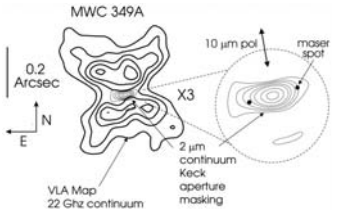
Above: The maser position data is plotted as a spotmap in the upper panel. We see that they trace the shape of the nearly edge-on disk. The maser spots are clustered approximately 0".05 apart in right ascension (RA), but are also present between the clusters. The variation in declination across the disk is very small. Thus it is instructive to plot radial velocity on an expanded scale against RA which produces the lower panel. The velocity-RA plot shows a region of apparently rigid rotation with wings reminiscent of the Keplerian wings of NGC4258. However as the three candidate Keplerian curve fits corresponding to 10, 20 and 30 solar masses show, the wings are in fact much steeper. The simple Keplerian prescription cannot be correct.

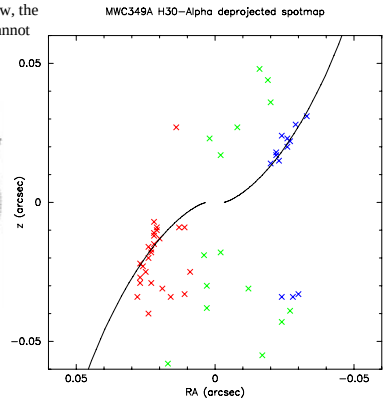


Above: A simple model showing the maser positions within a purely edge-on unfilled uniform disk in true Keplerian rotation. The small filled circles represent the masers, and we show their position within the disk, and their corresponding position on the velocity-position diagram. Were the masers randomly distributed within the toroidal ring, they would randomly fill the characteristic "bowtie" envelope.



Left: Where does the spotmap lie in relation to the continuum image? For the extended SMA at 231.9 GHz the continuum image is unresolved. Still we can co-register the spotmap on the continuum image and thus show that the masers are centered on the continuum. For a more detailed view of the continuum showing its hourglass structure, see the figure to the **right**, which is from Danchi et al (ApJ 562:440, 2001), and shows a 22 GHz VLA continuum map (White and Becker, ApJ 297:677, 1985) as well as Danchi et al. Keck aperture masking data, and the two H30 Alpha maser spots previously observed at OVRO (Planesas et al, ApJ 386:L23, 1992). The masers appear to lie in the waist of the hour-glass shaped continuum.





Above: A view of the maser distribution along an axis perpendicular to the line of sight and the axis of the maser distribution. The deprojection was accomplished by assuming that the masers are in Keplerian orbits. The red- and blue-shifted features are assumed to arise from in front of and behind the midline respectively. The rapid change in azimuth angle with velocity can explain the PV plot. A possible spiral model is plotted over the data

Parameters of the ionized torus as traced by our observed H30 Alpha maser components
(Distance = 1200pc, so 1 sec =1200AU = 1.8 x 10^{16} cm)

Position angle of disk: ~100 degrees Outer radius: 0".028 (33 AU)
Inclination: greater than 75 degrees Inner radius: 0".018 (22AU)
Thickness: less than 0".02 (25 AU) Mass: ?

From recent VLA continuum observations of Tafoya, *et al.* ApJ **610**, 827, 2004, the expected radius of the continuum source at 230 GHz is 0".022 or 26 AU and the position angle of continuum emission is +10 degrees. Interestingly, recent VLA observations show significant changes to the continuum source morphology relative to that reported in Tafoya, *et al.* (Luis F Rodriguez, private communication.)