Unique Radio Stars: MWC 349A

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“Radio Stars: from kHz to THz”
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Introduction
Optical/Radio monitoring of variability
Optical/IR/Radio study of the surroundings
Binary? Triple?
Major problem: evolutionary status
Conclusions
Introduction
(Basic parameters of MWC 349A)

- $D = 1.5 \pm 0.3$ kpc
- $m_V = 13^m \pm 0.3^m$
- $A_V = 9.7^m \pm 0.3^m$
- $T_{\text{eff}} = 25,000 \pm 5,000$ K

\[
L = (7\pm3) \cdot 10^5 \, L_{\text{Sol}}
\]
Introduction
(Uniqueness of MWC 349A)

A dense ultra-compact bipolar circumstellar H+ region which makes MWC349A:

• An unusually bright source of Hα and other emission lines

• The only known high-gain atomic (H) maser and IR laser (in Hydrogen recombination lines)

• The brightest star in cm continuum
What is the evolutionary stage of this unique star?

No observable absorption spectrum → all the conclusions about the evolutionary status come from indirect evidence:

• Variability (periodicity, multiplicity?)
• Environment (molecular clouds? Very young objects?)
Variability (old data)
Gottlieb & Liller, 1978

PHOTOMETRIC HISTORIES

MWC 349

YEAR

1900.0  1920.0  1940.0  1960.0  1980.0
f) \( \text{V1515 Cygni} \)

Infrared objects, identified by Cohen (1974) as object 22 and a new object “a” which is actually a double object. The visual and infrared magnitudes of the objects are shown in Table 1. The visual magnitudes of the double object were combined by Herbig in an extensive study of V1515 Cyg. This curve shows the rise in brightness from \( \sim 1949 \) to the present, with mostly upper limits before that time.

Figure 8 shows the annual mean \( B \) magnitudes from 1927-1954.
9-year periodicity???

Jorgenson et al. 2000
Structure and Environment
(AU scale)
Radio Continuum at 13mm (gray scale) and 7mm (isophotes) VLA (Tafoya et al. 2004)
Zhang et al.
2017; SMA
IR and Radio Superimposed
(Tafoya et al. 2004)
Zhang et al.
2017; SMA
Variability (new data)
MMO VRI Photometry
(Lowell 31” + NURO CCD)
MWC349: H-alpha (MMO, 24’’; in preparation)

235 days?
Gordon et al. 2001 (ARO, 12m)
235 days?
H30-alpha line
MMO; ARO 10m;
in preparation
H30-alpha line
Average velocity of the Red and Blue components:
The velocity of the star’s center of mass?
Average Velocity, km/s vs. MJD

~1400d?
Structure and Environment (parsec scale)
Discovery of a pc-scale bipolar structure (Spitzer/MIPS)

Gvaramadze & Menten, 2012

Strelnitski et al. 2011; 2013
Figure 1. CO J = 2-1 contour maps of $T_A^*$ overlaying the Spitzer MIPS 24 μm image of the 10' x 10' vicinity of MWC 349A. The maps cover V$_{LSR}$ from -12.5 to +10.0 km s$^{-1}$, binned by 1.5 km s$^{-1}$. The velocity of the bin’s center is indicated in the top left corner of each map. The $T_A^*$ contours are shown with 0.5 K intervals, beginning with $T_A^*$ = 1.0 K. The color bar gives the brightness of the 24 μm emission in units of MJy sr$^{-1}$. It is log stretched to show the low-level emission better.

(A color version of this figure is available in the online journal.)

Strelnitski et al. 2013
(Spitzer – IR; ARO 10m – CO)

MWC 349; V(LSR) = +9 km/s

CO cloud; V(LSR) = +9 km/s
Young, star-birth pc-scale environment of MWC 349 (Strelnitski et al. 2013)

“Cradle” nebula
Age < 2 Myr
Pc-scale bipolar flows are observed around both old and young massive stars.
The strongest argument for MWC349A being old:
2.4” distant companion B0III (5 Myr old)
(Cohen et al 1985)
The radial velocity difference of MWC 349 A and B is >35 km/s \(\rightarrow\) they are NOT gravitationally bound (Drew et al 2013, ApJ, in press)

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Spatial Res., arcsec</th>
<th>Spectral Res., km/s</th>
<th>(V_B) (HEL), km/s</th>
<th>(\Delta V_{BA}), km/s</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tillenghast/TRES</td>
<td>2.4</td>
<td>6.8</td>
<td>30(\pm)10</td>
<td>40(\pm)10</td>
<td>Average over three lines</td>
</tr>
<tr>
<td>Keck/HIRES</td>
<td>0.7</td>
<td>6.25</td>
<td>27.2(\pm)1.5</td>
<td>37(\pm)2</td>
<td>A single line</td>
</tr>
<tr>
<td>CFHT (Manset et al. 2017)</td>
<td>5</td>
<td>26(\pm)1</td>
<td>36(\pm)2</td>
<td></td>
<td>Average over two lines</td>
</tr>
</tbody>
</table>
Conclusions

• MWC 349A is a unique hot massive star undergoing a phase of intensive loss of mass that seems to have started ~1000 years ago.
• Intensive studies in visible, IR and radio domains during the past 3 decades revealed many details of its variability and the structure of the AU- and parsec-scale environment.
• Its evolutionary stage remains unclear: it may be an evolved (~5 Myrs) supergiant or the first case of a >10 M_{sol} PMS (<1 Myr) star seen just outside of its natal cloud.
• Careful study of the chemical and isotopic composition of its neutral and ionized disk and wind may help solve this dilemma.
• Care must be taken when comparing radial velocities from optical and radio observations (“radioastronomical” LSR uses old parameters of solar motion to apex!).