Unique Radio Stars: MWC 349A

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“Radio Stars: from kHz to THz”
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Outline

- ✓ 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 ± 0.3 kpc
- m_V = 13^m ± 0.3^m
- A_V = 9.7^m ± 0.3^m
- T_{eff} = 25,000 ± 5,000 K

$L = (7 \pm 3) \cdot 10^5 \, L_{Sol}$

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

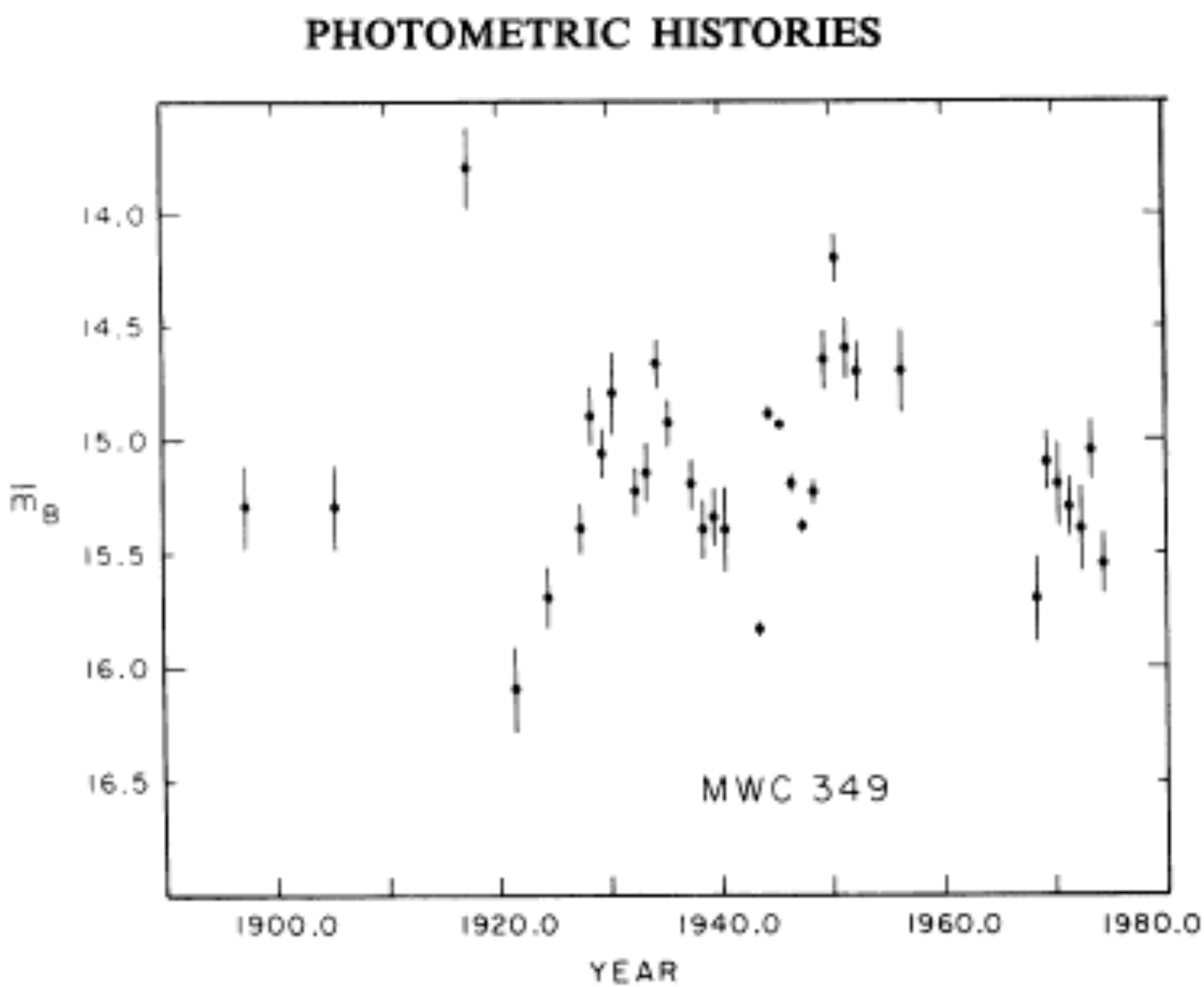
What is the evolutionary stage of this unique star?

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



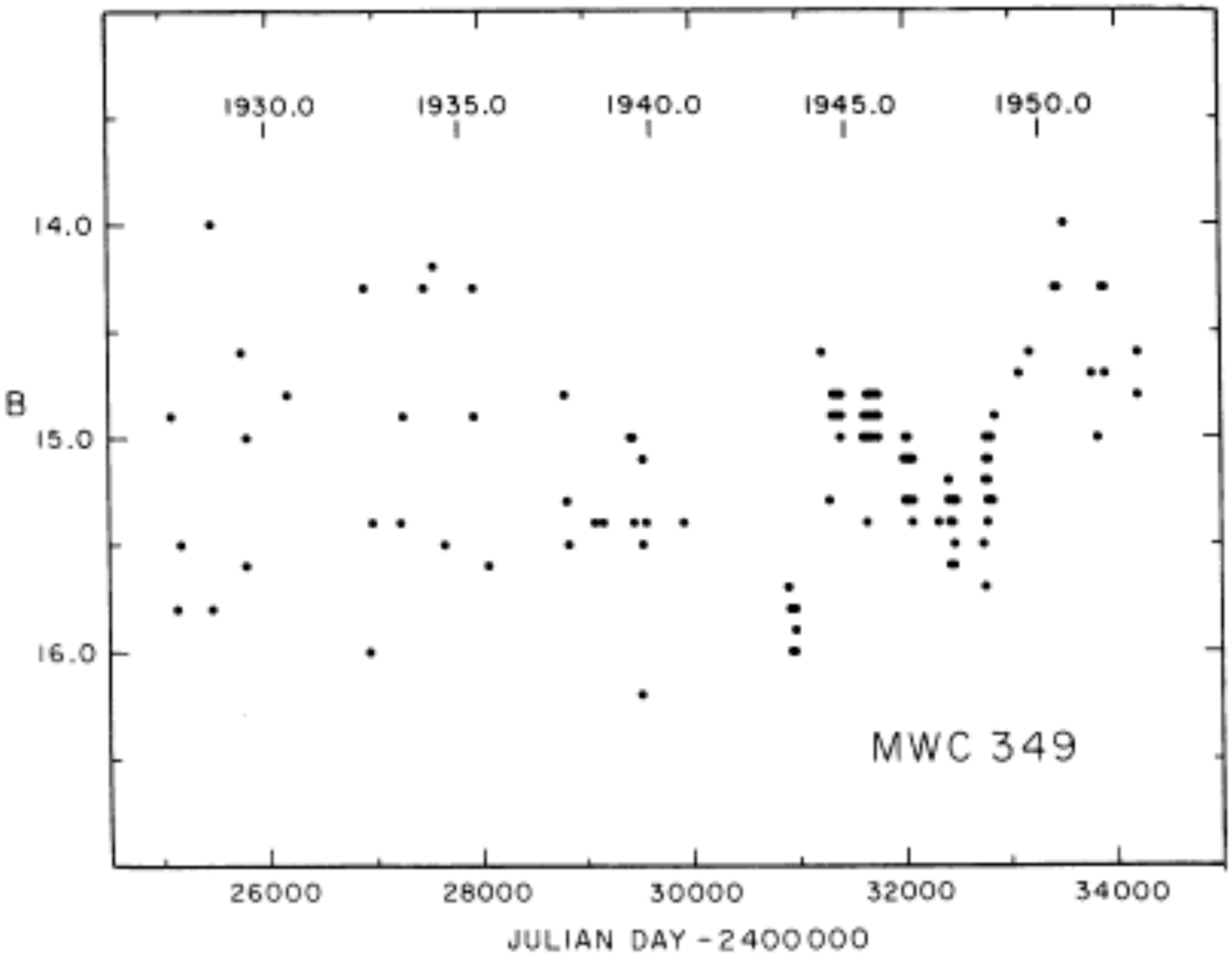
ut one of a temporary nature only.

f) *V1515 Cygni*

frared objects, identified by Cohen (1974) as
n 22 and a new object "a" which is actually

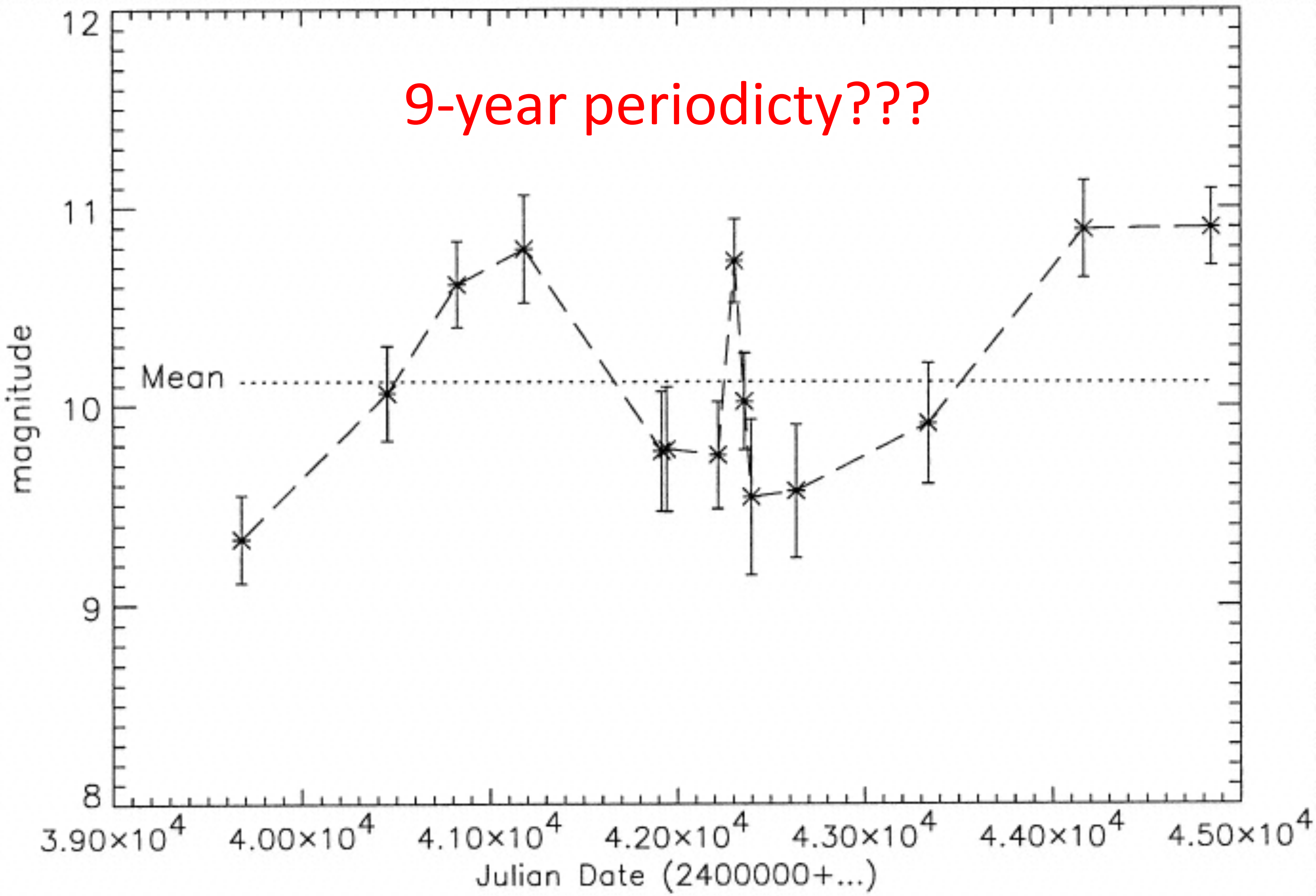
(see Herbig 1977) were combined by Herbig in a
extensive study of V1515 Cyg. This curve shows th
rise in brightness from ~1949 to the present, wit
mostly upper limits before that time.

Figure 8 shows the annual mean *B* magnitudes fro



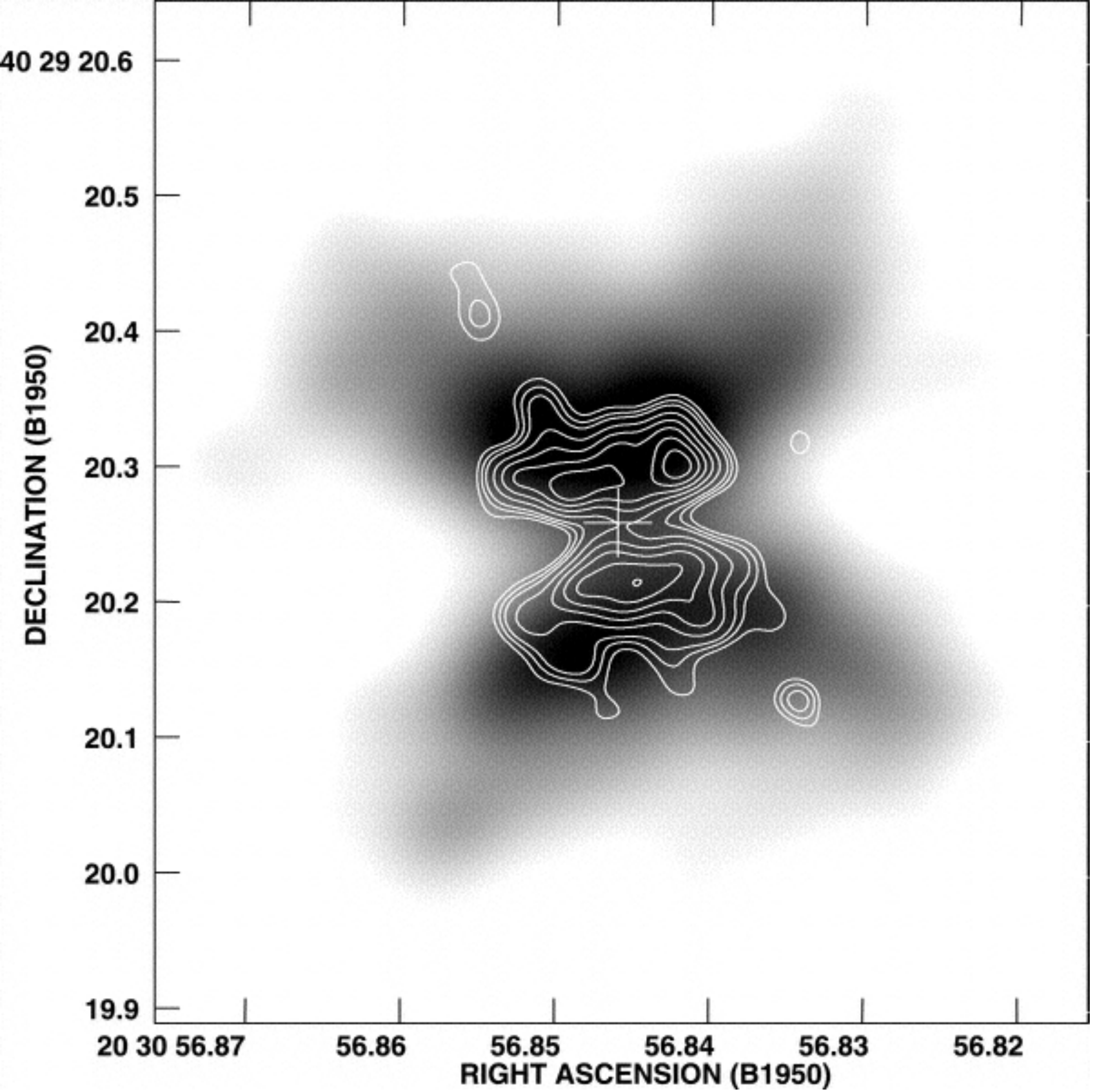
–Individual *B* magnitudes for MWC 349, 1927–1954, as measured on Harvard plates. The standard deviation of ea
ages close to ±0.10 mag.

9-year periodicty???



Jorgenson et al. 2000
(Red Harvard plates, 1967 – 1981)

Structure and Environment
(AU scale)

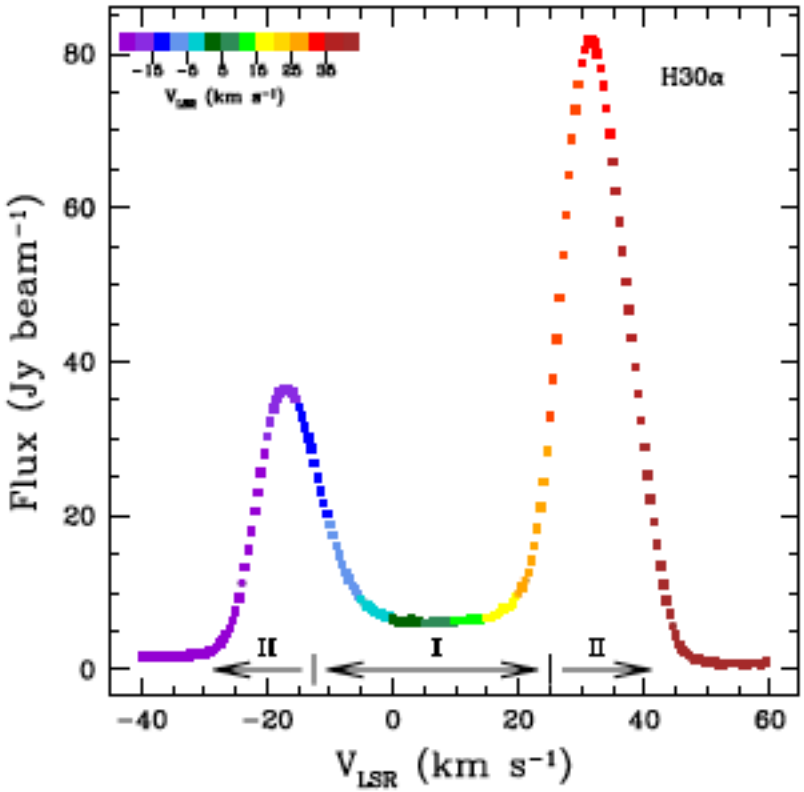


Radio Continuum

at 13mm (gray scale)

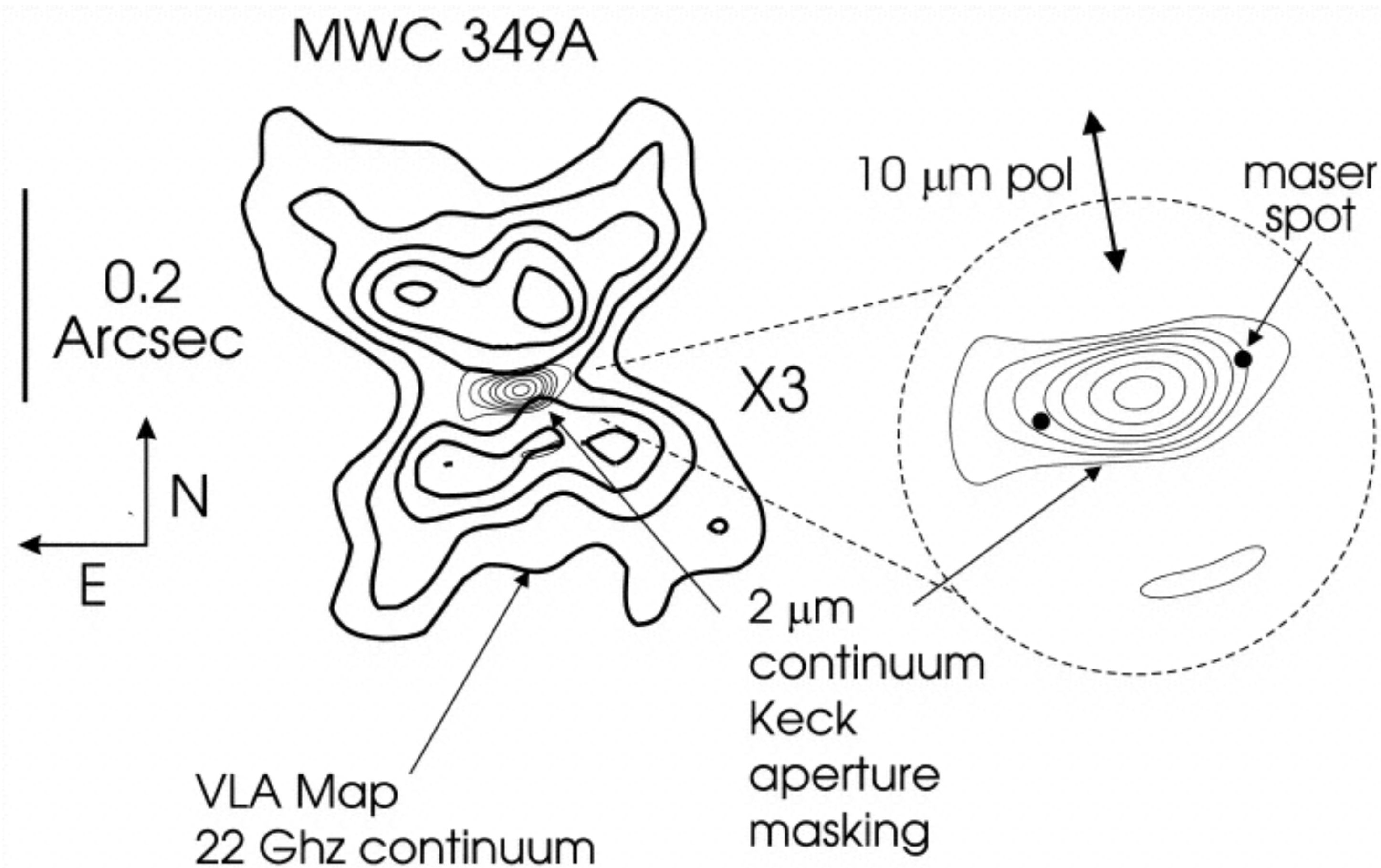
and 7mm (isophotes)

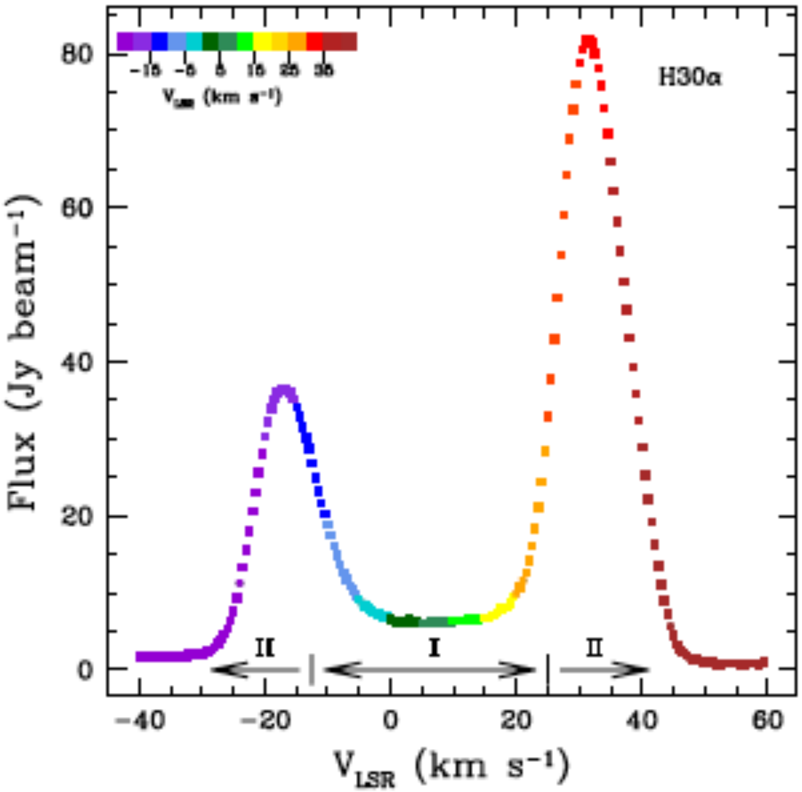
VLA (Tafoya et al. 2004)

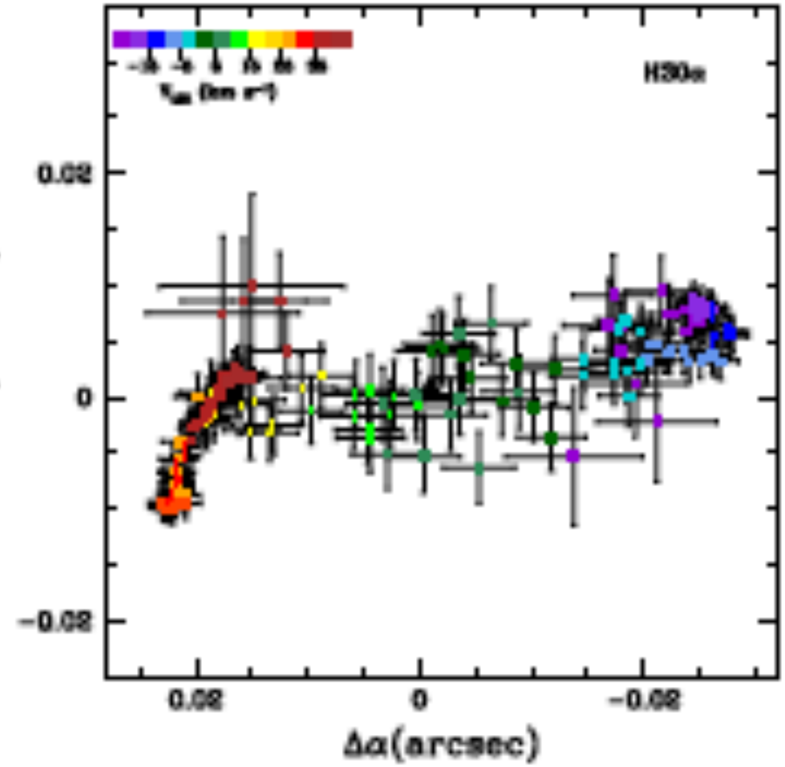


Zhang et al.
2017; SMA

IR and Radio Superimposed (Tafoya et al. 2004)



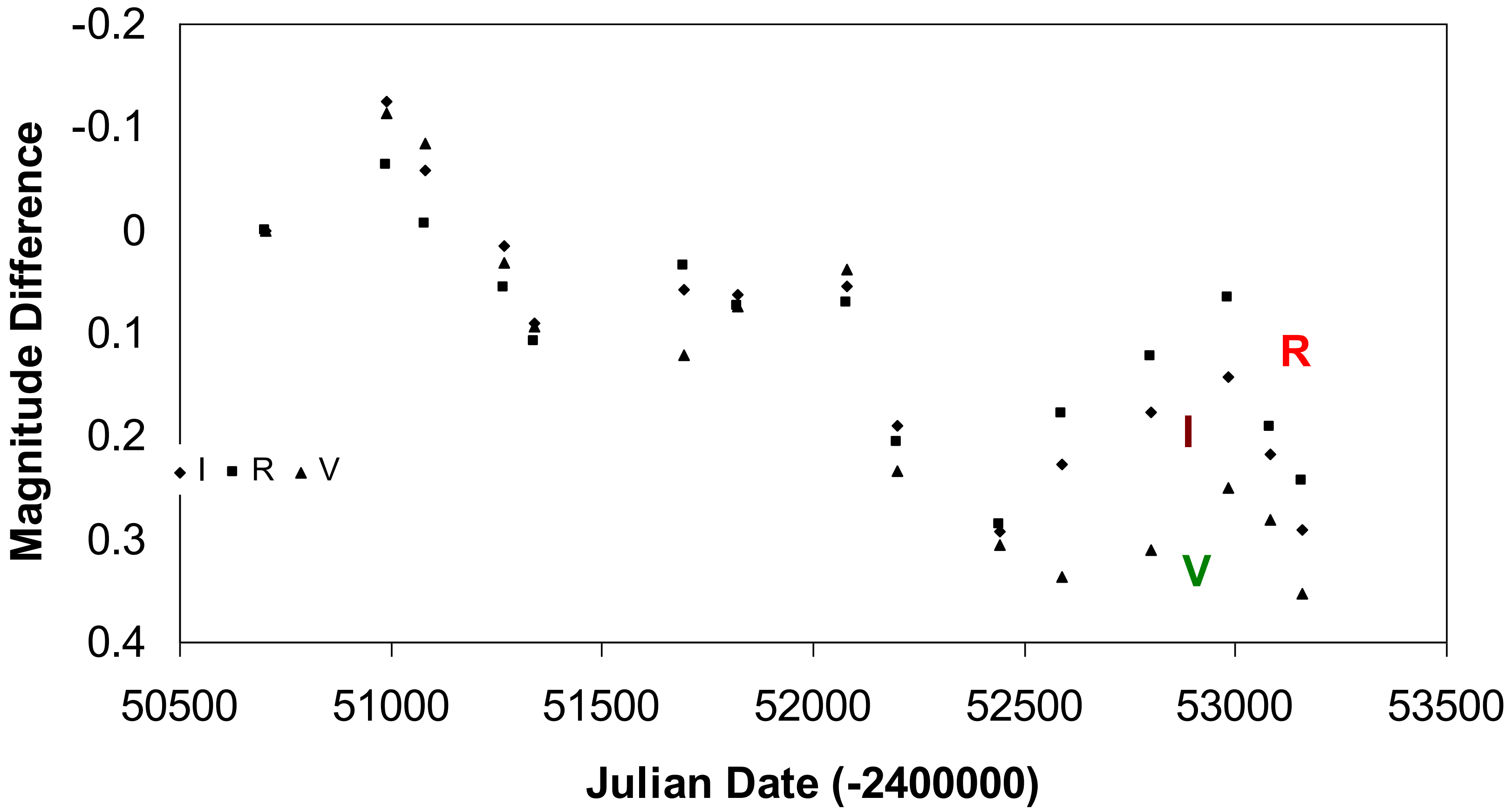


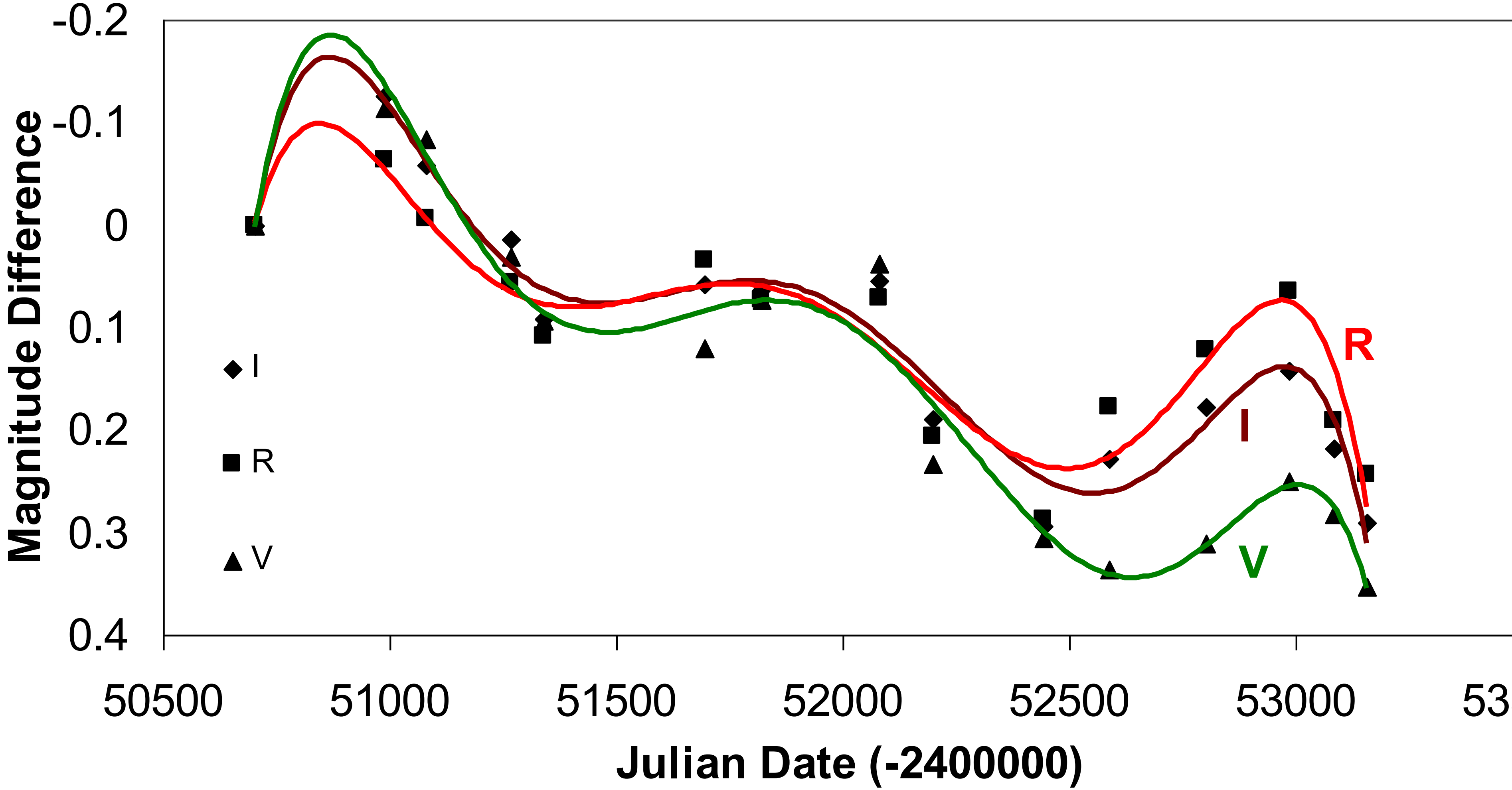


Zhang et al.
2017; SMA

Variability (new data)

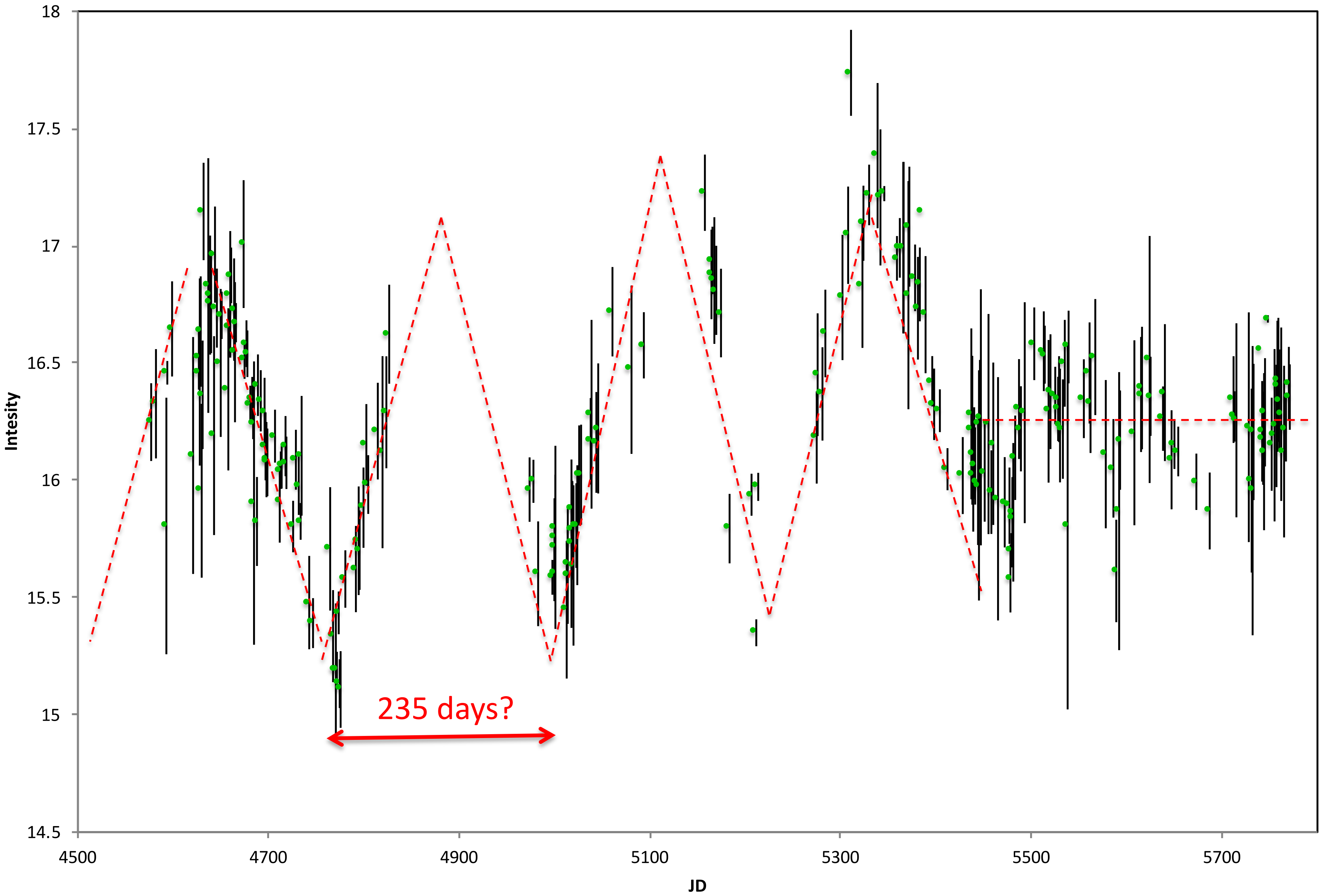
MMO VRI Photometry
(Lowell 31" + NURO CCD)

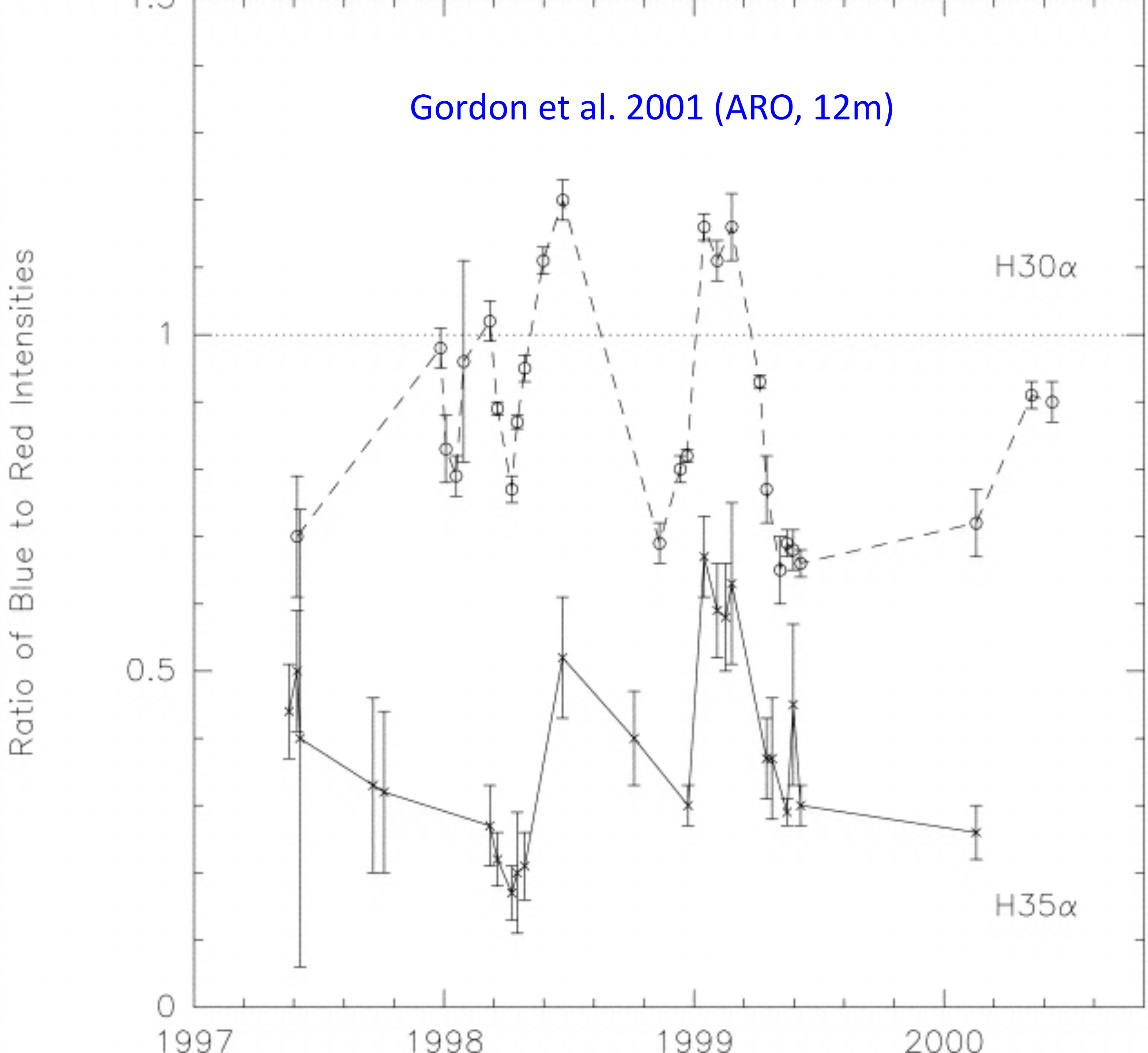




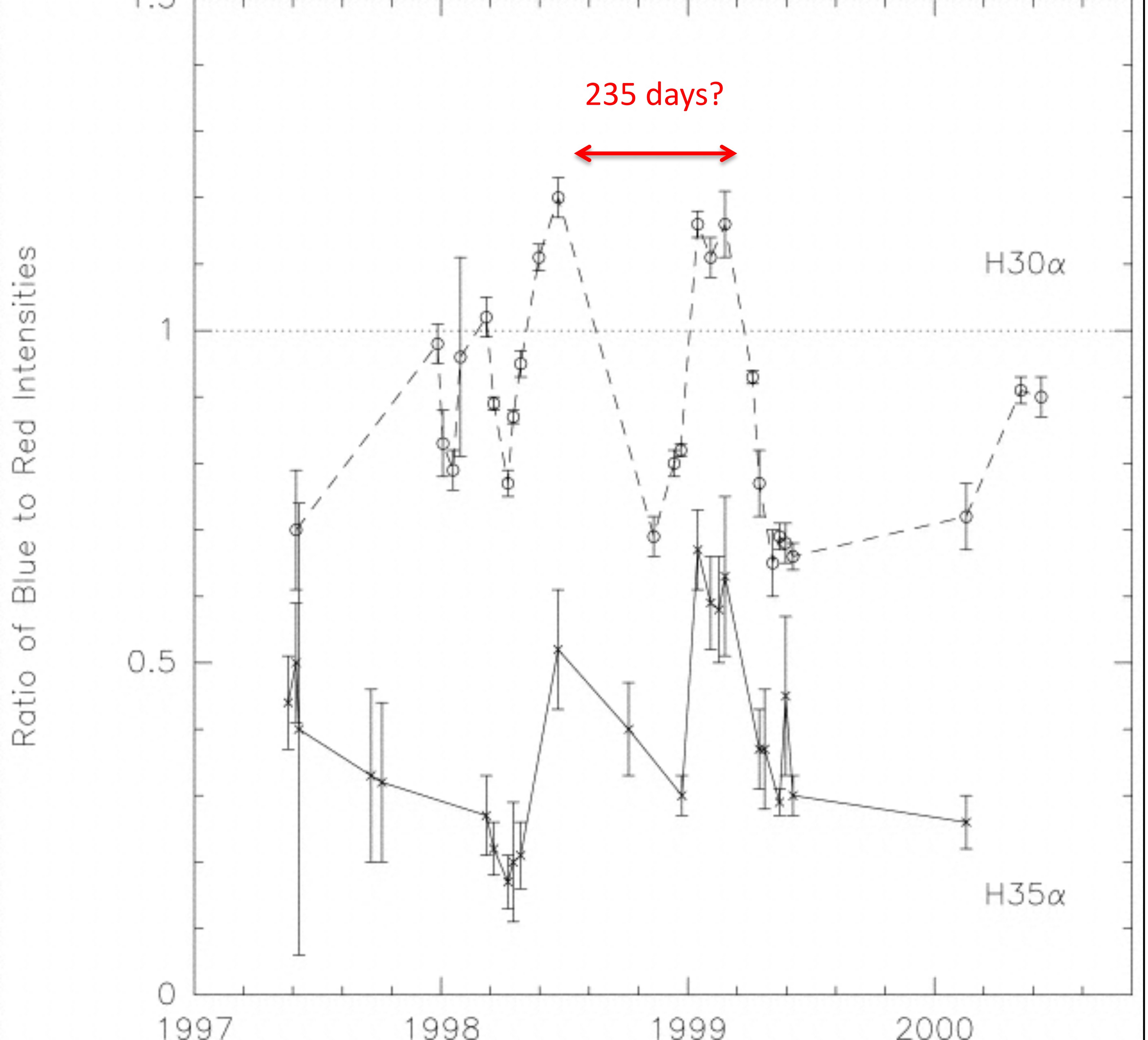
-0.2
-0.1
0
0.1
0.2
0.3
0.4
Magnitude Difference
I
R
V
R
I
V
50500
51000
51500
52000
52500
53000
53
Julian Date (-2400000)

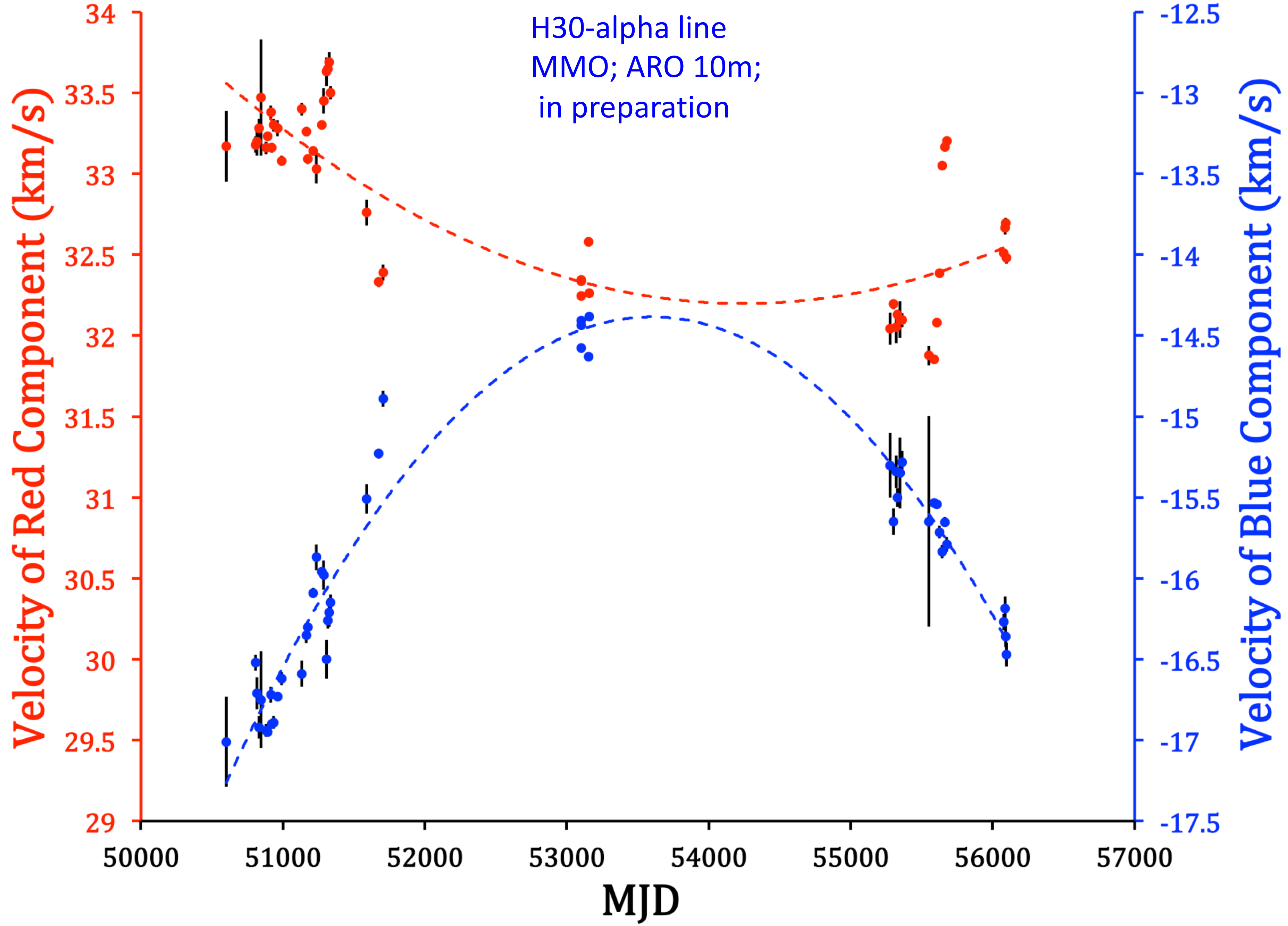
MWC349: H-alpha (MMO, 24”; in preparation)





Gordon et al. 2001 (ARO, 12m)
H30α
H35α
Ratio of Blue to Red Intensities
1
0.5
0
1997
1998
1999
2000

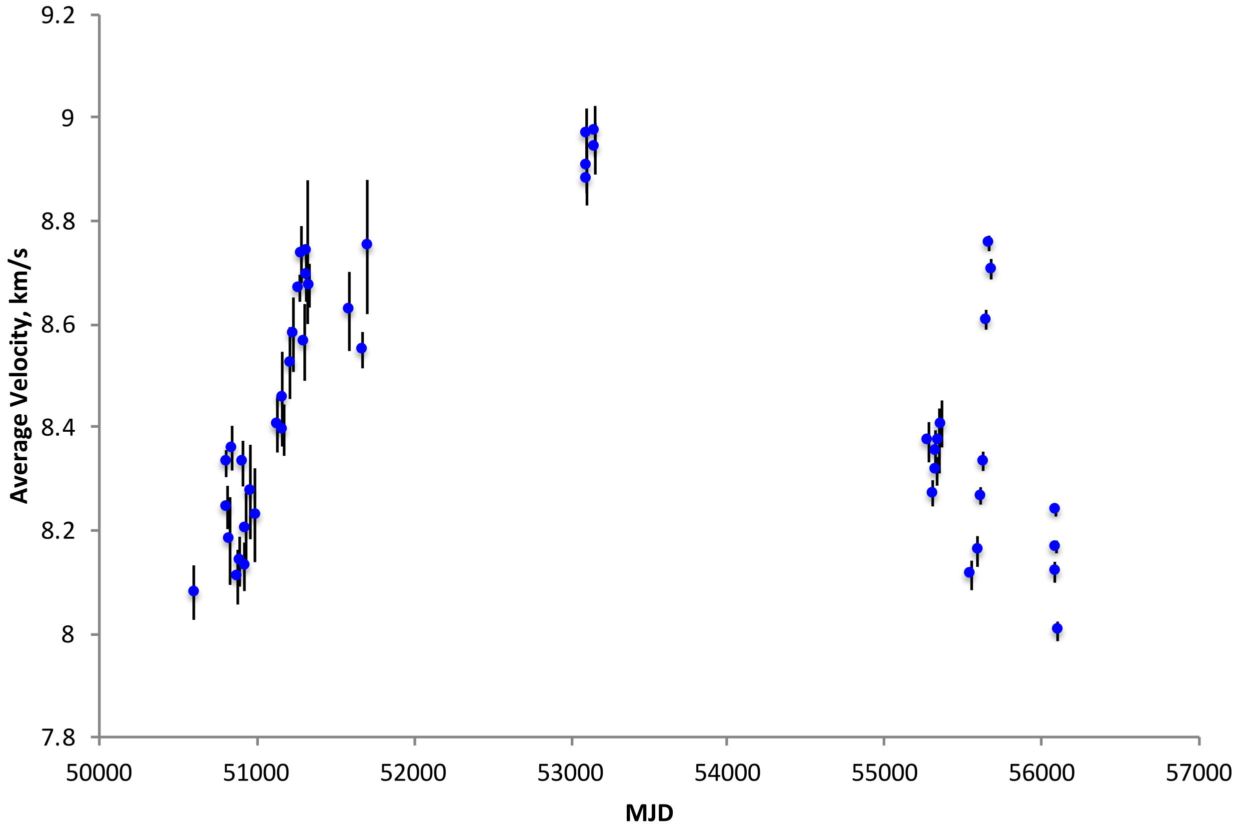

235 days?
H30α
H35α
Ratio of Blue to Red Intensities
0
0.5
1
1997
1998
1999
2000

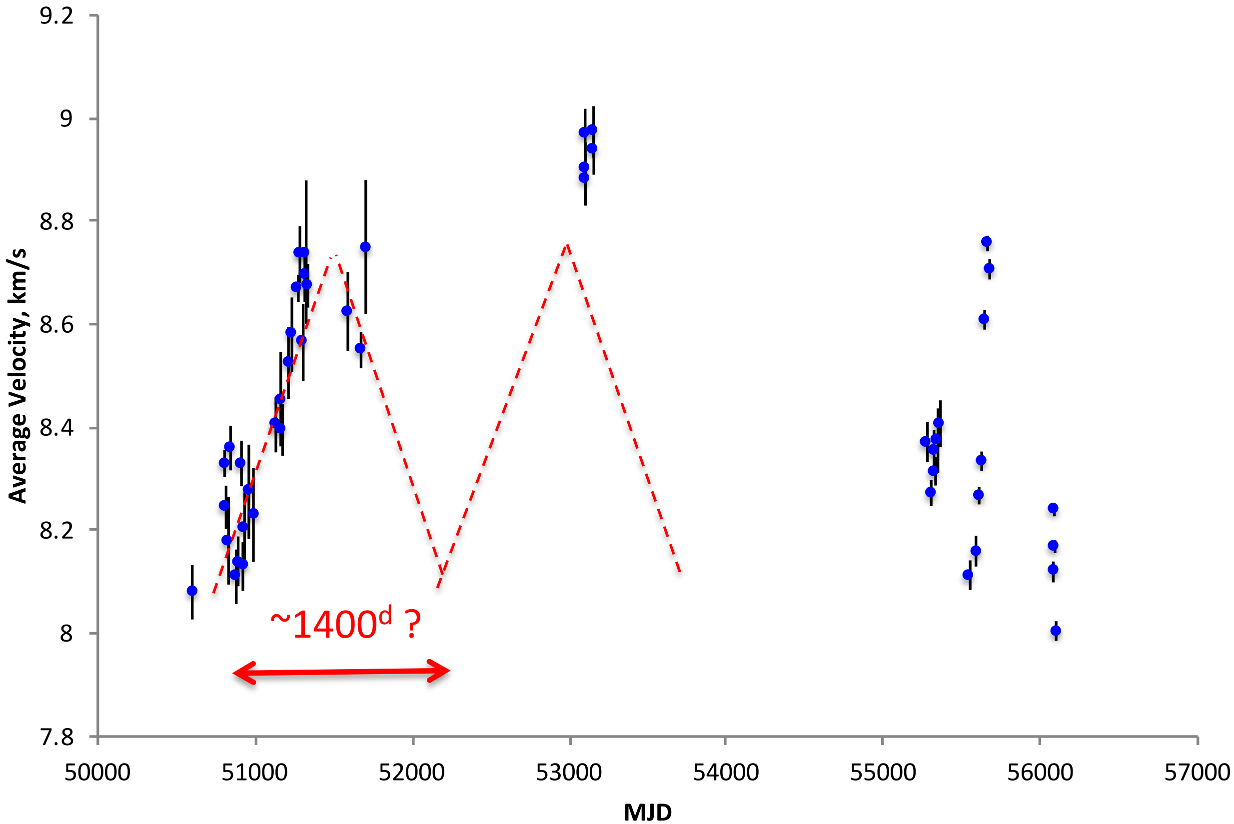

H30-alpha line
MMO; ARO 10m;
in preparation
Velocity of Red Component (km/s)
Velocity of Blue Component (km/s)
MJD
34
33.5
33
32.5
32
31.5
31
30.5
30
29.5
29
-12.5
-13
-13.5
-14
-14.5
-15
-15.5
-16
-16.5
-17
-17.5
50000
51000
52000
53000
54000
55000
56000
57000

H30-alpha line

Average velocity of the Red and Blue components:

The velocity of the star's center of mass?





9.2
9
8.8
8.6
8.4
8.2
8
7.8
Average Velocity, km/s
~1400^d ?
50000
51000
52000
53000
54000
55000
56000
57000
MJD

Structure and Environment (parsec scale)

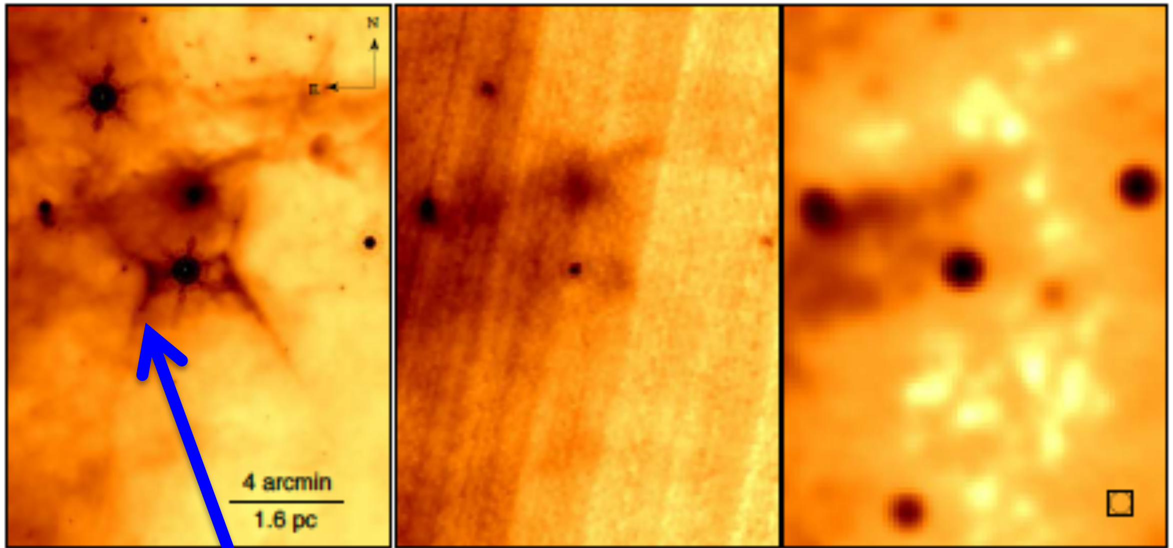
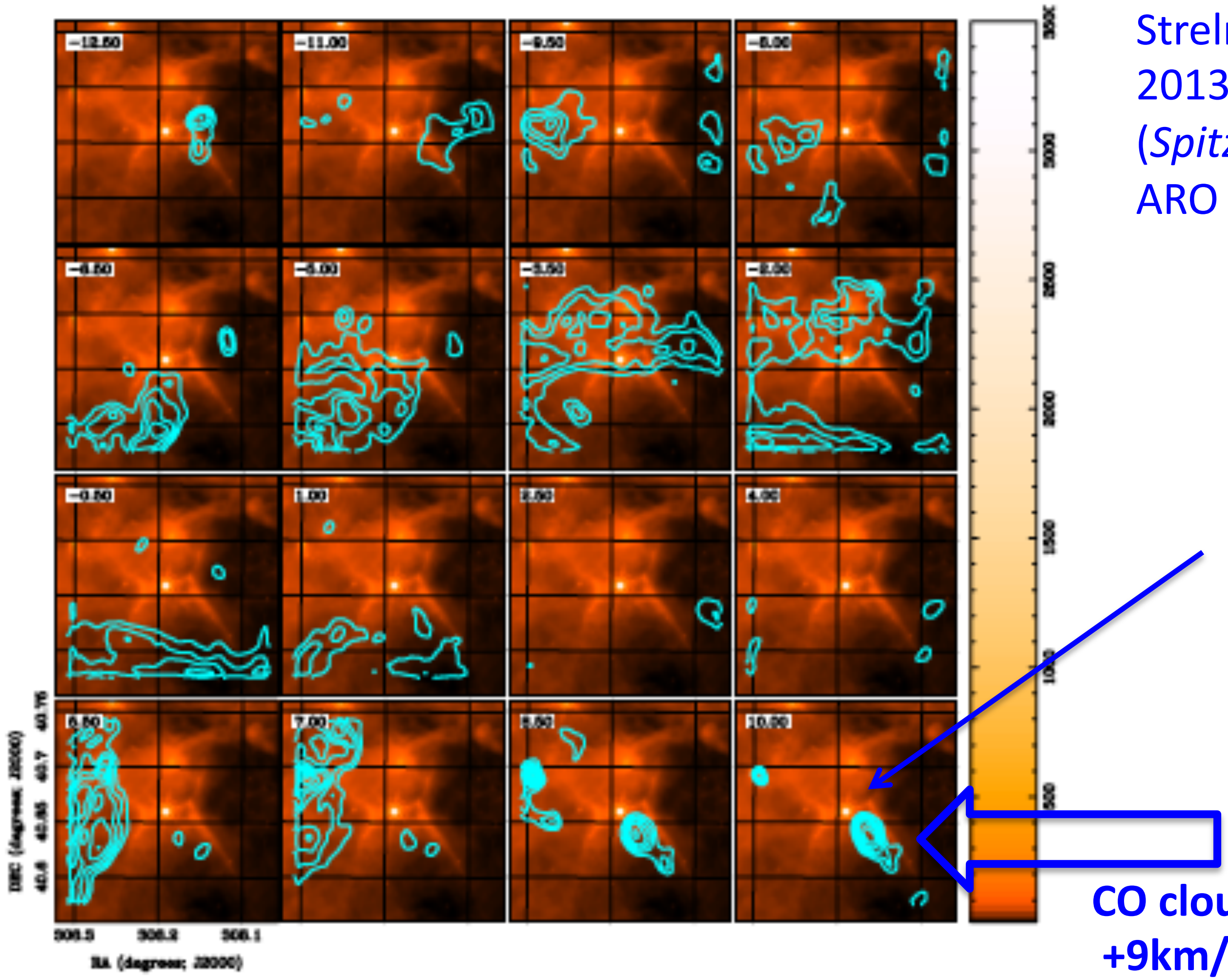


Fig. 1. *Left*: MIPS 24 μm image of the arcminute-scale bipolar nebula and its central star MWC 349A (a bright source in the waist of the nebula; note that a white dot at the centre of this source is due to saturation effect). *Middle* and *Right*: MIPS 70 μm and VLA 17 cm images of the same field. The 47″ FWHM restoring beam is represented in the bottom right corner of the radio image.

Discovery of a pc-scale bipolar structure (*Spitzer*/MIPS)

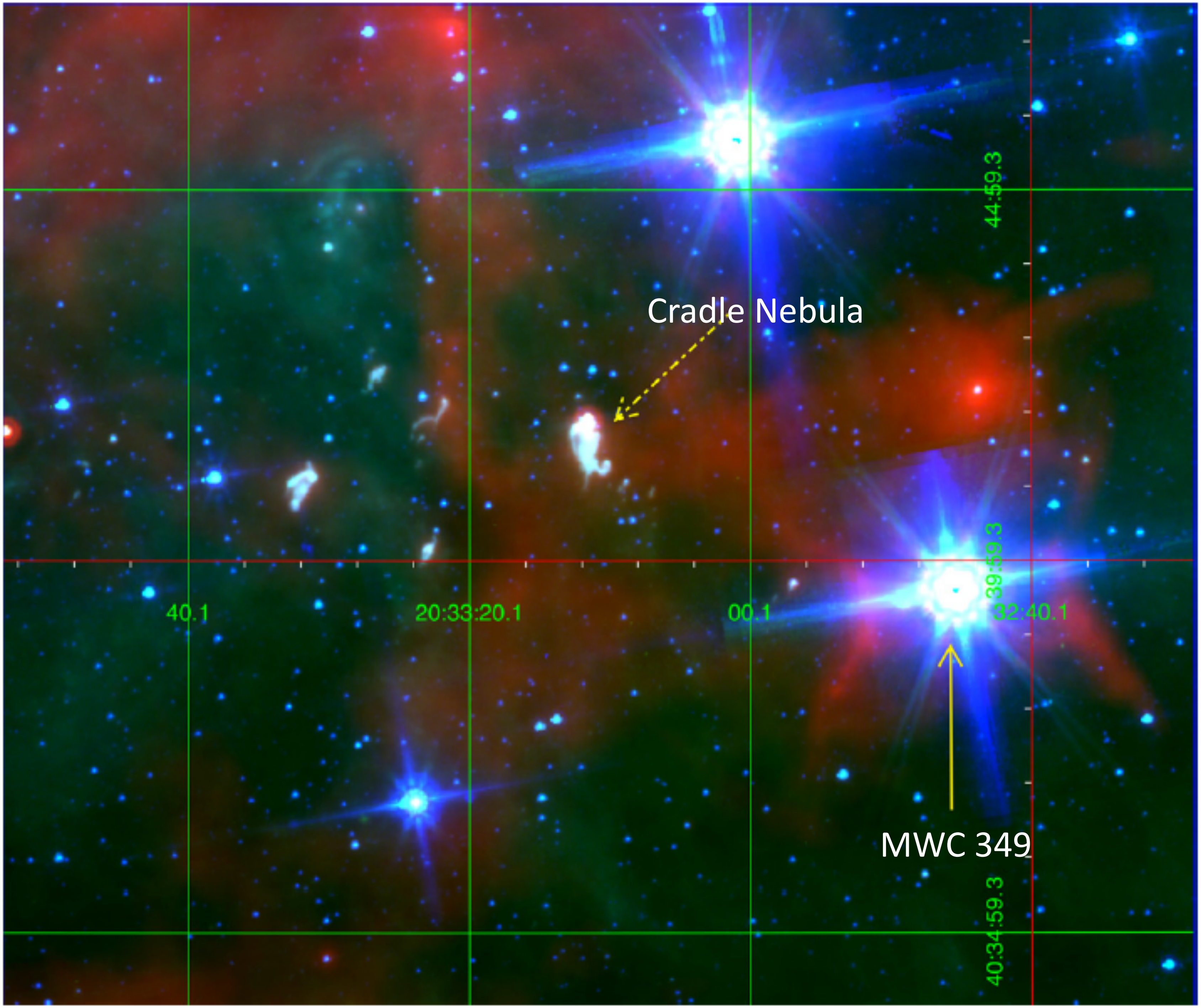
Gvaramadze & Menten, 2012

Strelnitski et al. 2011; 2013



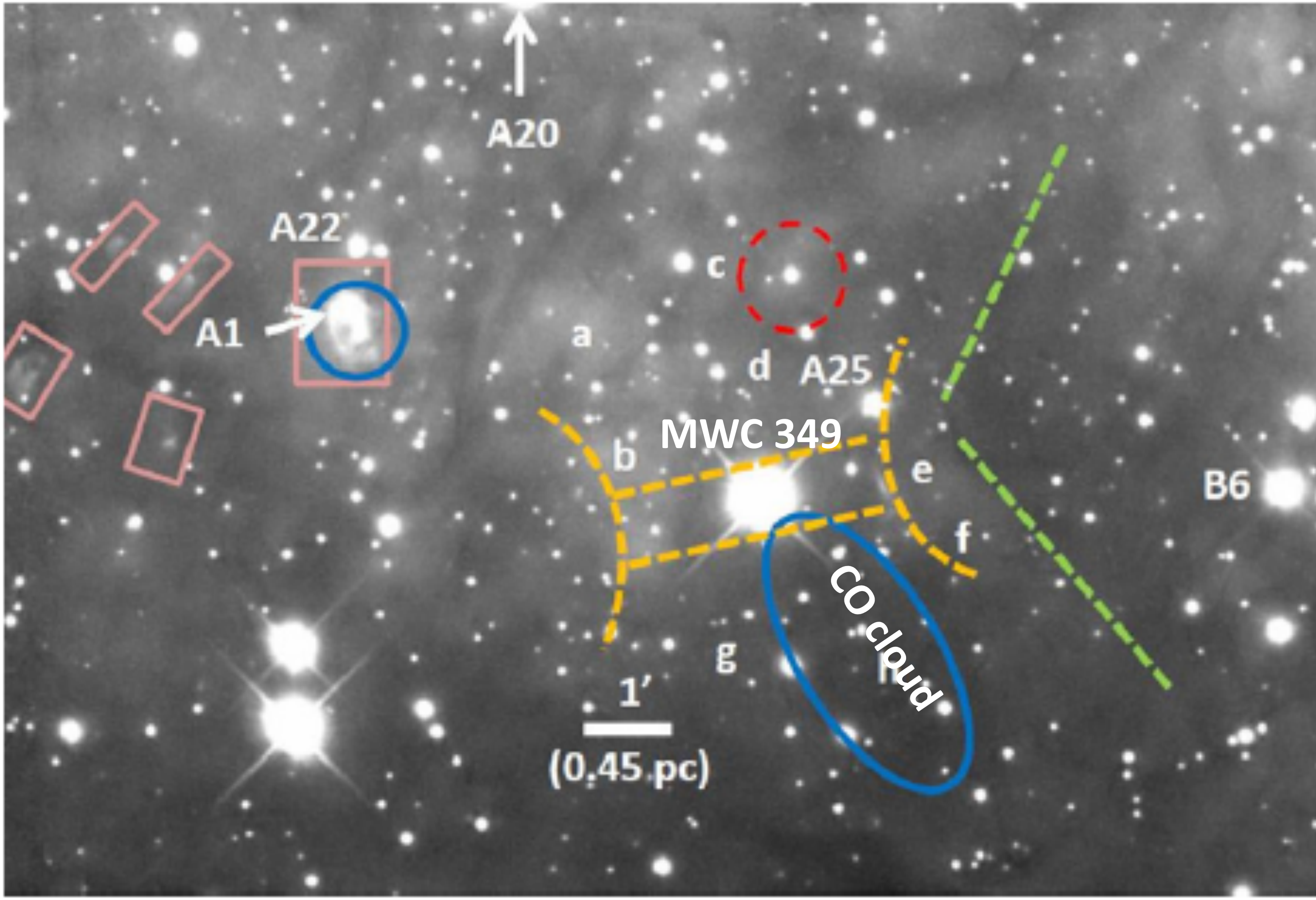
Strelnitski et al. 2013 (*Spitzer* – IR; ARO 10m – CO)

Figure 1. CO $J = 2\text{–}1$ contour maps of T_A^* overlaying the *Spitzer* MIPS 24 μm image of the 10′ × 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.)


Cradle Nebula
MWC 349
40.1
20:33:20.1
00.1
32:40.1
44:59.3
39:59.3
40:34:59.3

Young, star-birth pc-scale environment of MWC 349
(Strelnitski et al. 2013)

"Cradle" nebula
Age < 2 Myr



OMC 1/SiO maser: Greenhil et al. 2010

Pc-scale bipolar flows are observed around both old and young massive stars

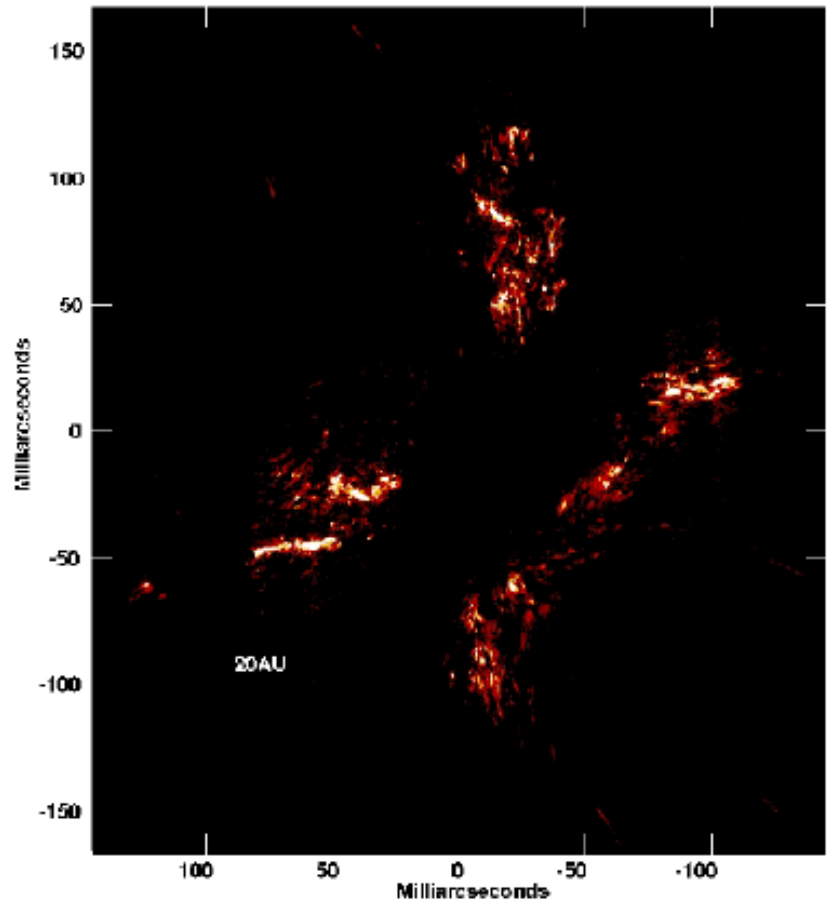
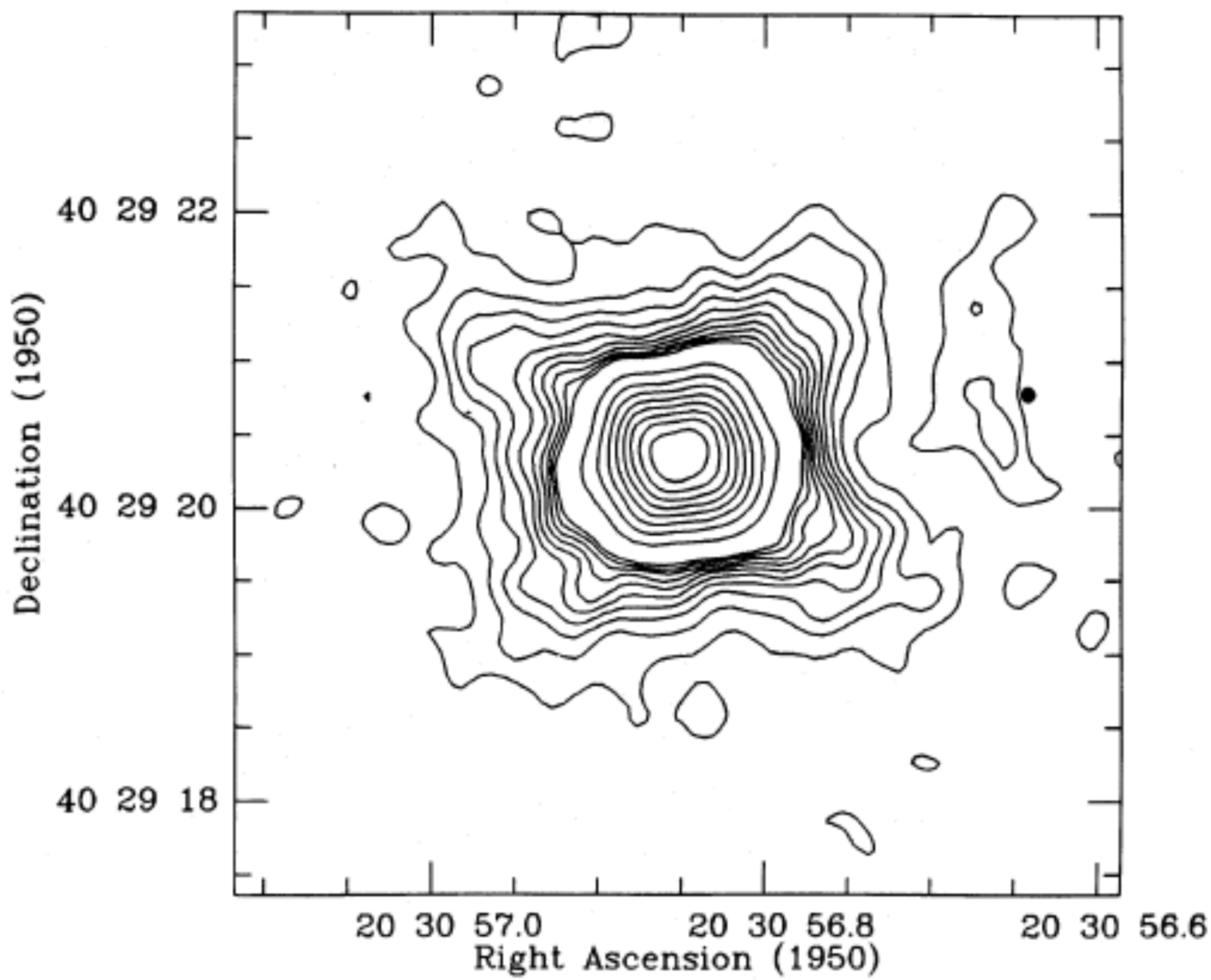


Fig. 5.— Total intensity map showing the combined ^{28}SiO v=1 and v=2, J=1-0 emission distribution, summed over 19 observing epochs (see Table 1). An intensity range of 25 to 30000 Jy beam^{-1} m s^{-1} is shown using a logarithmic transfer function. A GIF animation showing the individual frames comprising this figure is available at http://www.cfa.harvard.edu/kalypso/Figure5b.gif.

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 → they are NOT gravitationally bound (Drew et al 2013, ApJ, in press)

Table 1. Comparison of three sources of $\Delta V_{\mathbf{BA}}$.

Instrument	Spatial Res., arcsec	Spectral Res., km/s	V_B (HEL), km/s	ΔV_{BA}, km/s	Comments
Tillenghast/ TRES	2.4	6.8	30±10	40±10	Average over three lines
Keck/ HIRES	0.7	6.25	27.2±1.5	37±2	A single line
CFHT (Manset et al. 2017)		5	26±1	36±2	Average over two lines

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!).