Imaging the ejecta in V407 Cyg with Very Long Baseline Interferometry

by

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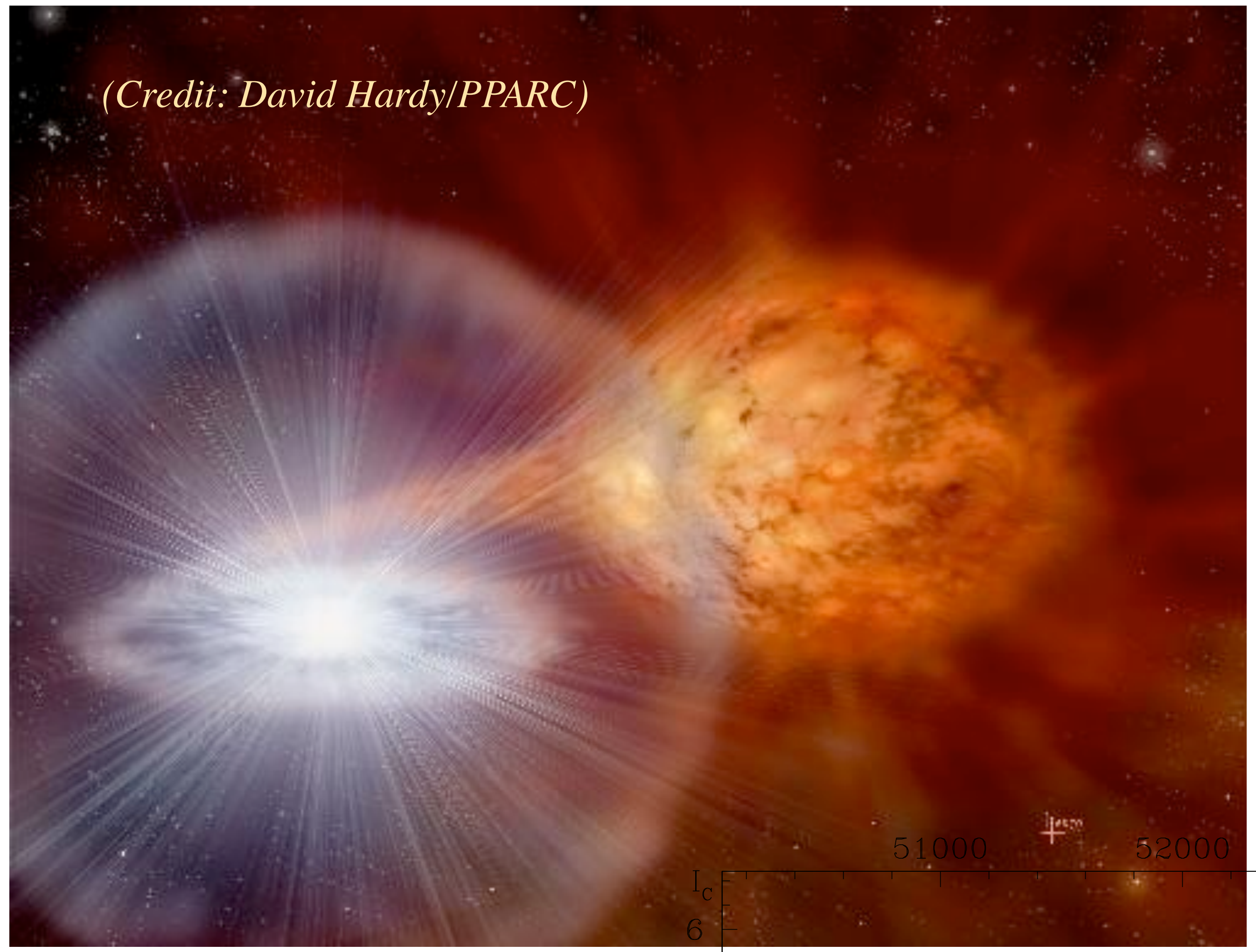
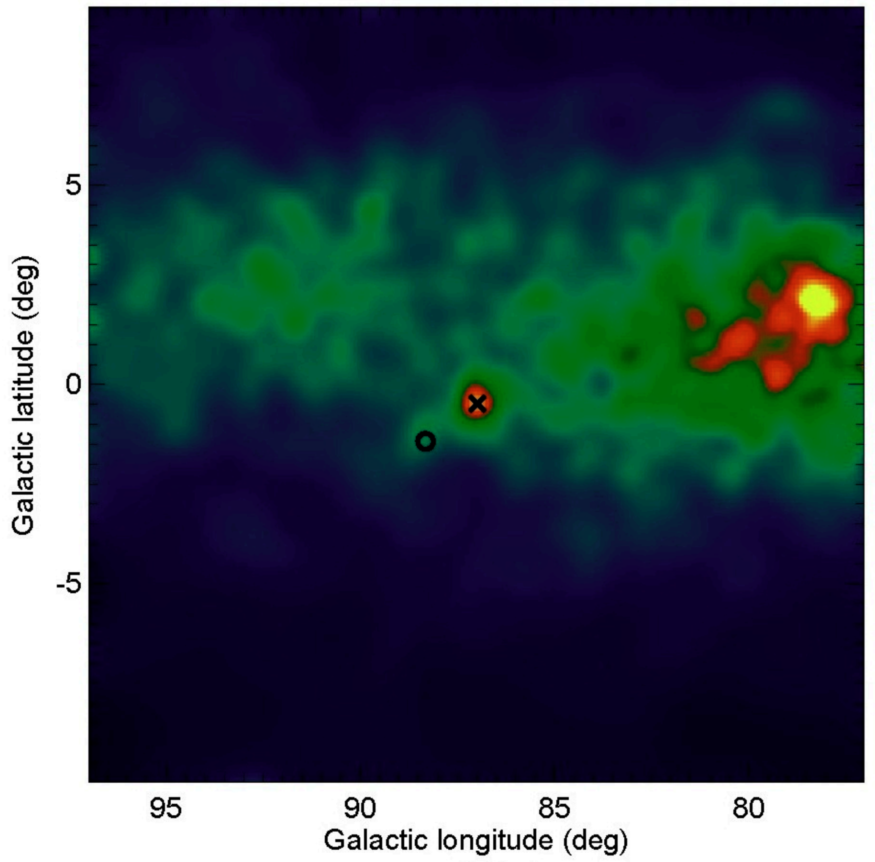
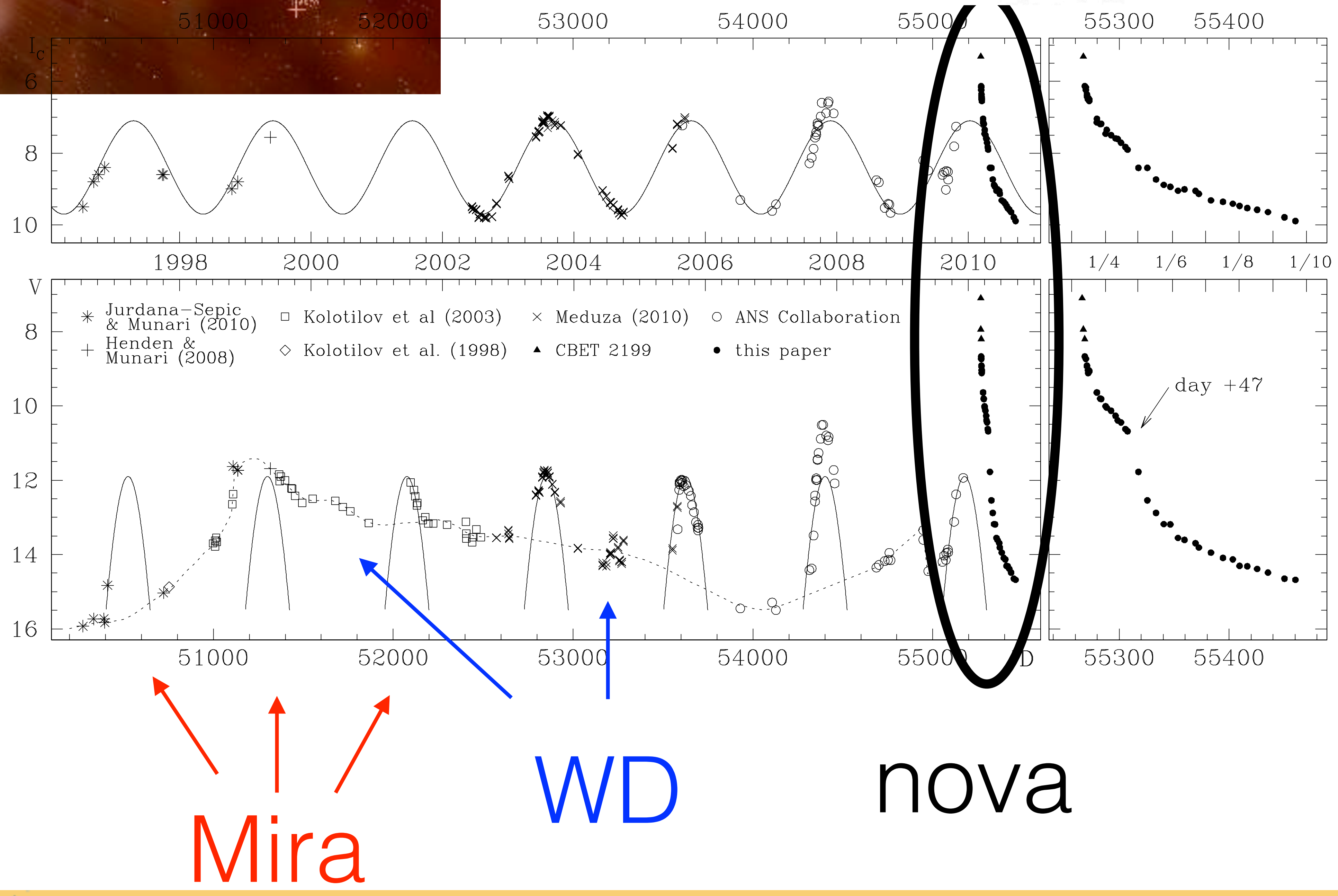
About novae and V407 Cyg





I-, V-band light curves 1997-2010 Munari+11



Novae are thermonuclear outbursts in binary systems containing an accreting white dwarf (WD)

Accreted material accumulates until pressure at base of accreted shell produces thermonuclear ignition; result is ejection of shell, expanding into surroundings

Symbiotic novae: the WD companion is a pulsating red giant (RG); the nova ejecta expand in its dense wind

V407 Cyg (d~2.7kpc) was detected in γ-rays by Fermi-LAT in March 2010: first high energy detection of any nova/WD

Gamma-ray emission scenarios:

- pion decay from collisions of accelerated protons
- inverse Compton by accelerated electrons

The 2010 V407 Cyg VLBI campaign

VLBI detection requires significant flux density in very compact region: high brightness temperature, eg blazar jets, maser spots

Previous case of symbiotic nova: RS Oph in 2006 (O'Brien et al, Nature, 2006)

What about V407 Cyg? 16 observing runs, from day 20 to day 203

6 EVN observations, alternating 5 and 1.6 GHz epochs; real time; longer, better signal-to-noise, short baselines sensitive to more diffuse regions

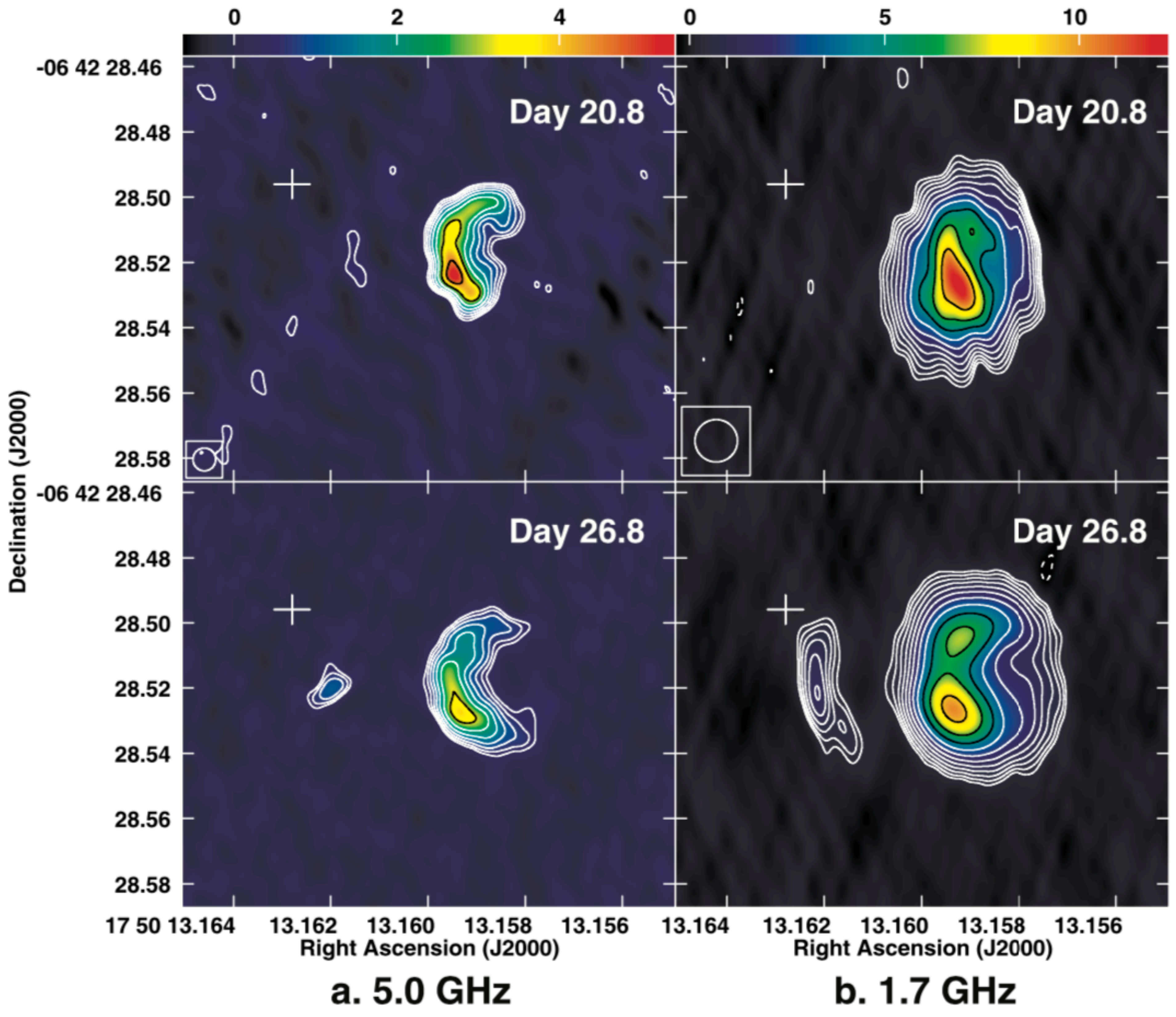
10 VLBA observations, each one at both 1.6 and 5 GHz; disk recorded; shorter, lower signal-to-noise

Detection rate:

- 6/6 with EVN,

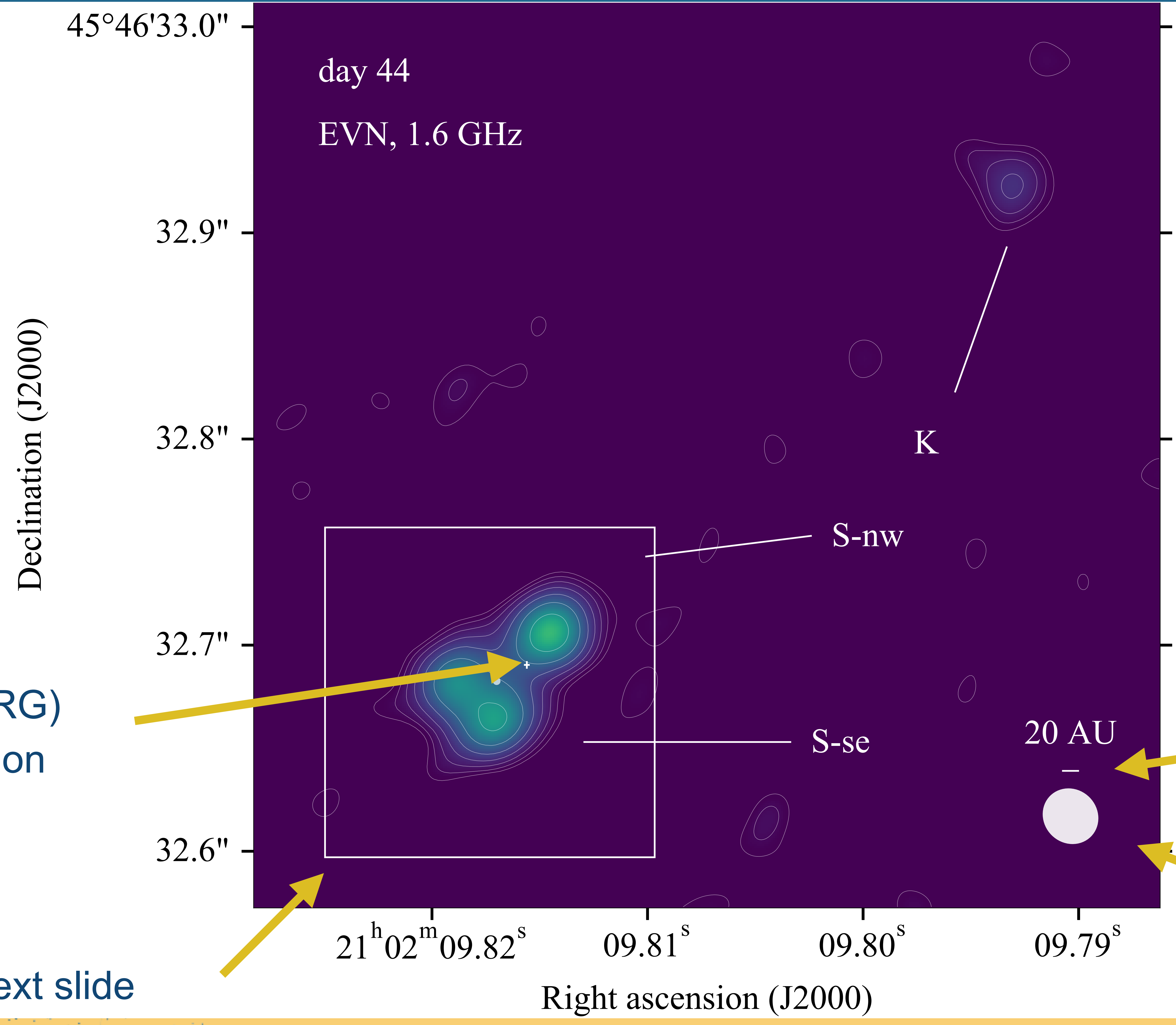
4/10 with VLBA, one at both 1.6 and 5 GHz

Strong structural evolution



Rupen, Mioduszewski & Sokoloski, 2008

EVN observation, 1.6 GHz, day 44



Gaia (RG) position

see next slide

total flux density

~3.5 mJy

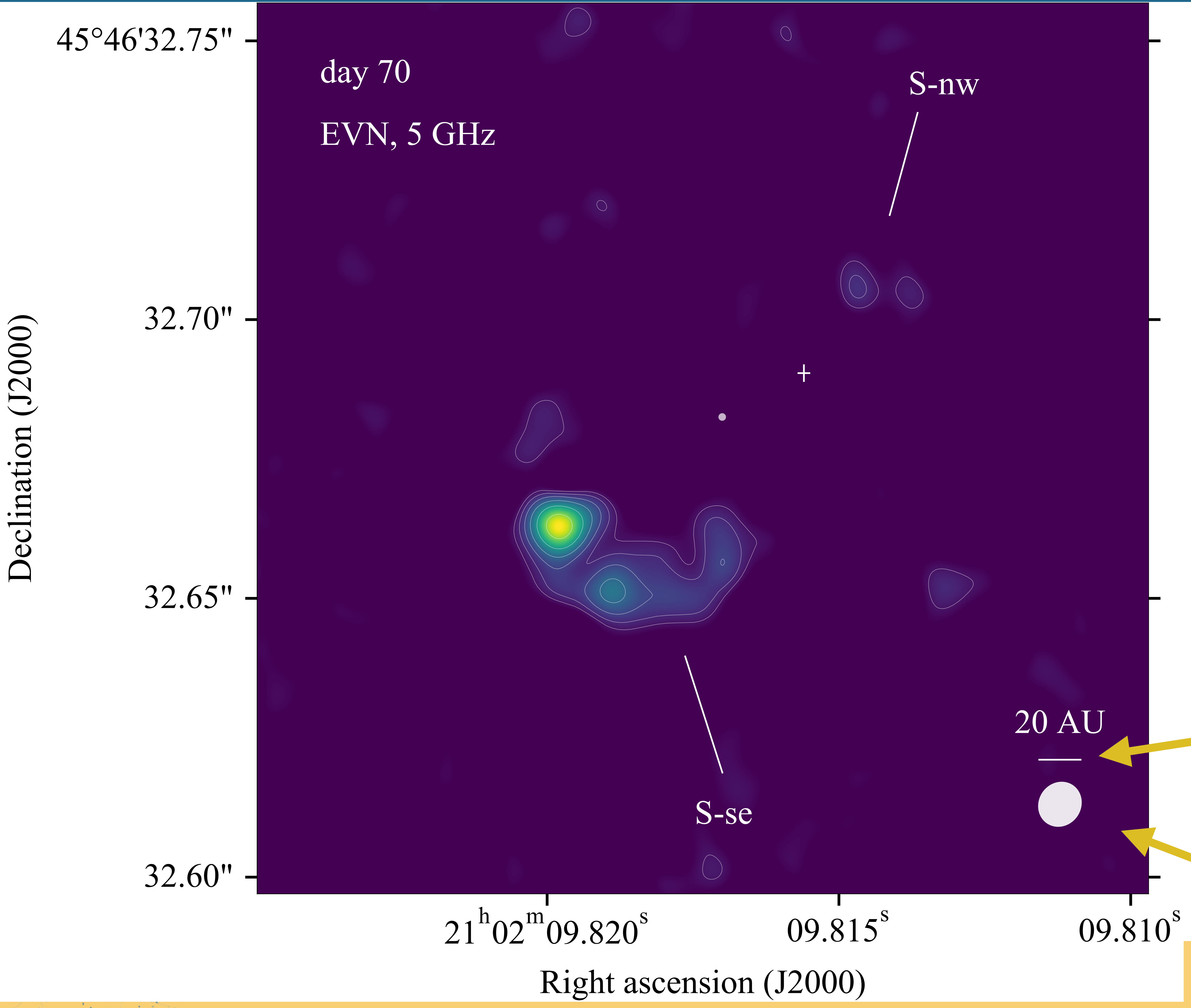
1σ rms 18 μJy/beam

linear scale

(~orbital separation)

restoring beam

EVN observation, 5 GHz, day 70



total flux density

~5.0 mJy

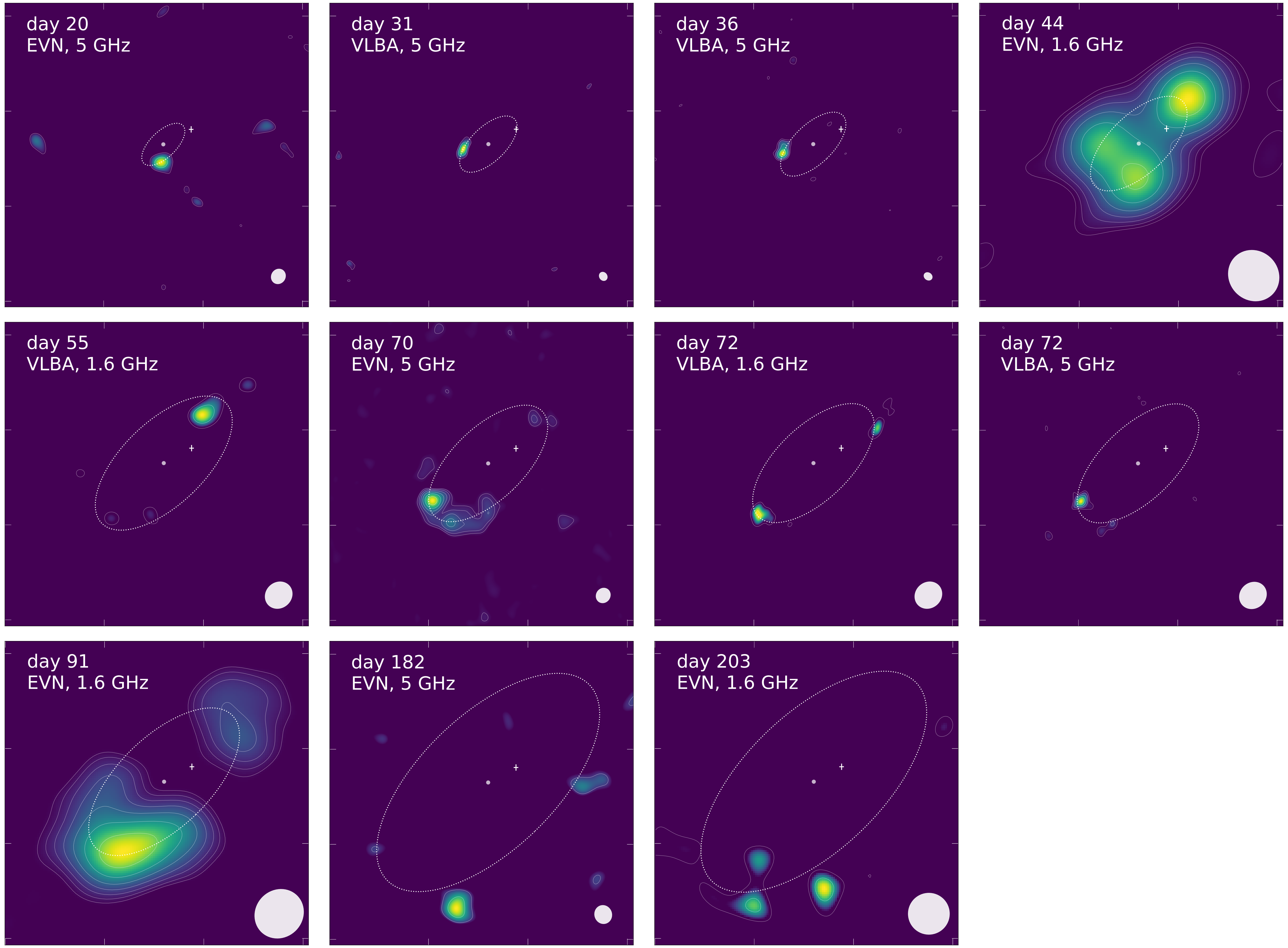
1σ rms 55 μJy/beam

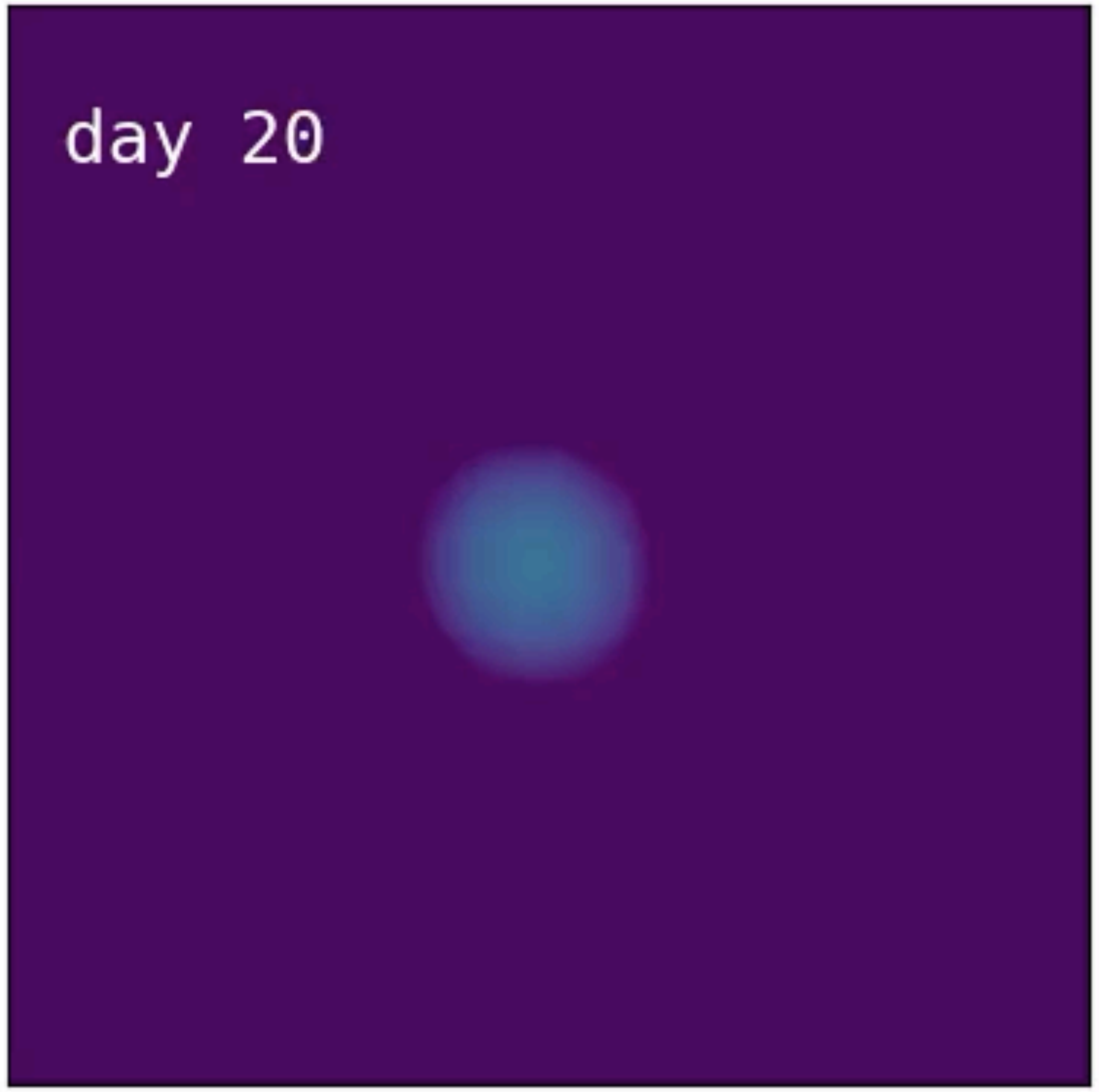
linear scale

(~orbital separation)

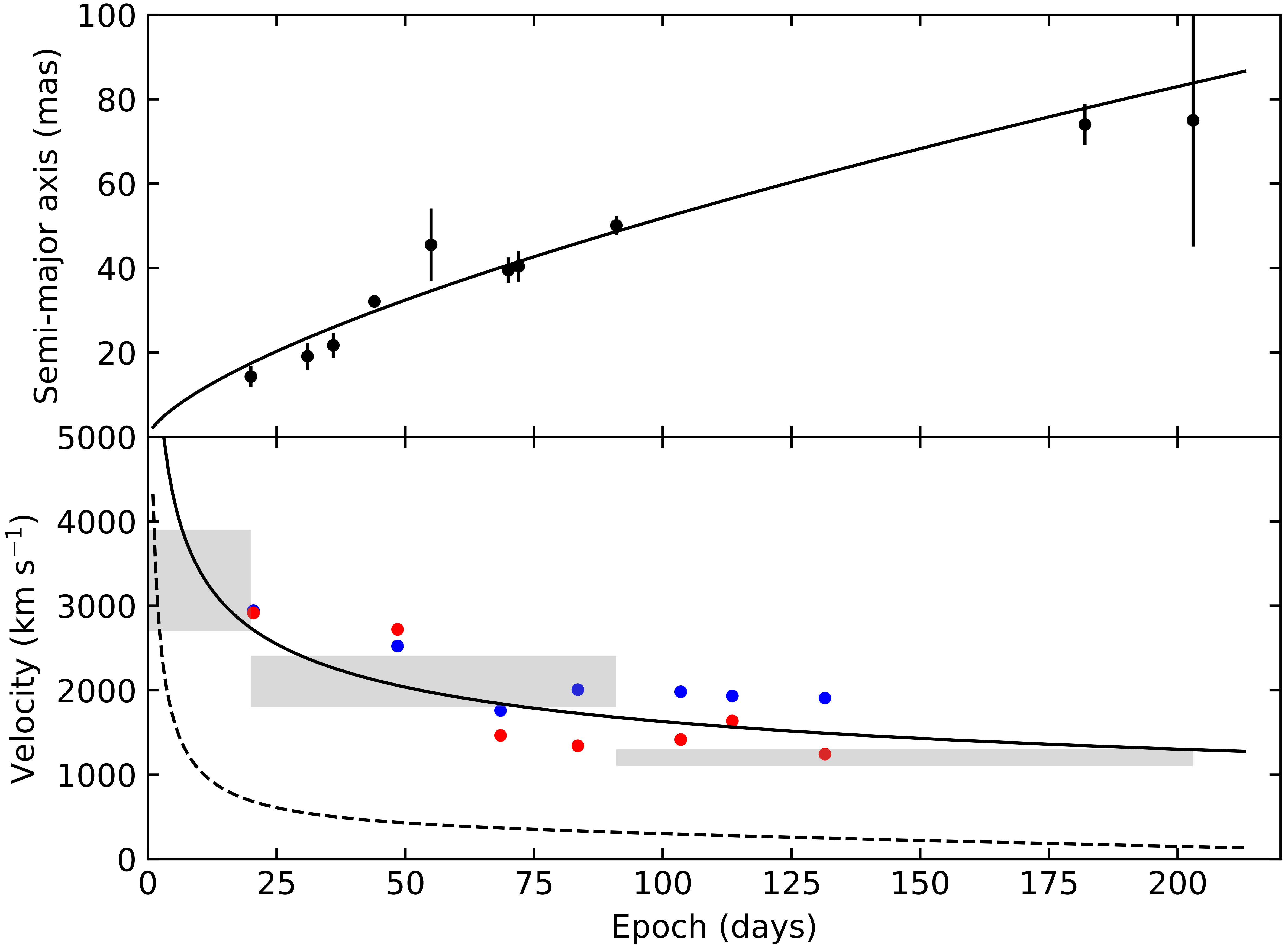
restoring beam

Full set of images





Expansion velocity



Total extension of components grows as a function of time from 39±7 AU (day 20) to 200±13 AU (day 182)

Features advance mainly along p.a. -45deg, but with significant transversal motion component

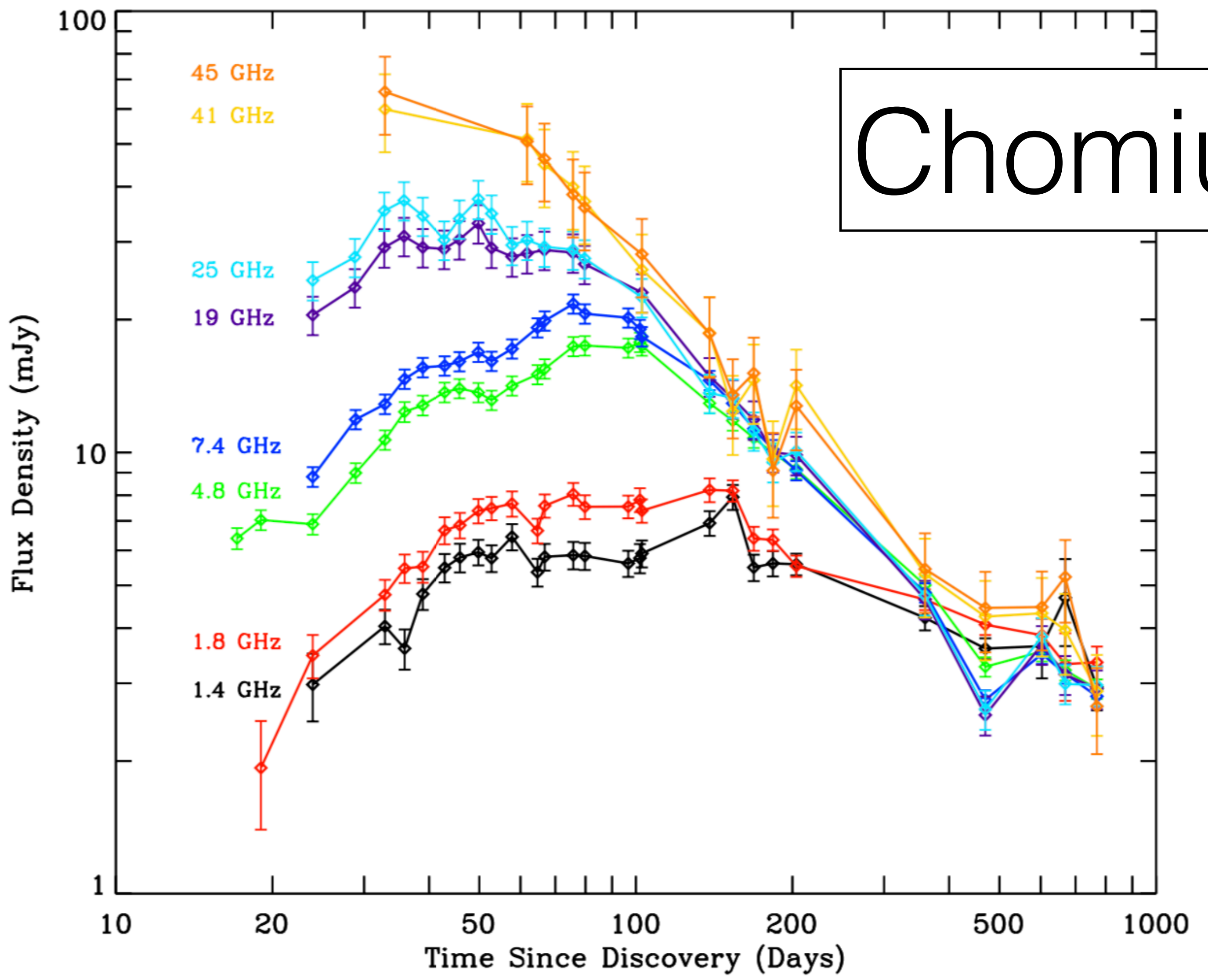
$r \sim t^p$, p=0.68±0.04

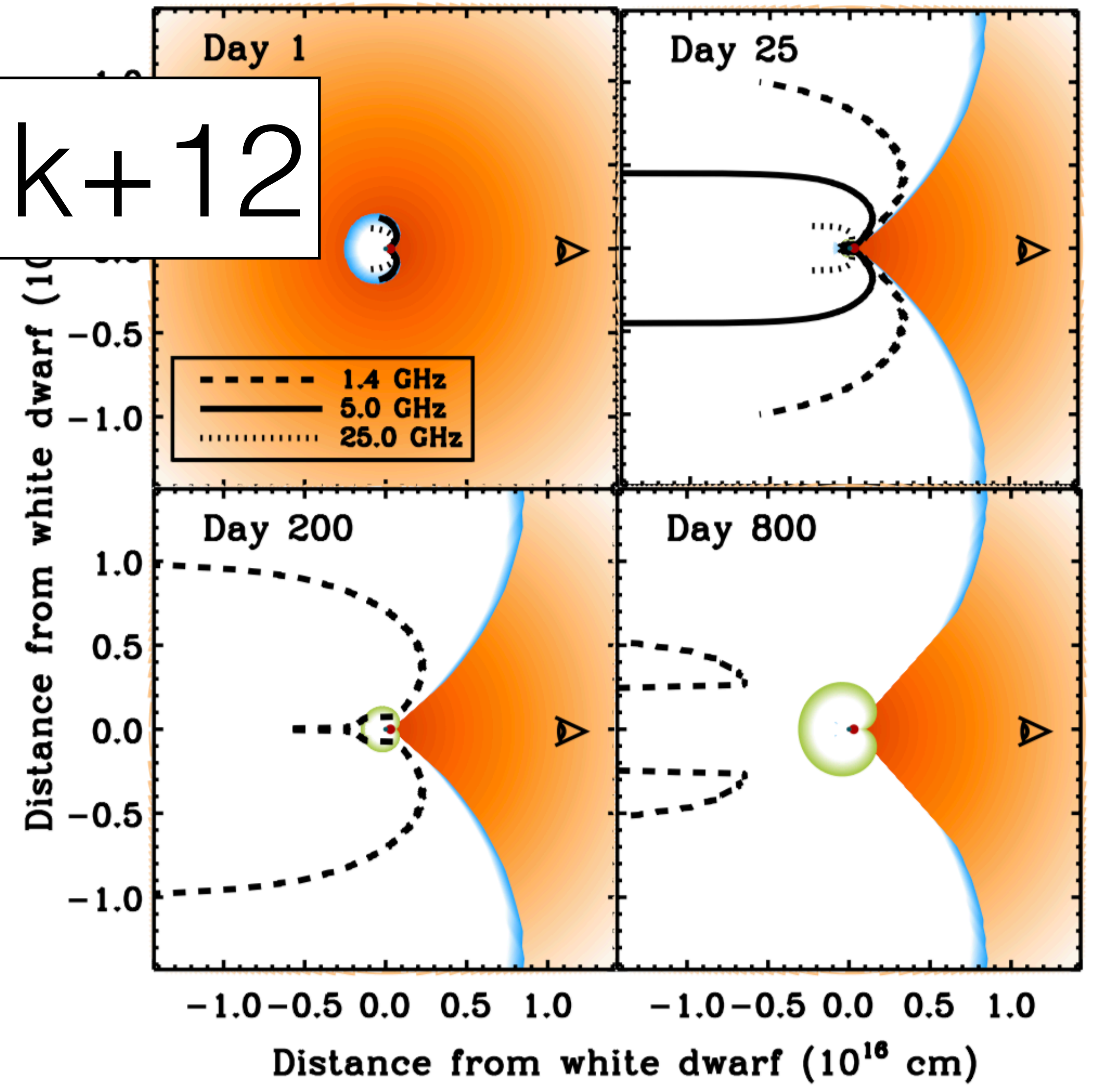
$v \sim t^{p-1}$, p-1=-0.32±0.04

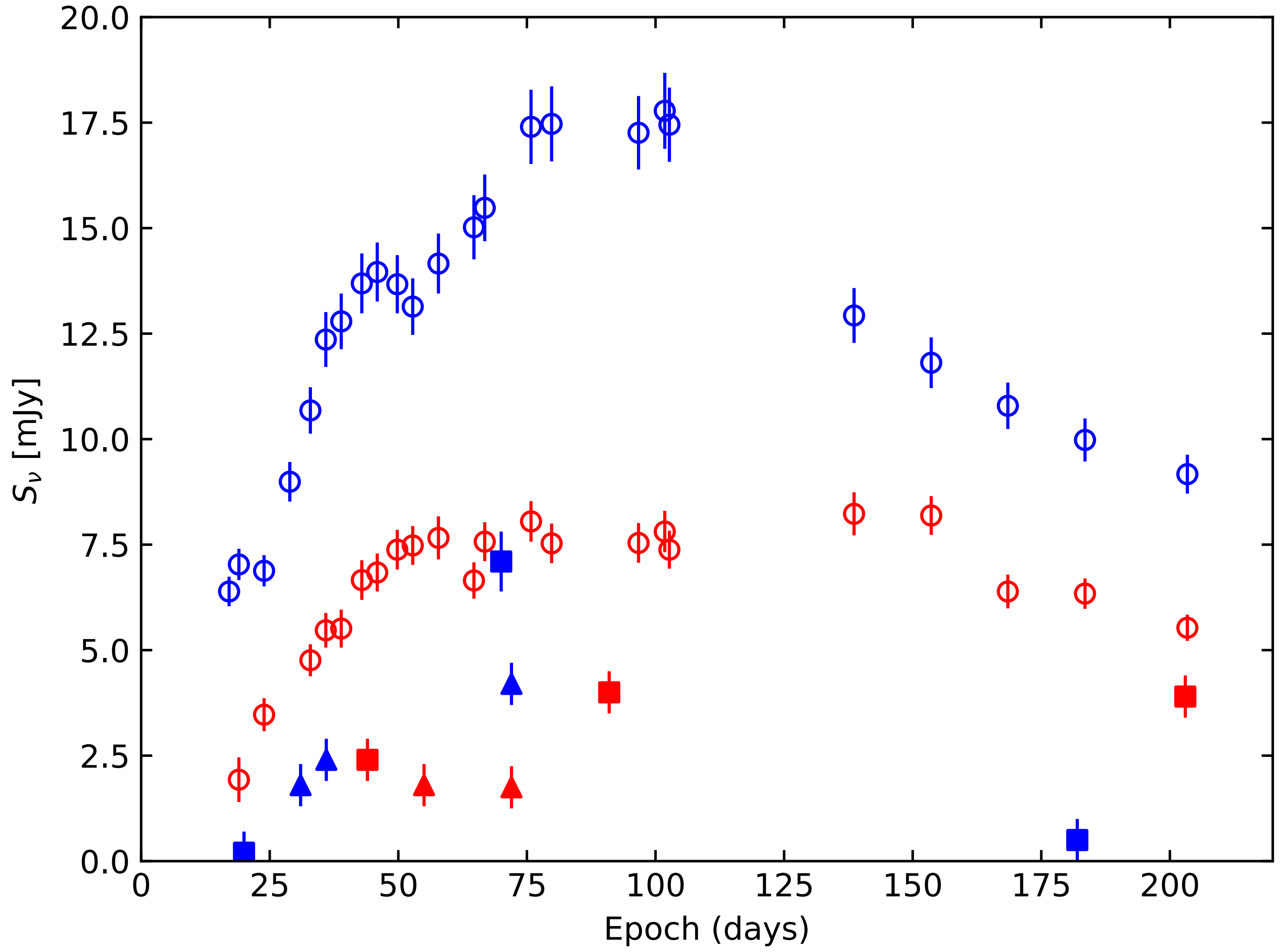
initial velocity ~3300 km/s or larger, then slows down to 2100±300 km/s (20d<t<90d), 1200±100 km/s (t>90d)

good agreement with maximum velocity from optical lines (Shore et al. 2011), excess w.r.t line width (Munari et al. 2010)

The emission mechanism







empty=VLA

filled=VLBI

red=1.6 GHz

blue=5 GHz

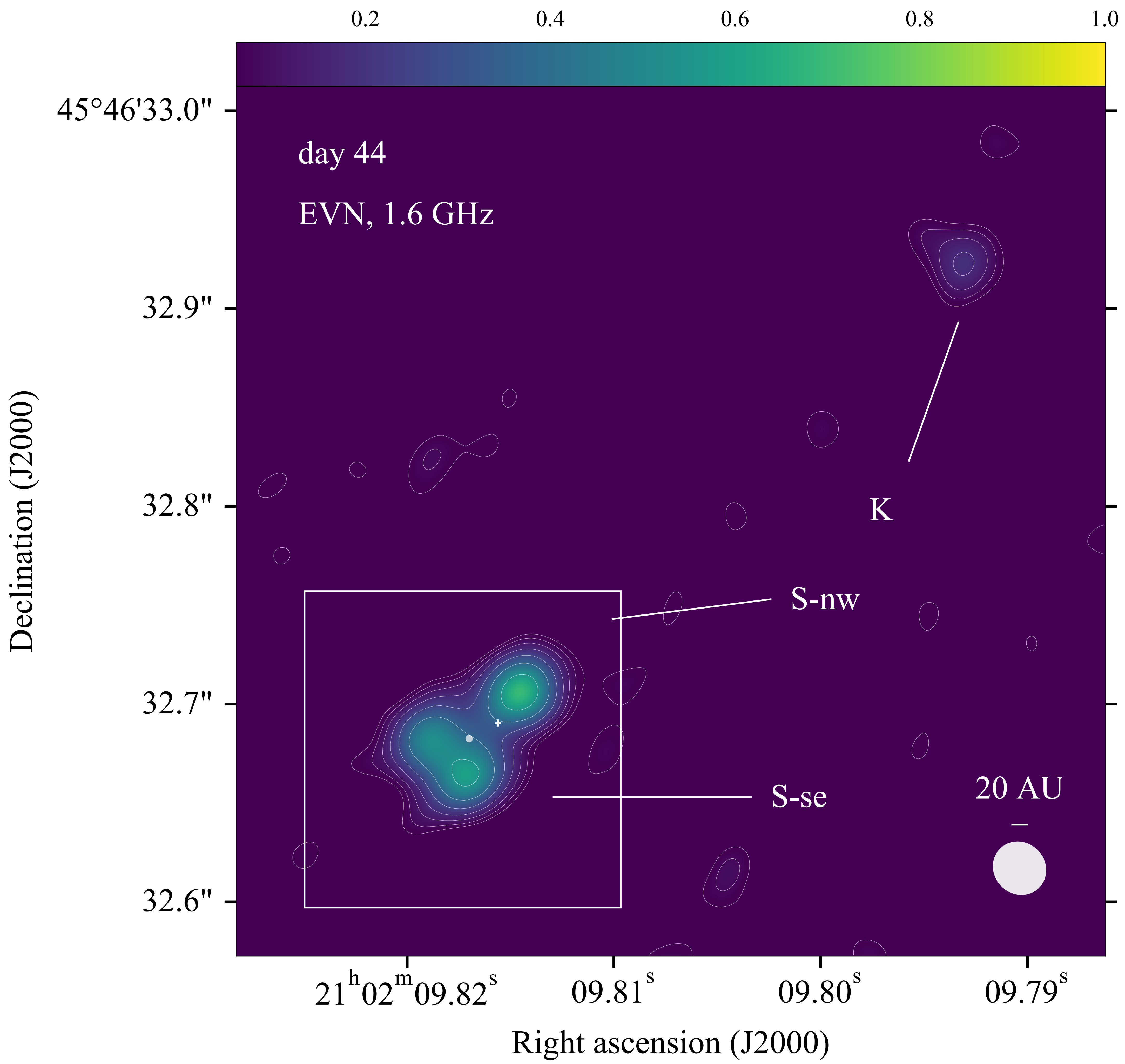
VLA light curve dominated by thermal emission from ionised Mira wind

VLBI data resolve out wind emission:

- too bright for thermal ejecta
- most likely synchrotron from shocked ejecta
- ok with gamma rays, unusual spectral index

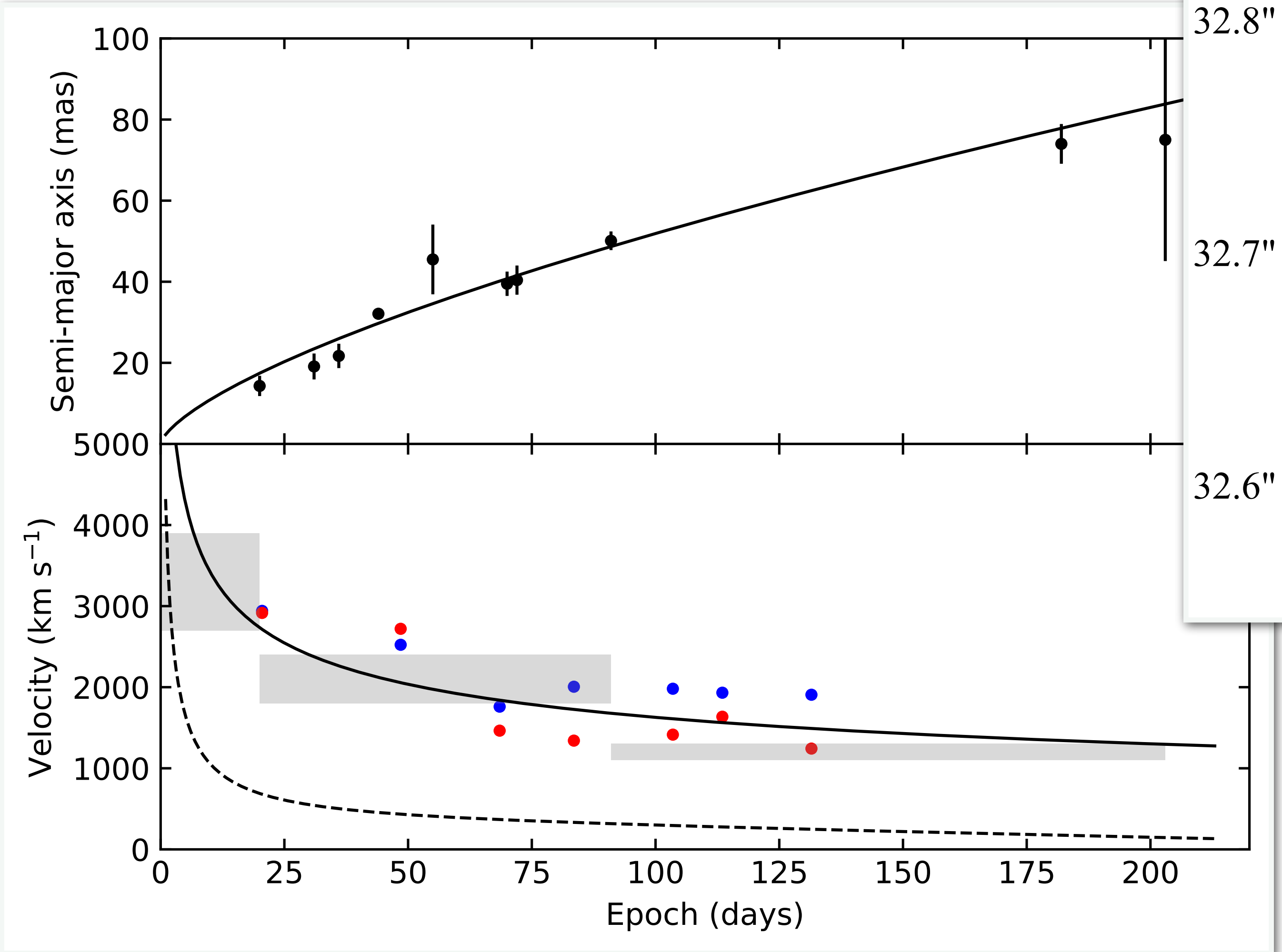
The orientation

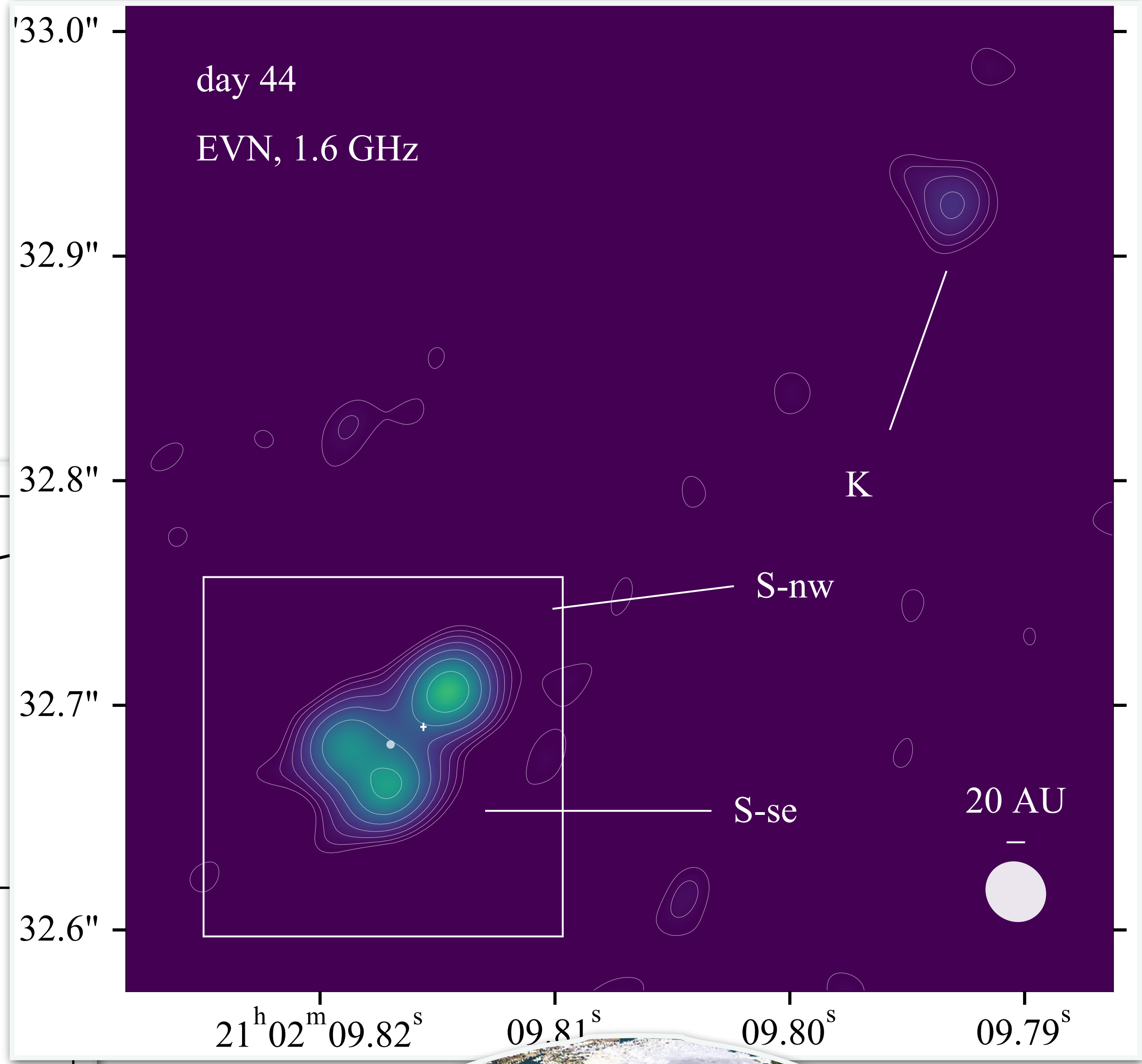
- Asymmetries in optical spectra (Shore et al. 2011) suggest WD-Mira vector is aligned with our line of sight - with Mira in foreground
- Works well also with VLA, X-ray light curves
- VLBI structure is bipolar, but asymmetric
- expanding ring on equatorial plane
- presence of distant component suggests expansion along an axis; polar, less dense medium?



Take home messages

- VLBI observations directly image the expansion of the ejecta in V407 Cyg
- The ejecta advance on opposite fronts, mostly along a bipolar axis, with a starting velocity >3000 km/s and later slowing to ~1000 km/s
- Brightness temperature (size & flux density) confirms shock acceleration
- Emission is present also on larger scales, connected to previous episode of activity





See Giroletti, Munari, et al. 2020, A&A, and….
http://old.jive.nl/array-radio-telescopes-reveals-explosion-surface-hot-dead-star