LOFAR monitoring of the 2015 V404 Cyg outburst

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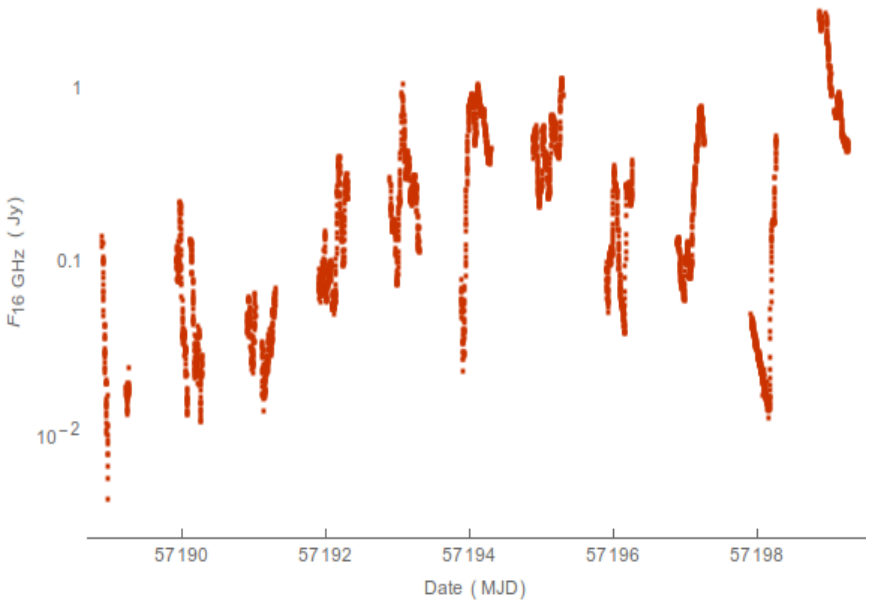
Background

* V404 Cygni: a relatively nearby black hole X-ray binary (distance 2.39 ± 0.14 kpc; Miller-Jones et al. 2009).

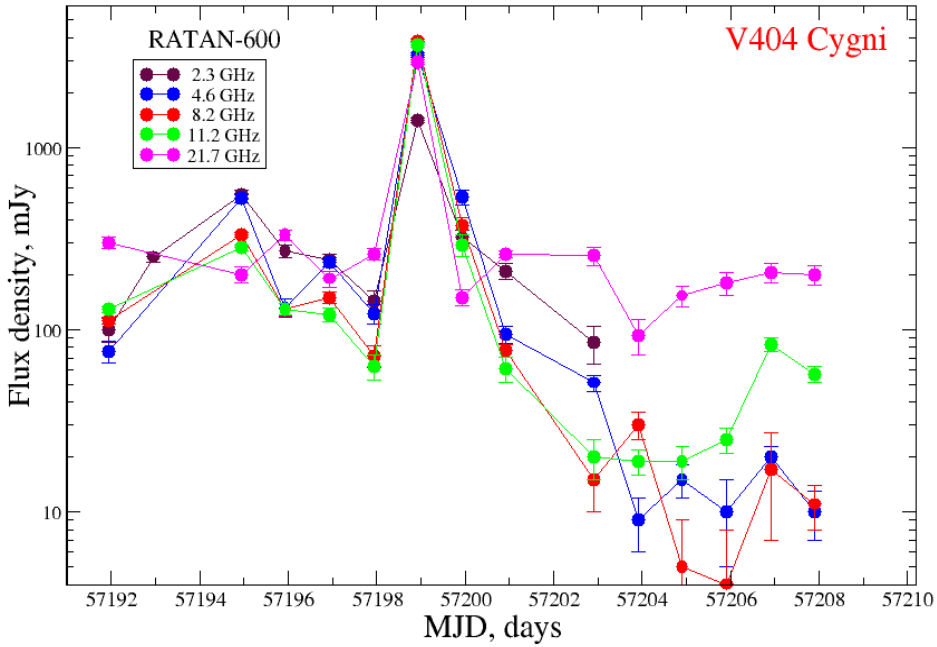
* Went into outburst on 2015 June 15 (MJD 57188; e.g. Barthelmy et al. 2015, Gazeas et al. 2015, Oates et al. 2015, Negoro et al. 2015, Kuulkers et al. 2015, Mooley et al. 2015).

* Brightest outburst from a X-ray binary for a decade or so. Last V404 Cyg outburst in 1989 (e.g. Han & Hjellming 1992).

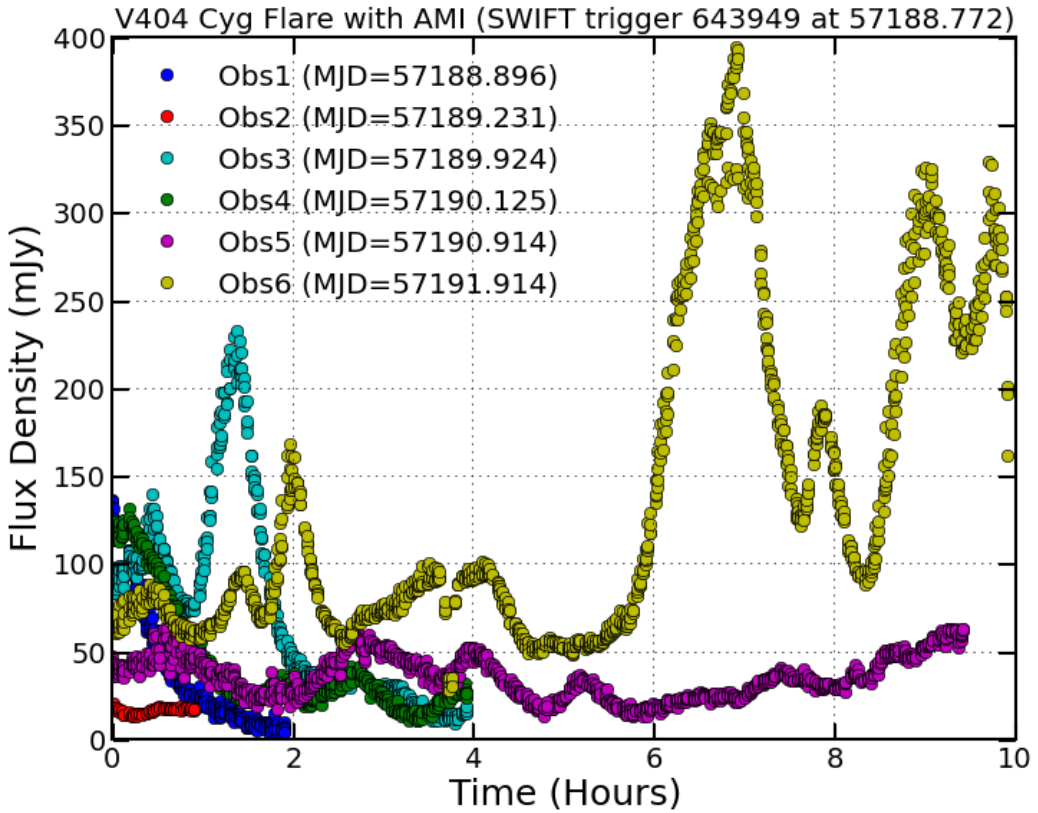
* One of the closest known X-ray binaries → unique opportunity to study the physics of relativistic jets launched from a black hole.



AMI/ALARRM 16 GHz monitoring
(Kunal Mooley / Gemma Anderson / AMI Team)

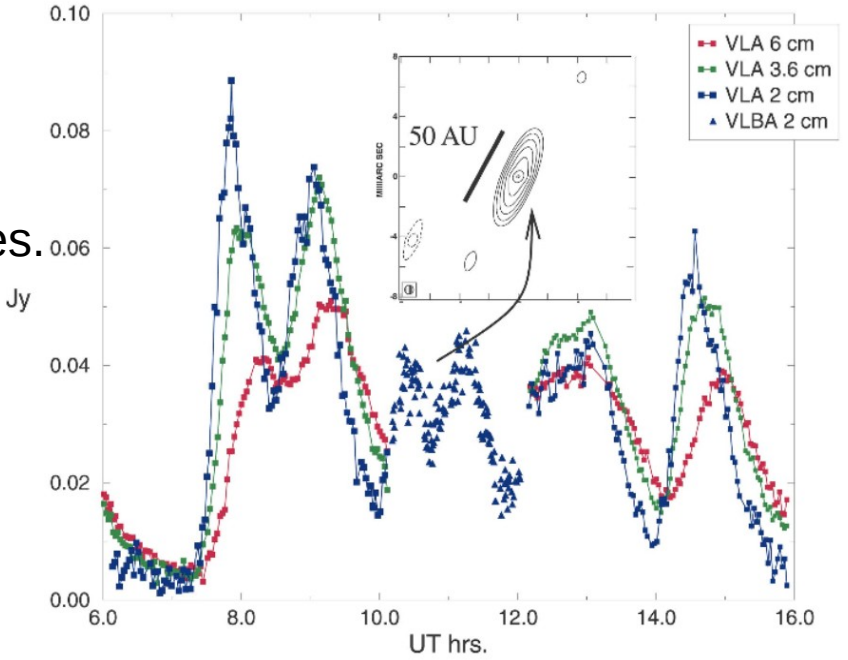


RATAN-600 monitoring (Trushkin et al. 2015; ATel #7667, #7716)



AMI/ALARRM monitoring; Mooley/AMI team

Jet oscillation events - similar to GRS 1915+105?

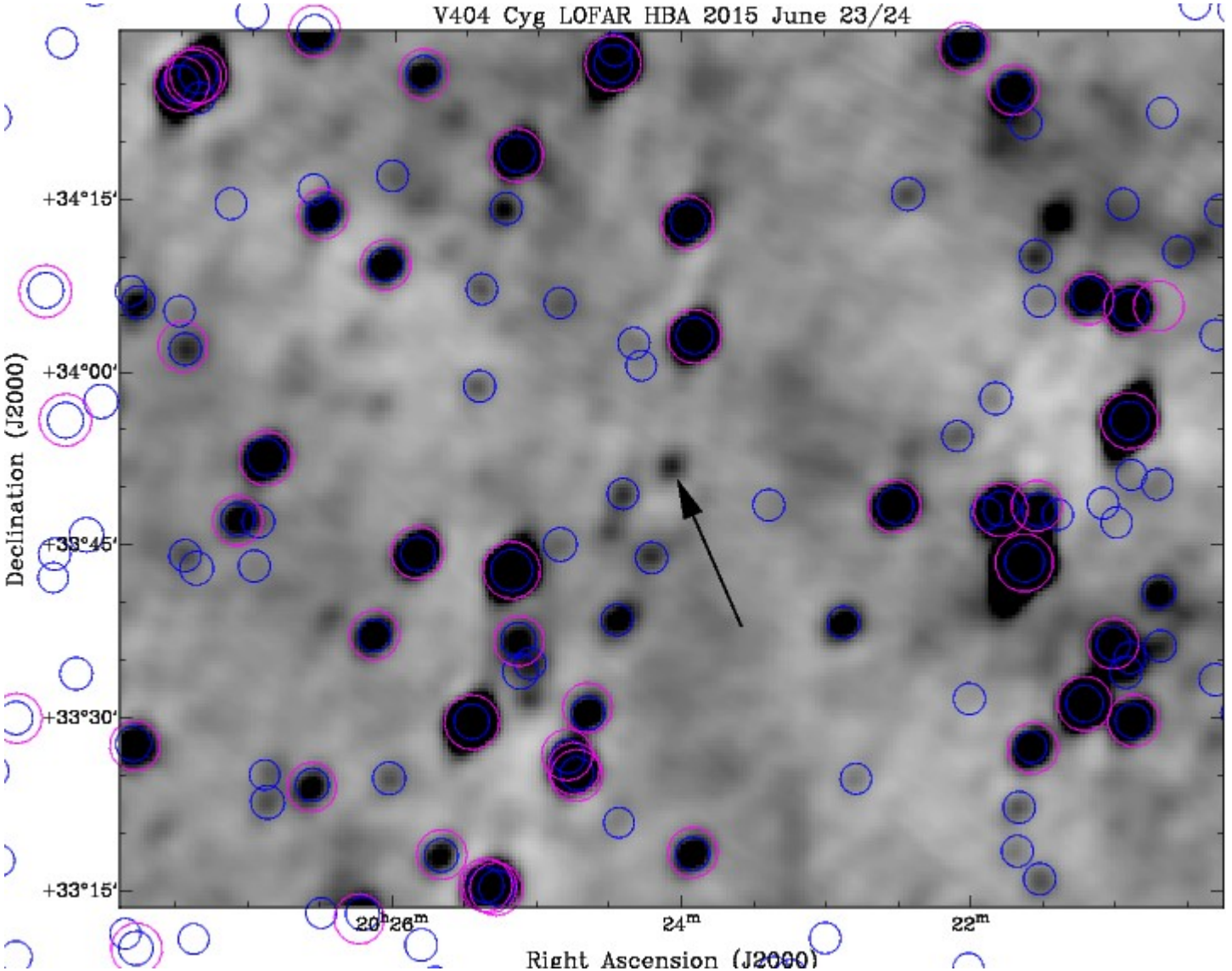


GRS 1915+105; Dhawan et al. (2000)

* Quasi-periodic oscillations, delayed at lower frequencies.
* Similar amplitudes at different frequencies.
* Infrared counterparts, also associated with hard X-ray dips.
* Discrete plasma ejections? Variations in jet power in a self-absorbed, conical outflow? (etc.)

(see e.g. Pooley & Fender 1997, Mirabel et al. 1998, Fender & Belloni 2004)

LOFAR observations



WENSS

NVSS

HBA_DUAL_INNER

115-189 MHz

Calibrator 3C 380

WENSS-NVSS sky model

Baselines 0.075-3 kλ

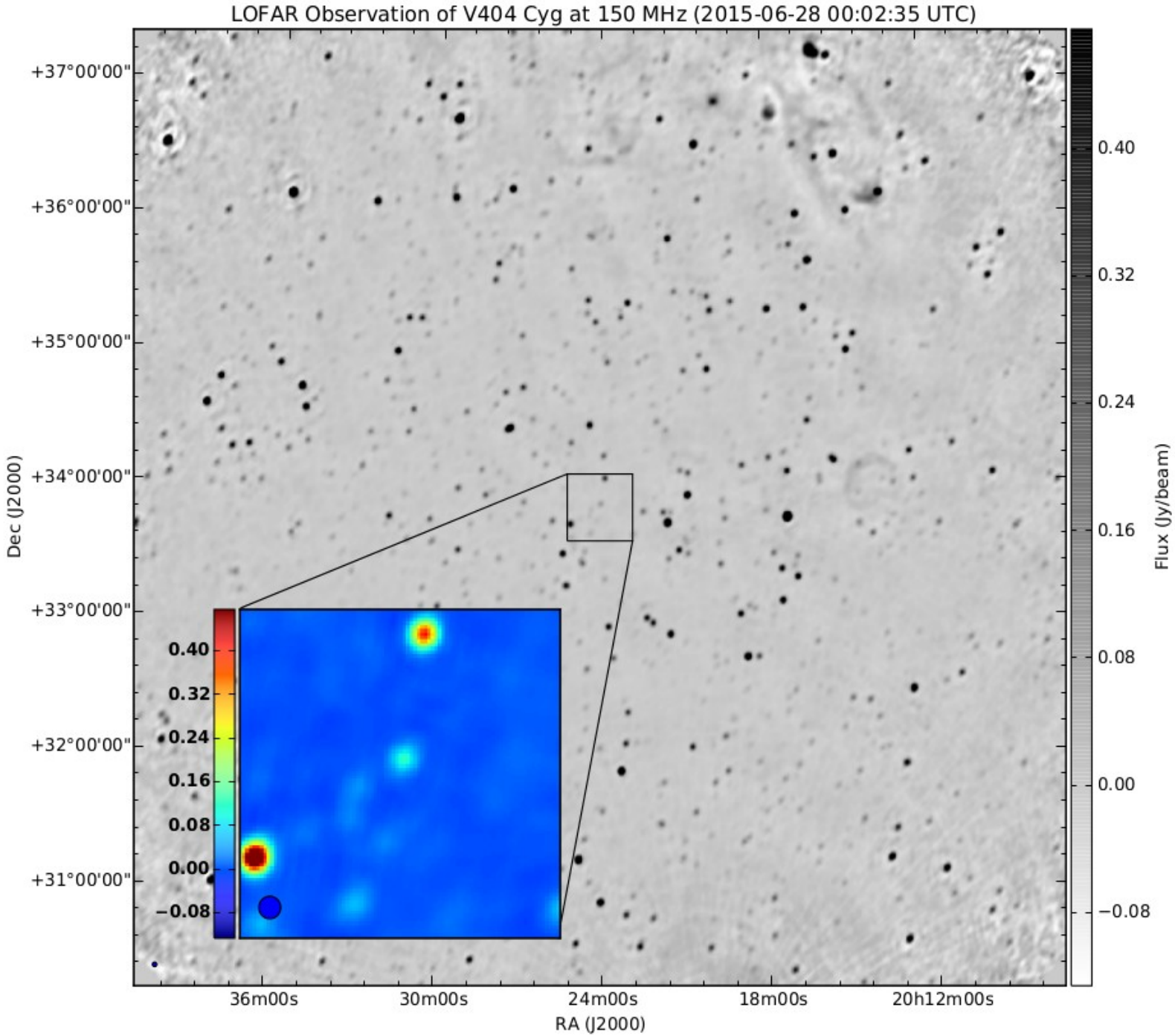
Cyg A only 8.4° from target

* DDT4_002: three HBA observations (June 23, 26, 28). 1 x 6 hr + 2 x 3 hr

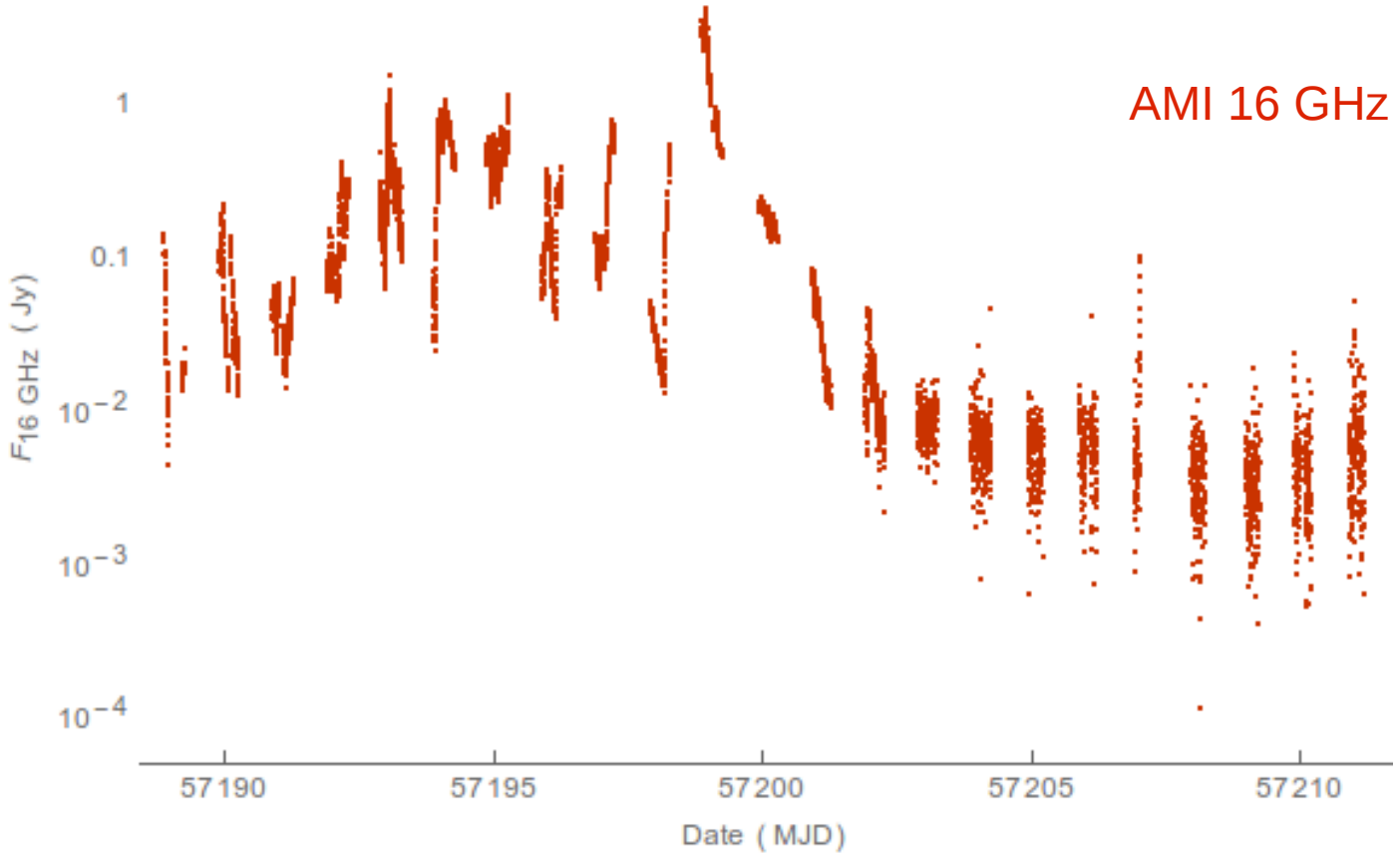
* ~1.5 days from end of June 23 observation to first image (with some problems along the way)

* Flux density ~30-40 mJy in the June 23/26 runs (σ ~ 4-5 mJy/beam)

* ATel #7720 (Broderick et al. 2015). First LOFAR detection of a transient X-ray binary.

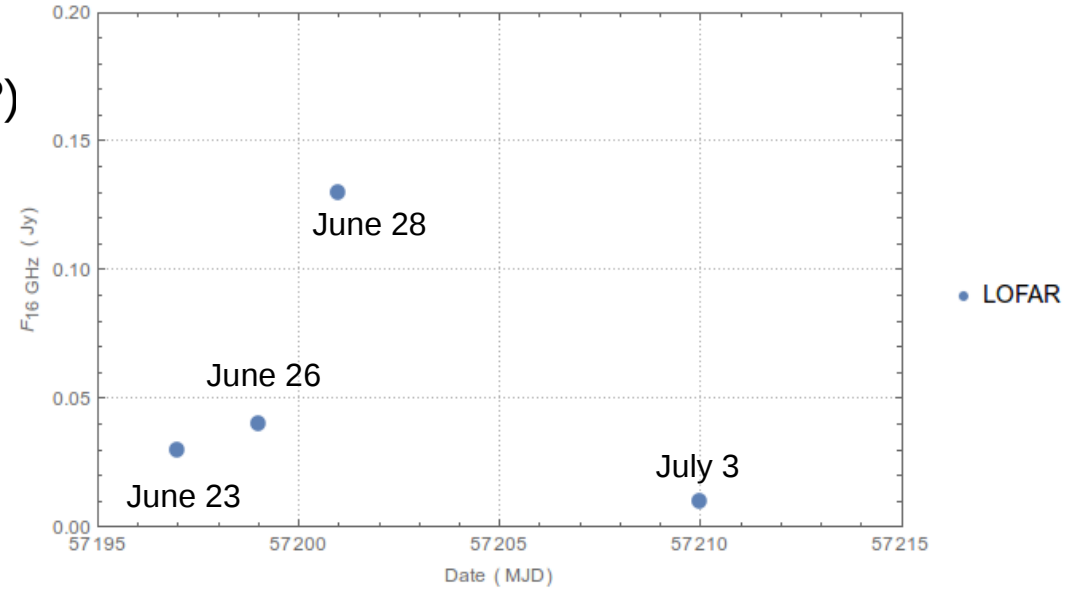


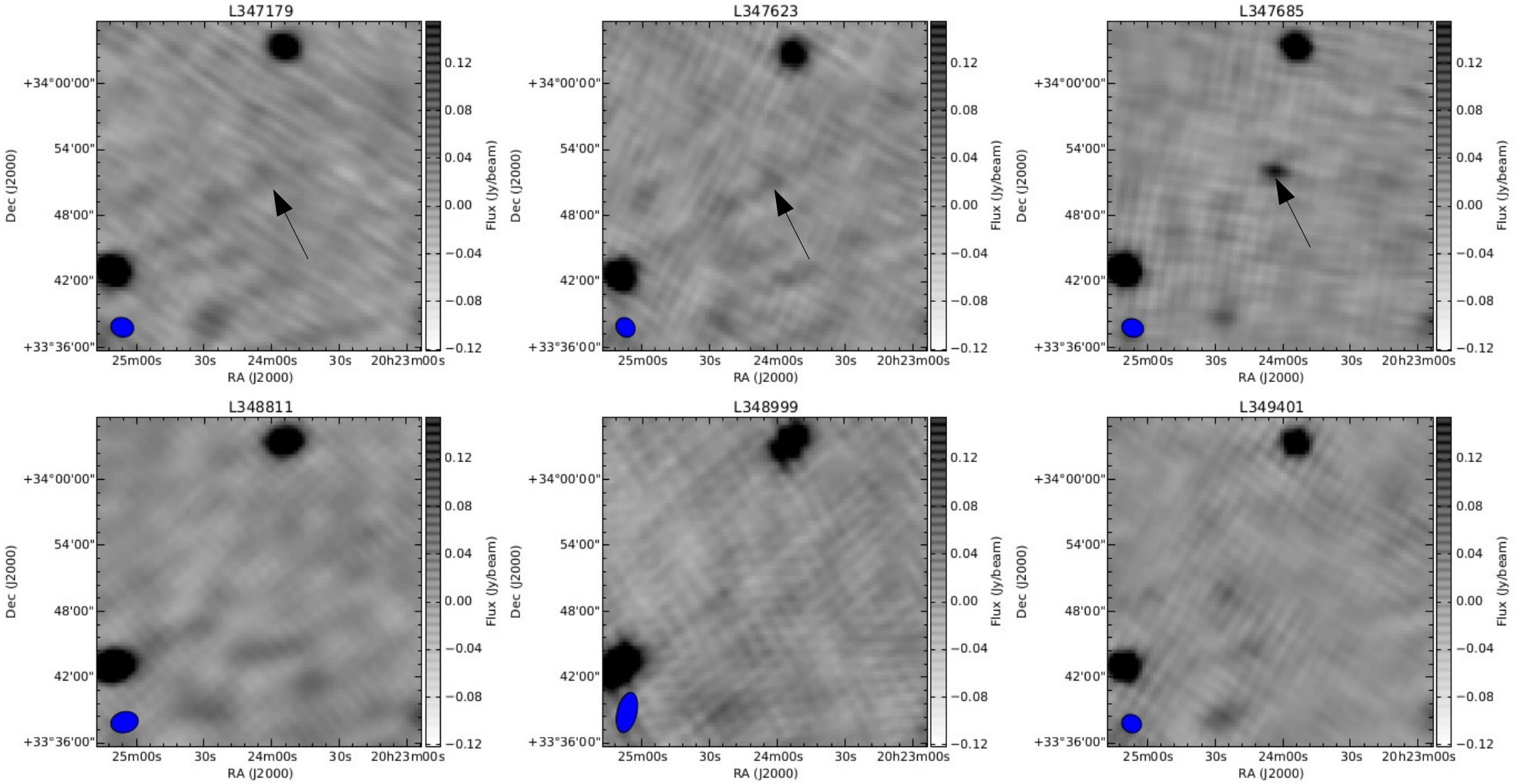
* June 28: source had brightened to ~120-140 mJy.
* Low-frequency variability also seen in 341 MHz VLITE observations over the period June 17-25 (Kassim et al. 2015; ATel #7728).



* Source now fading towards quiescence (?)

* Ongoing LOFAR monitoring campaign (DDT4_003)





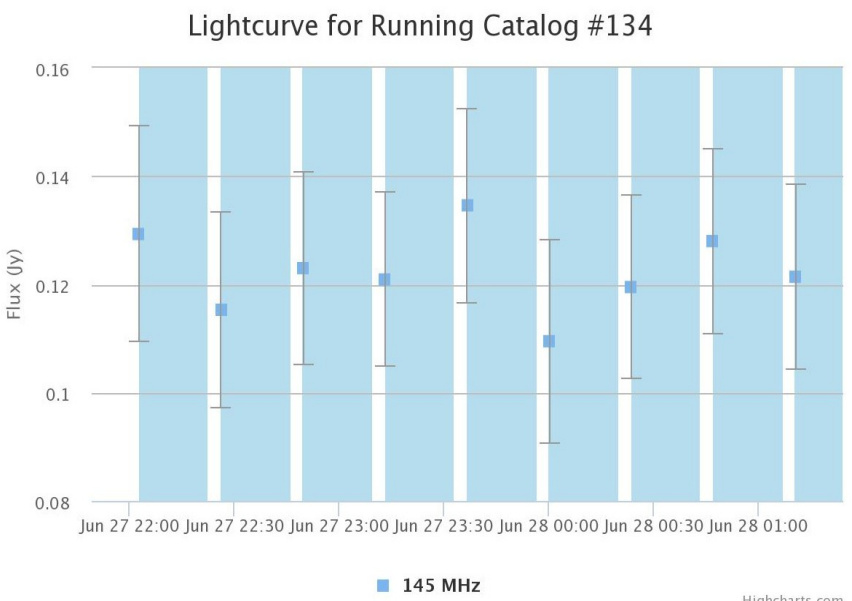
Top: June 23, 26, 28

Bottom: July 3, 6, 10 (20 min monitoring runs; (σ ~ 10 mJy/beam)

Future work

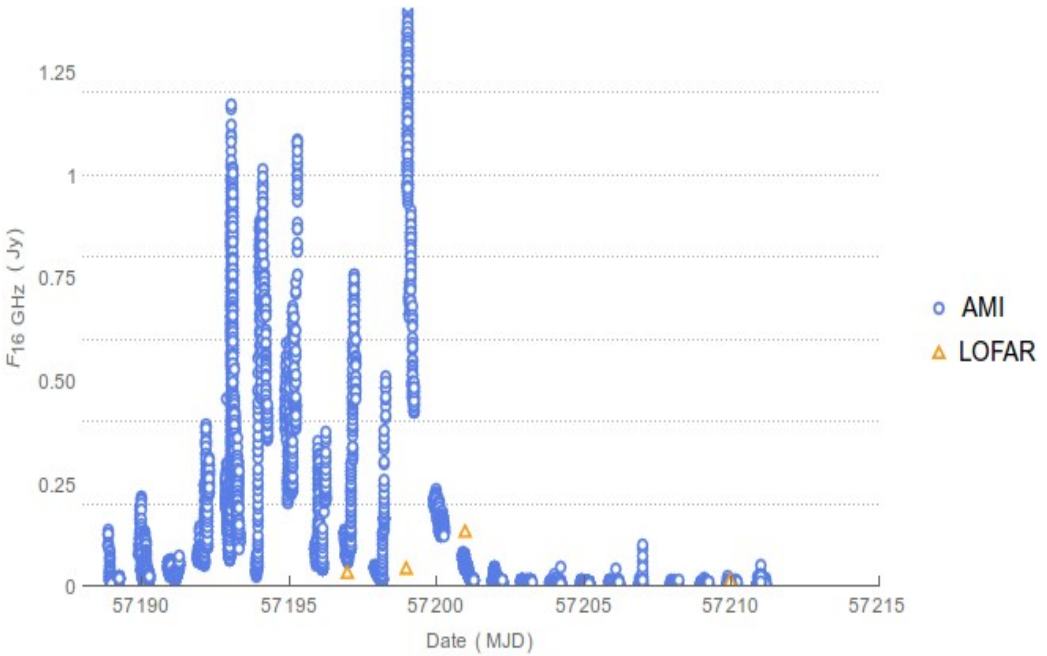
* Finer time / frequency resolution
* Improved sky model; self-cal pipeline

* International baselines -
  resolving relativistic ejecta



June 28 observation; TraP output

* Coordination of observations – lessons learned for
  next similar event.



Many thanks to the
ASTRON Radio Observatory!