Low-frequency radio observations of Galactic microquasars

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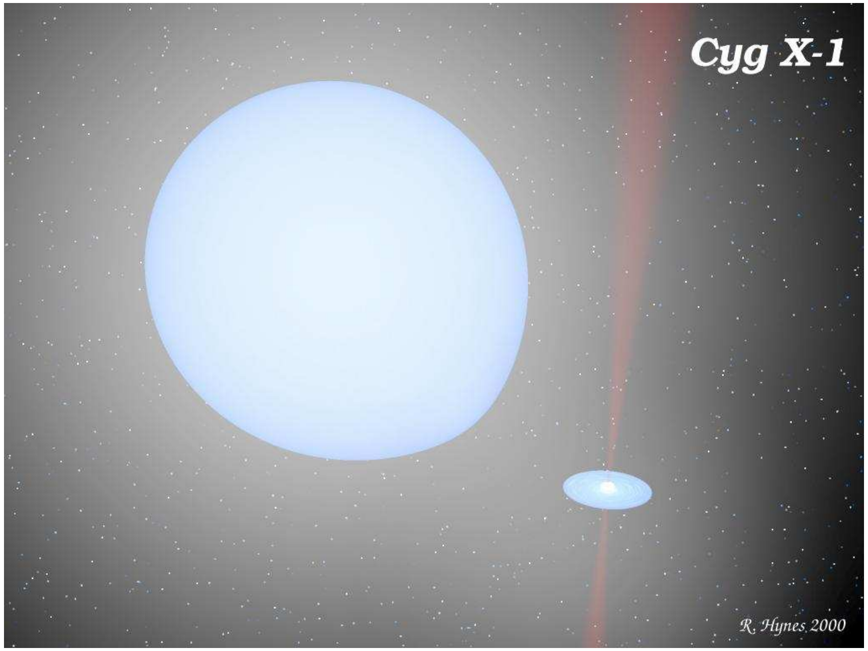
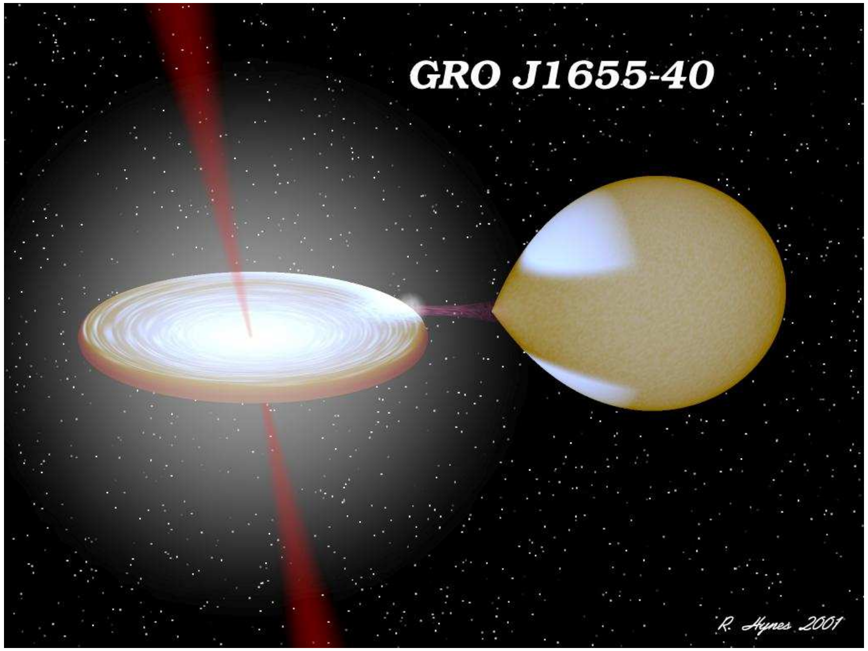
Overview

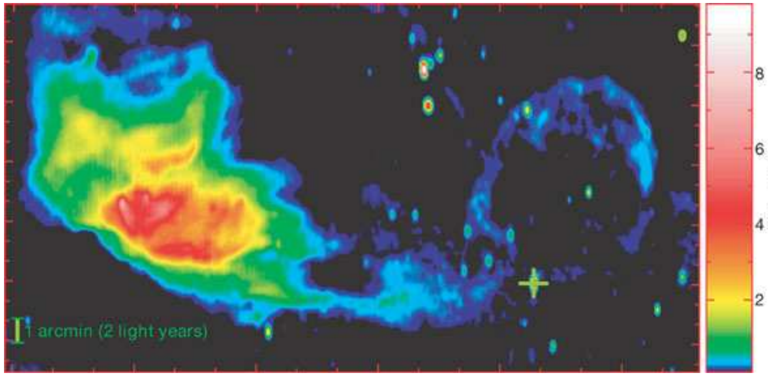
- Introduction & context
- SS 433 observations
- Monitoring of persistent X-ray binaries in quiescence
- Cygnus X-3 during the May 2006 flare



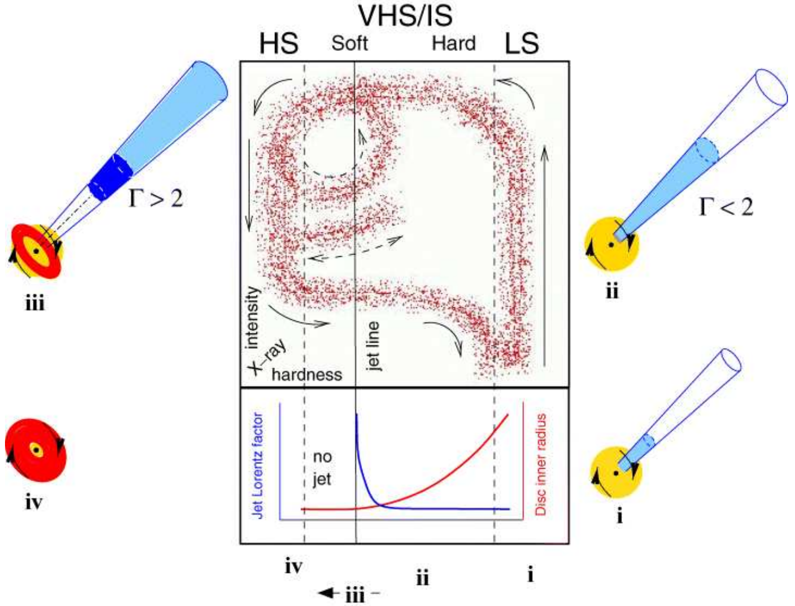


What can we learn at low frequencies?

- Shape of the low-energy electron distribution
- Jet energetics
- Impact of the jets on their surroundings
- Duty cycles
- Census of transient sources



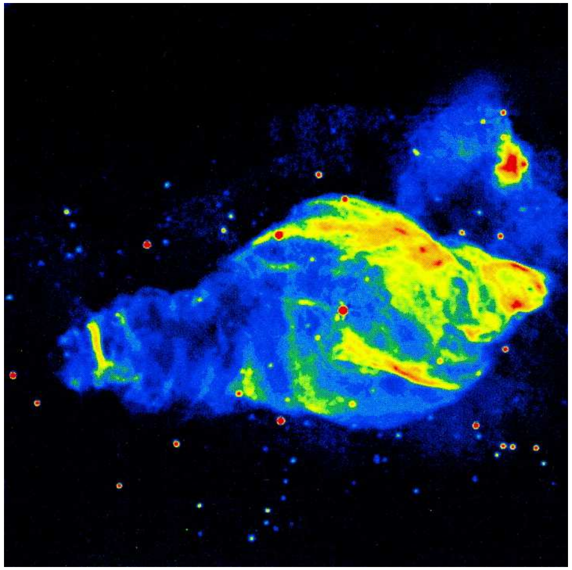
Gallo et al. (2005)



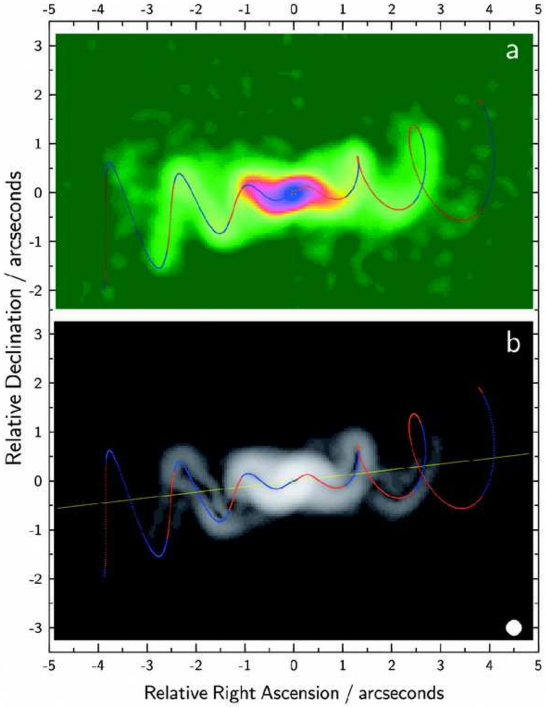
Fender, Belloni & Gallo (2004)

SS 433

- Super-Eddington X-ray binary jet source
- Jets precess with 162.5 d period
- Jets inflate W 50 nebula



Dubner et al. (1998)

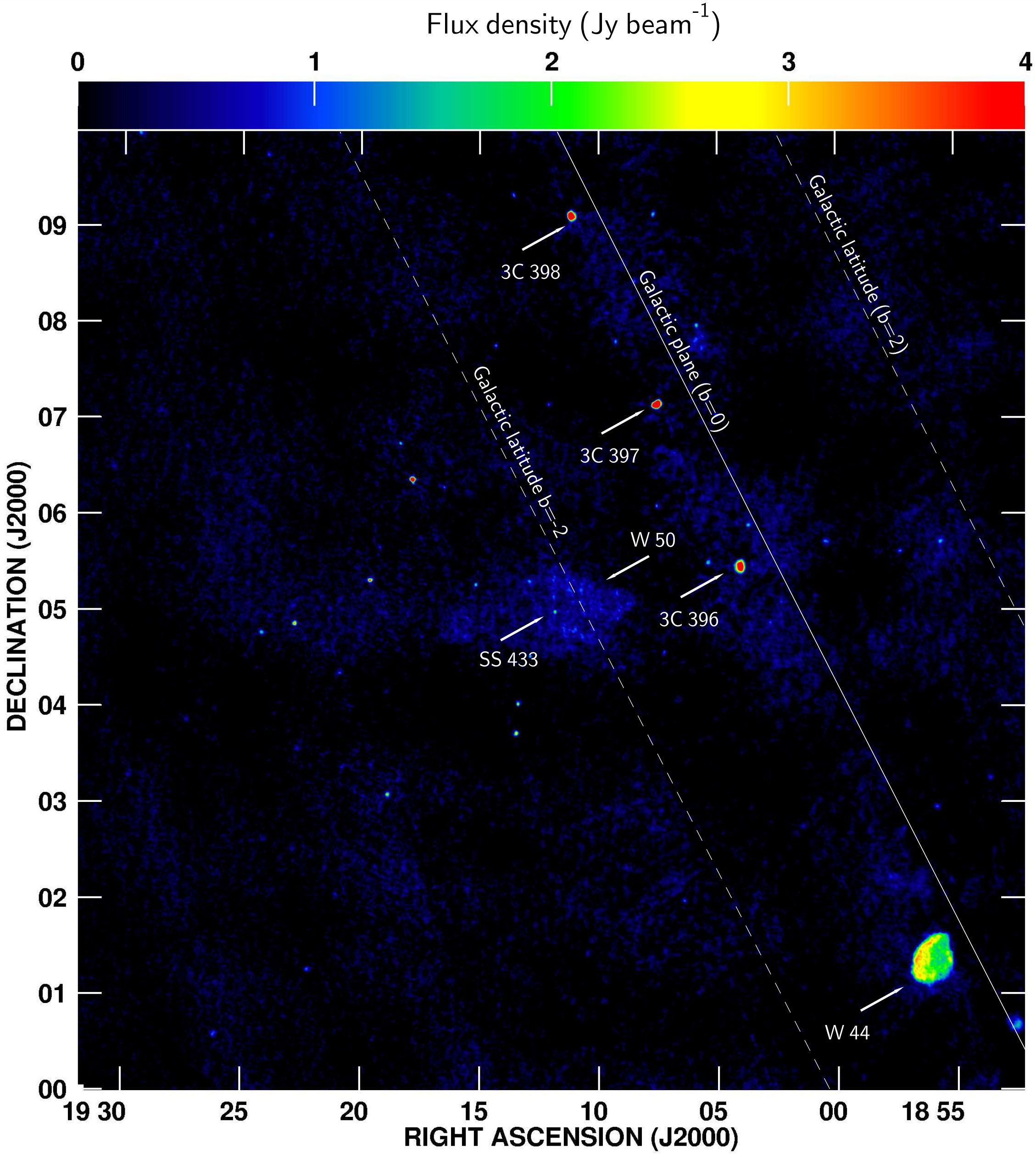


Blundell & Bowler (2004)

VLA 74/330-MHz observations of SS 433

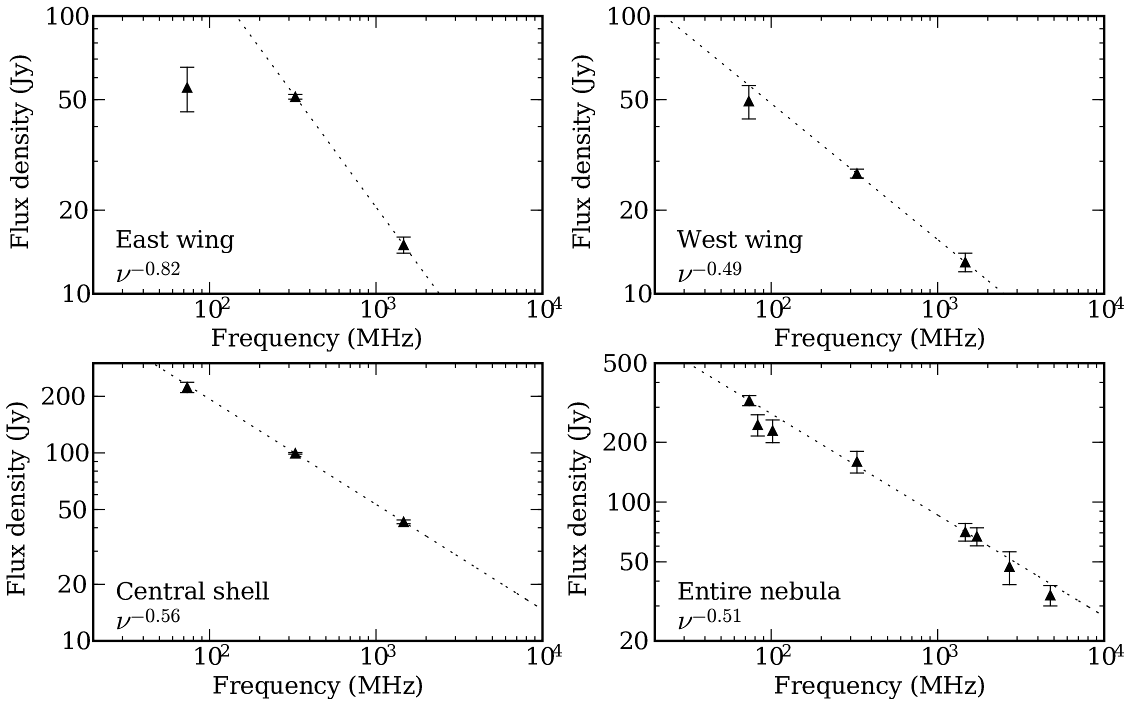
- Simultaneous 74/330-MHz VLA observations
- All four VLA configurations (A–D)
- Ionospheric imaging algorithm
- 11.9° primary beam at 74 MHz
- rms noise of 8 mJy bm^{-1} at 330 MHz
- Significantly greater at 74 MHz: 190 mJy bm^{-1}

Combined 74-MHz data



Combined 74-MHz data

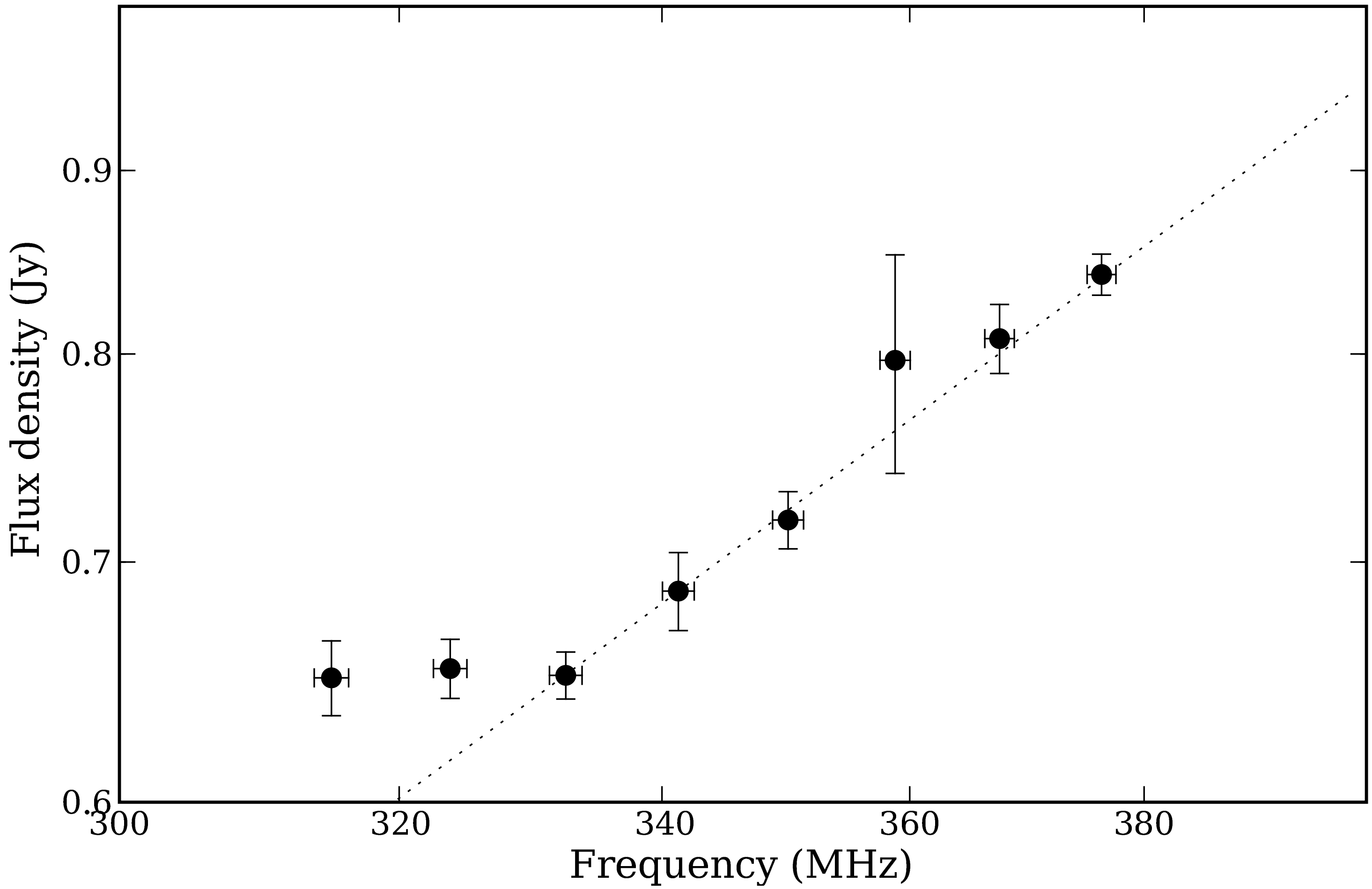
- SS 433 detected and variable at 74 MHz!
- W 50 has an unbroken integrated spectrum $S_\nu \propto \nu^{-0.51}$ down to 74 MHz
- Eastern wing shows a turnover in the spectrum



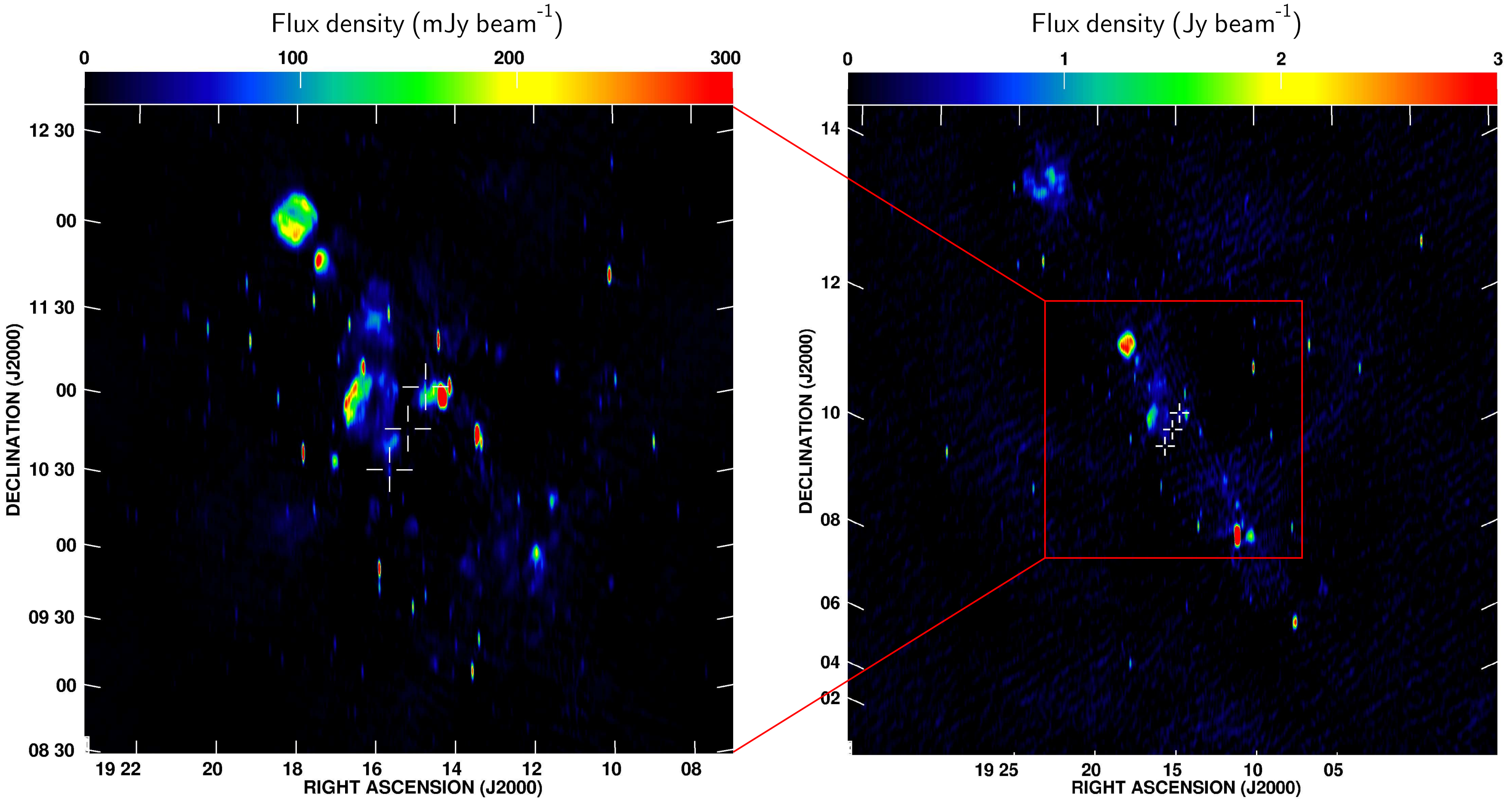
WSRT observations

- 3 persistent X-ray binaries observed quasi-simultaneouly at 310–380 and 115–170 MHz:
  - SS 433
  - GRS 1915+105
  - Cygnus X-3
- 8 simultaneous spectral windows in both bands
- 4 further ToO monitoring epochs triggered during the May 2006 outburst of Cygnus X-3

SS 433

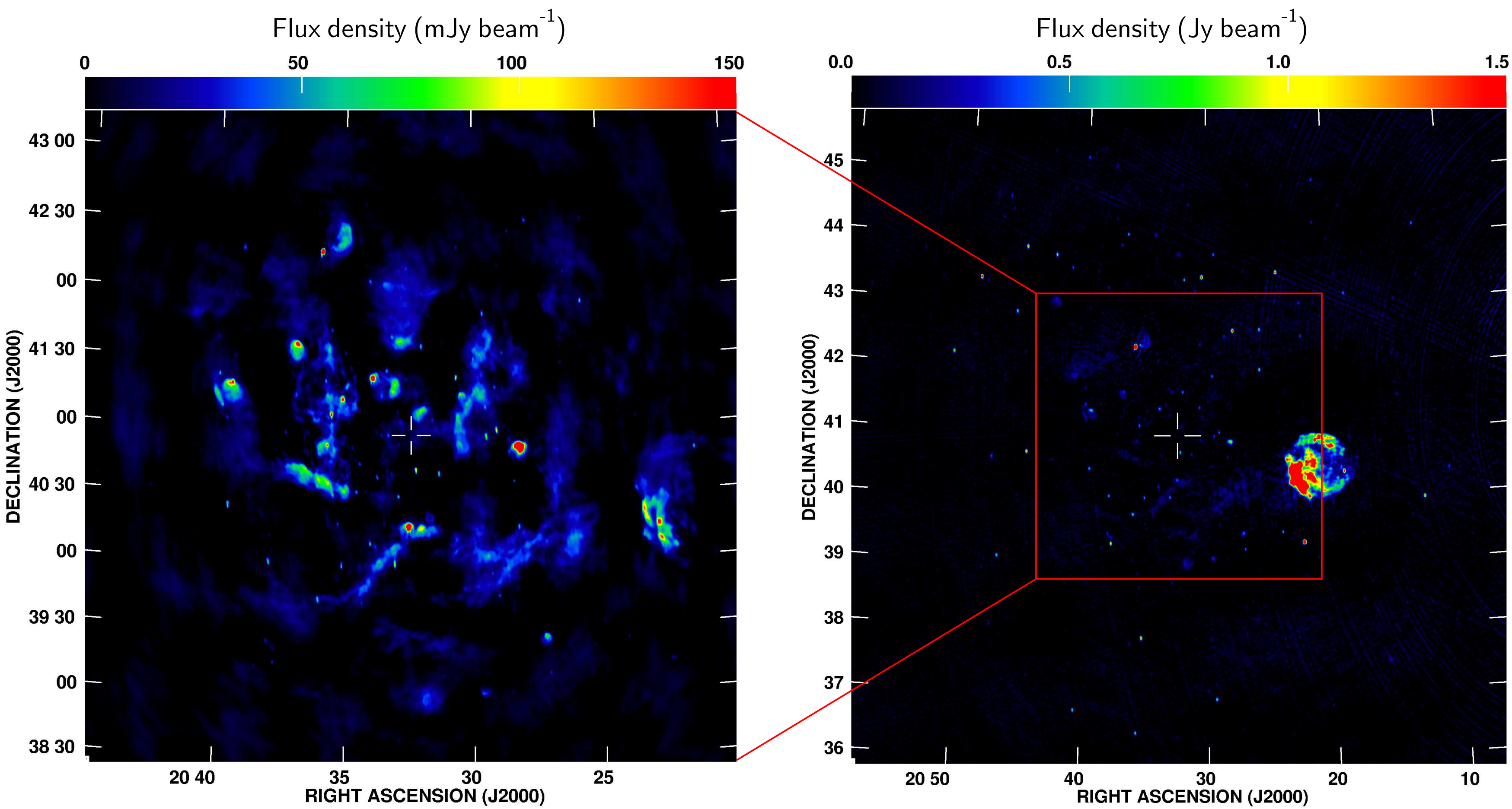


GRS 1915+105



Flux density (mJy beam^{-1})
0
100
200
300
12 30
00
11 30
00
10 30
00
09 30
00
08 30
DECLINATION (J2000)
19 22
20
18
16
14
12
10
08
RIGHT ASCENSION (J2000)
Flux density (Jy beam^{-1})
0
1
2
3
14
12
10
08
06
04
02
19 25
20
15
10
05

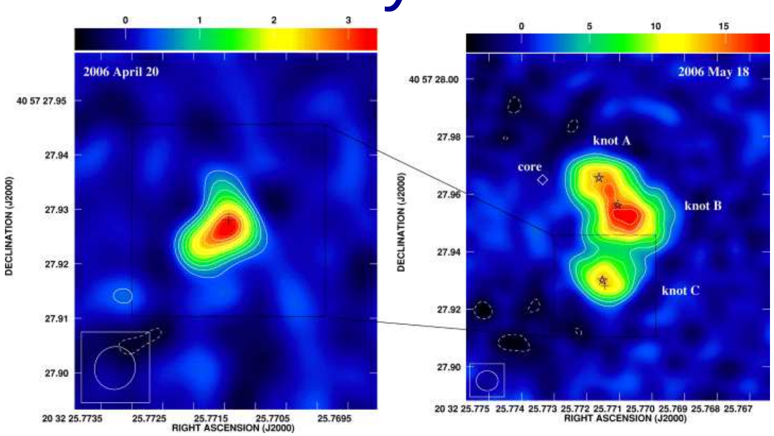
Cygnus X-3

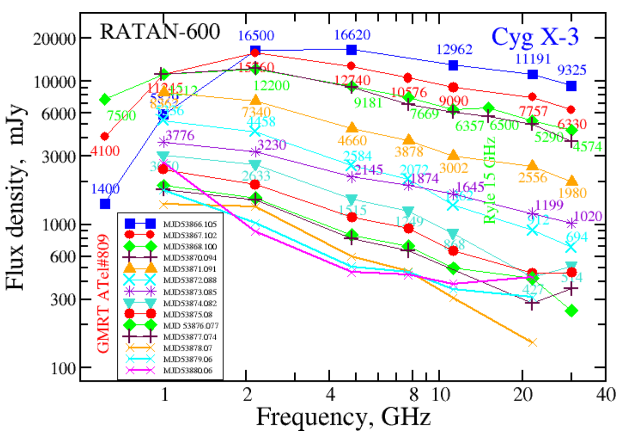


- Non-detections constrain spectral index to be more inverted than $\nu^{0.5}$

Cygnus X-3: May 2006 outburst

- Rose out of pre-flare quench state on 2006 May 4
- Peaked at ~ 14 Jy at 15 GHz on May 9
- e-VLBI imaging shows jet-like structures
- Ryle and RATAN-600 monitoring
- GMRT 610-MHz monitoring shows rising flux density from May 10-12

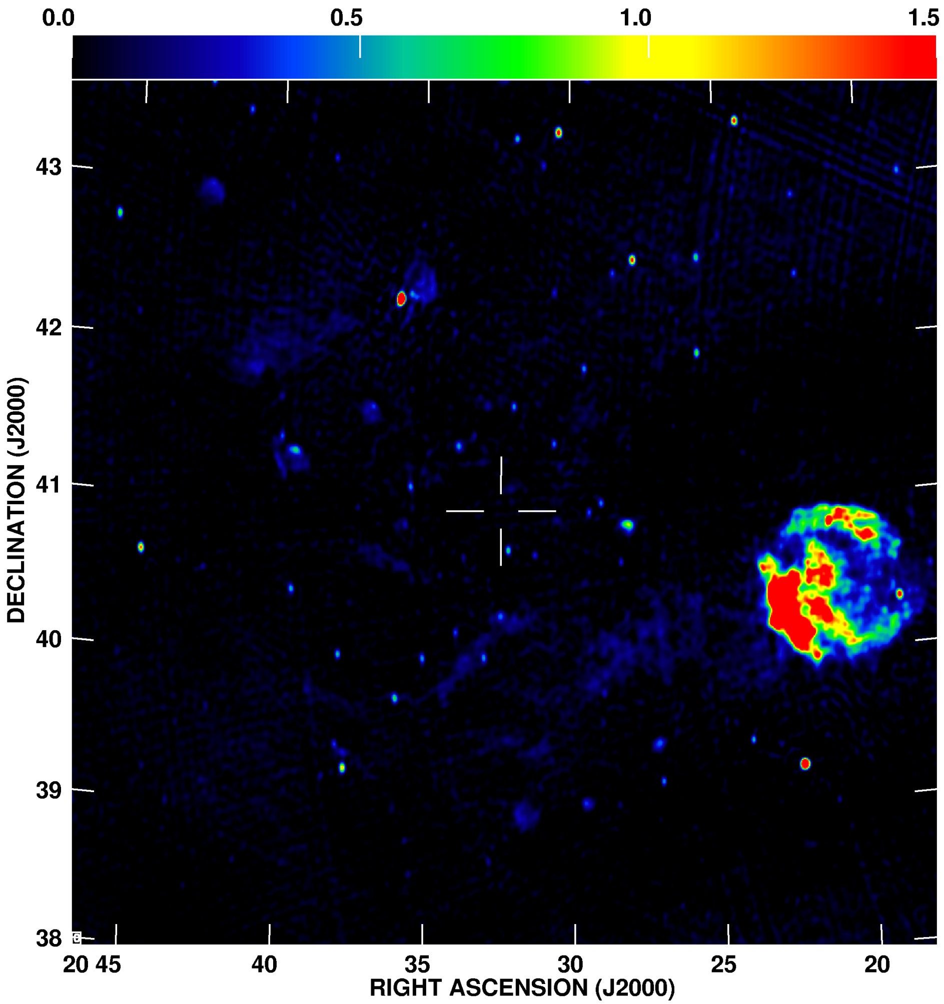




Tudose et al. (2007)

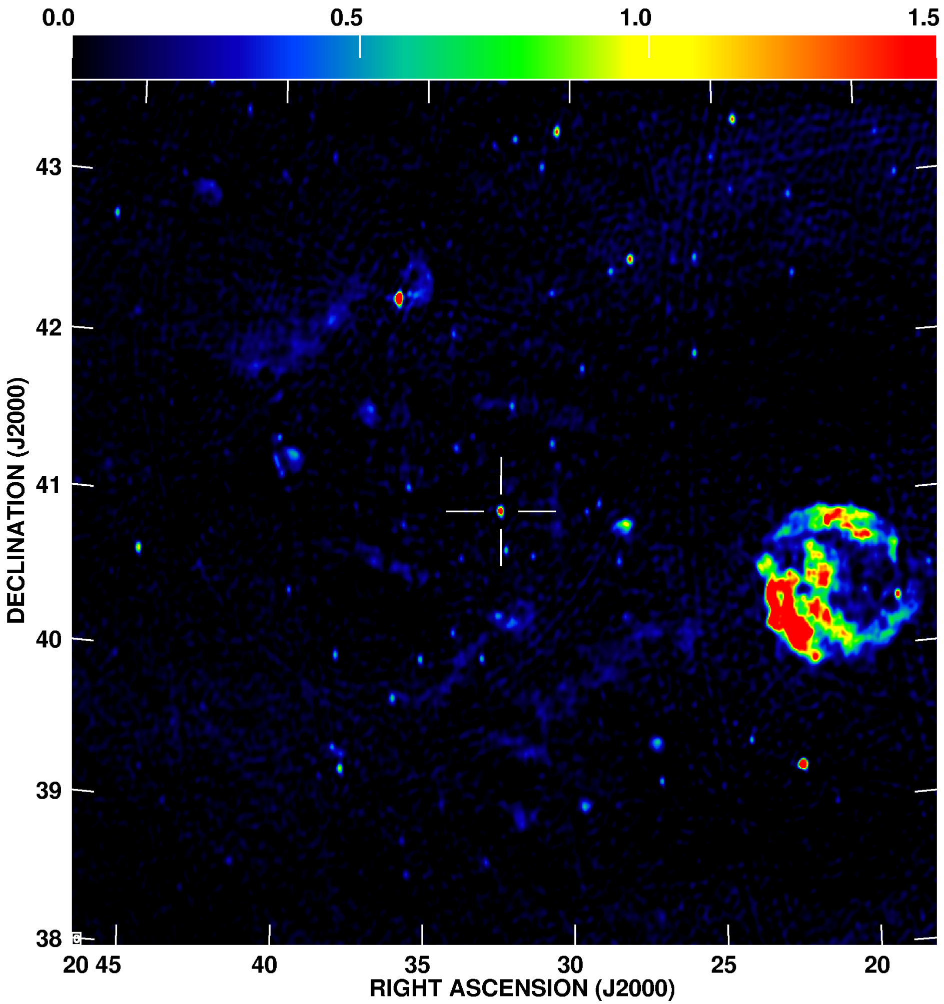
Trushkin et al., astro-ph/0702393

Cygnus X-3: May 2006 outburst



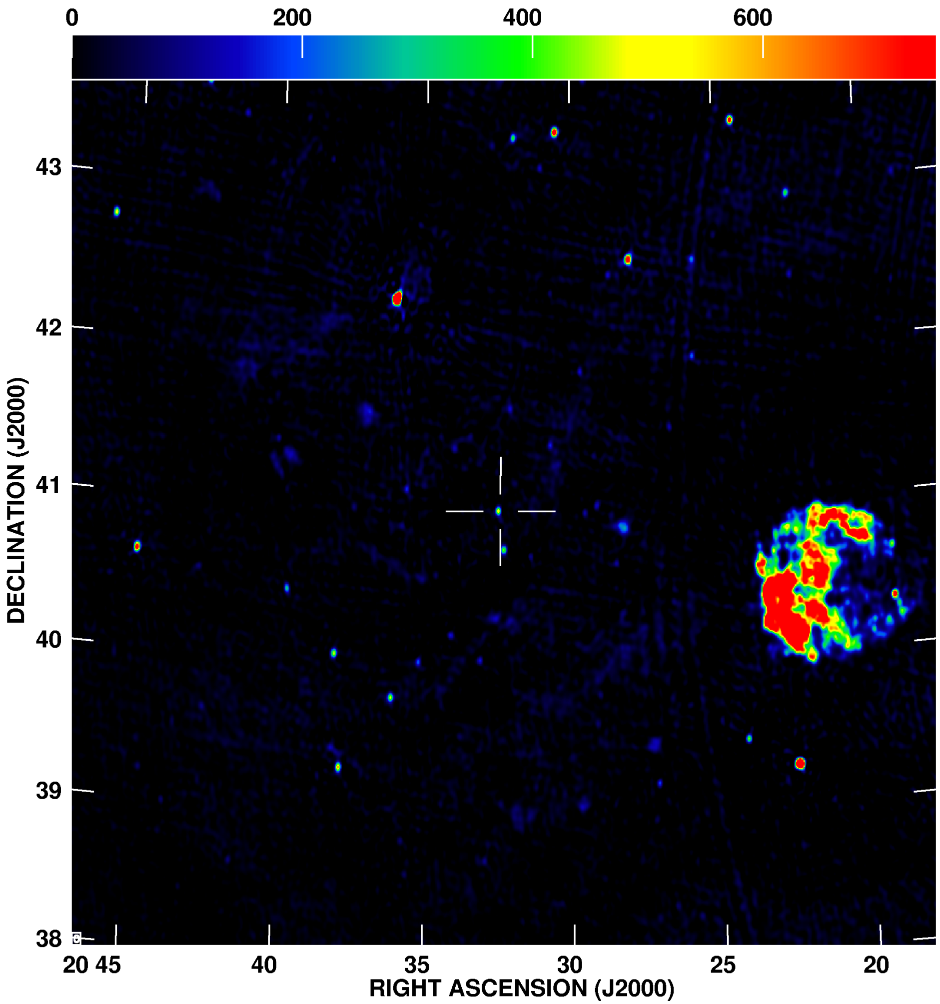
- 27 July 2005
- rms 42 mJy bm^{-1}
- Non-detection during quiescence
- 15 GHz flux density 110 ± 15 mJy bm^{-1}
- Constrains $\alpha \geq -0.03$

Cygnus X-3: May 2006 outburst



- 20 May 2006
- rms 42 mJy bm^{-1}
- Cyg X-3 detected at 2300 ± 40 mJy bm^{-1}

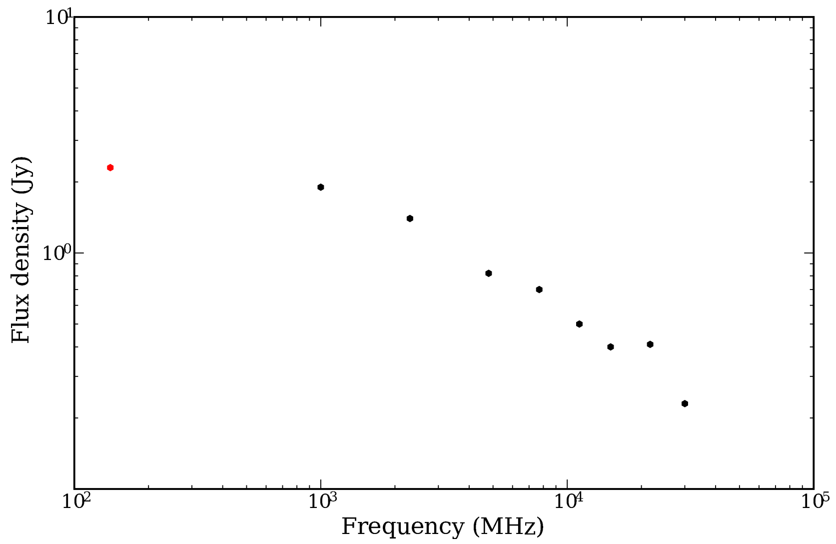
Cygnus X-3: May 2006 outburst



- 10 June 2006
- rms 19 mJy bm^{-1}
- Cyg X-3 detected at 554 ± 10 mJy bm^{-1}

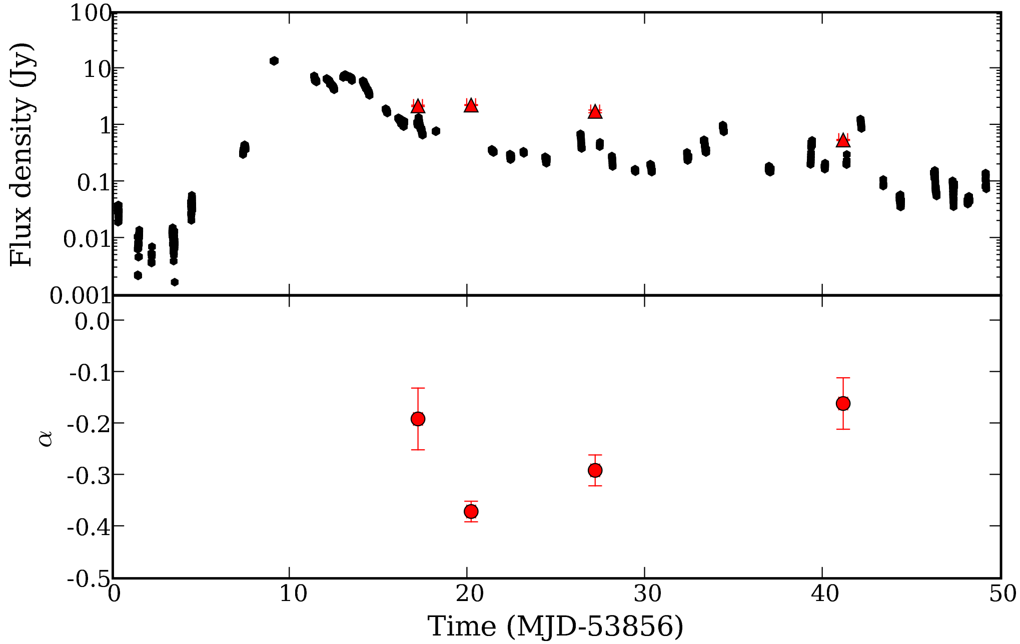
Cygnus X-3: May 2006 outburst

- 140 MHz to 30 GHz broadband radio spectrum
- Still not optically thick on May 20
- Constrains 140-MHz rise time to > 16 d



Cygnus X-3: May 2006 outburst

- Decaying flux densities at 140 MHz
- Spectral index α_{140}^{15000} rises with time ($S_\nu \propto \nu^\alpha$)
- Evidence for reflaring



Future work

- Frequency dependence (115-170 MHz) of May 2006 Cygnus X-3 outburst
- Full analysis of February 2006 Cygnus X-3 outburst
- Compare low-frequency radio coverage with data from other wavebands
- Stack data to get better *uv*-coverage and perform a detailed analysis of the field
- Difference images to search for further transients in the field

Implications for LOFAR

- Not all X-ray binaries are turned over at low frequencies
- X-ray binaries are variable sources in the low-frequency sky
- We *will* detect these with LOFAR
- The broad bandwidth of LOFAR will allow us to monitor changing spectral indices
- With international baselines, jet sources may be resolved

LOFAR simulation: SS 433

- NL-only LOFAR will marginally resolve the central source
- Adding in international baselines allows us to delineate the precessing jets

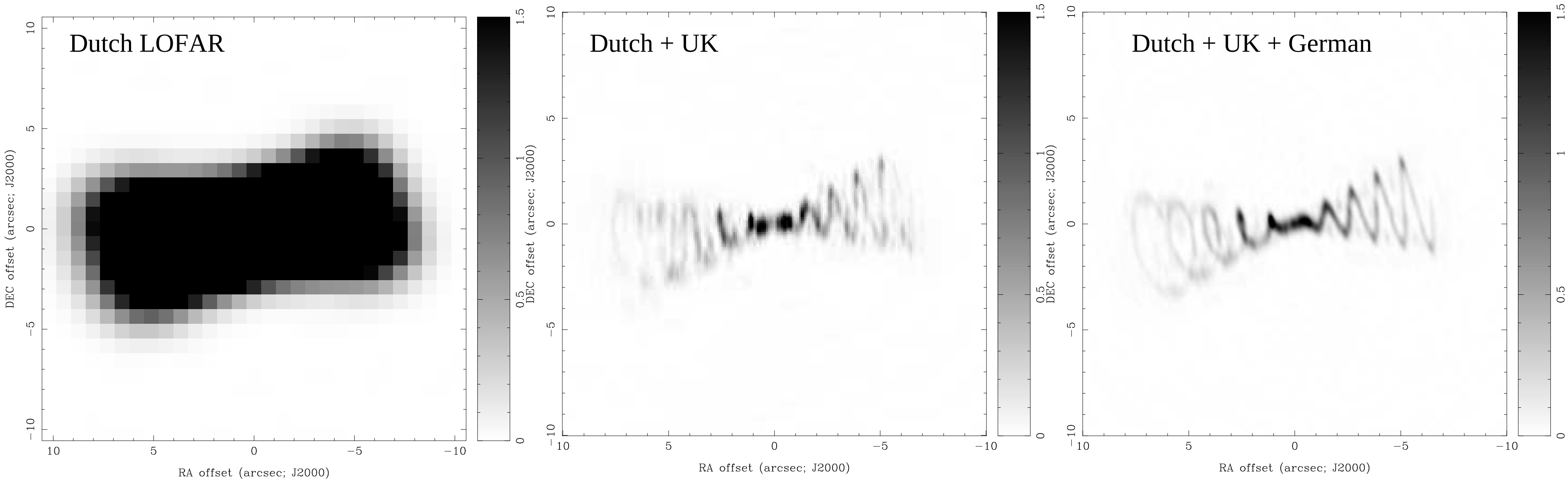


Image courtesy of Faye Cashman, Mark Hill, & Rob Fender