
The University of Manchester
Jodrell Bank
MANCHESTER 1824
Anthony Rushton
"Polarisation changes in microquasar GRS1915+105"

Introduction – X-ray Binaries

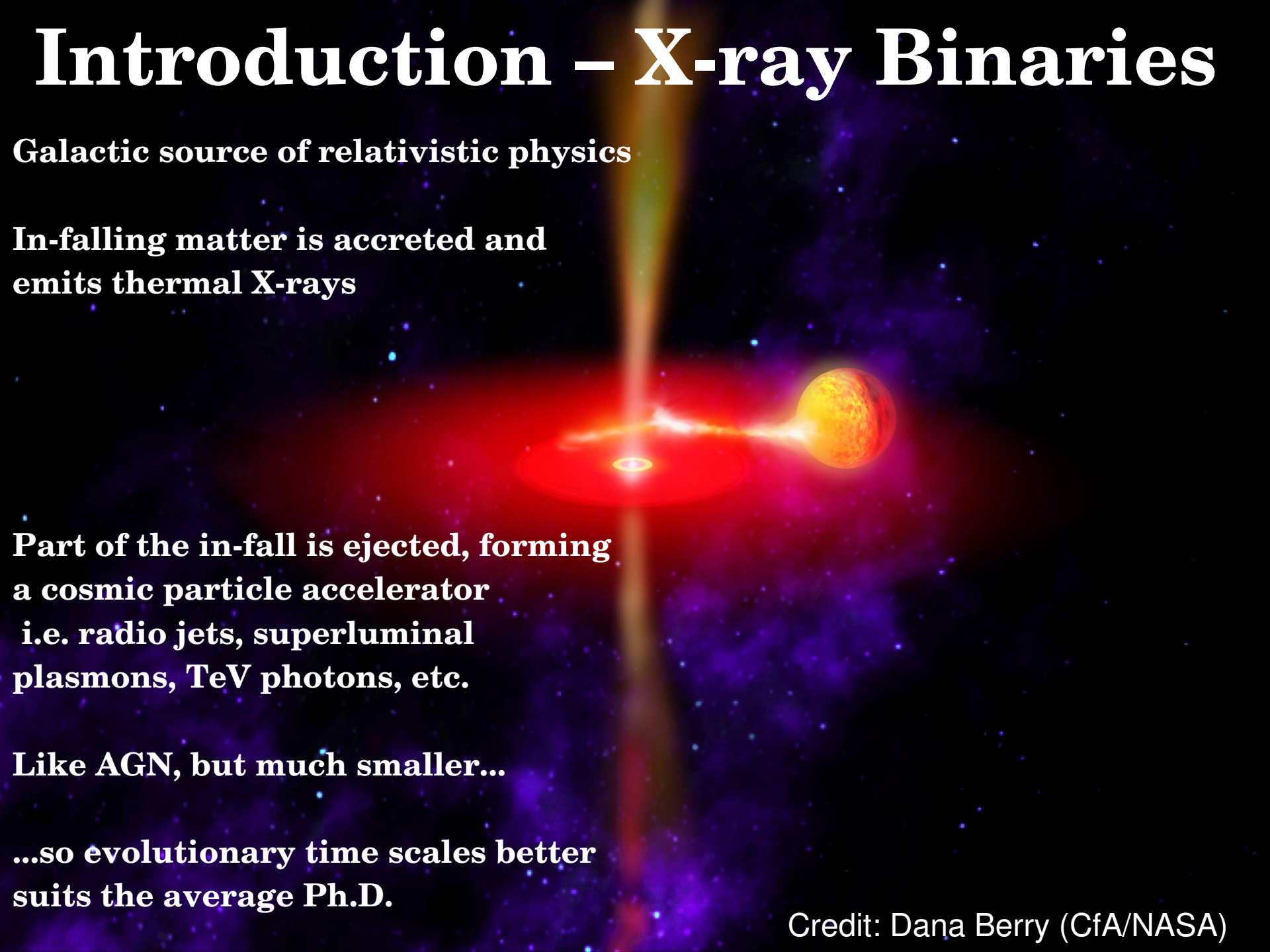
Galactic source of relativistic physics

In-falling matter is accreted and emits thermal X-rays

Part of the in-fall is ejected, forming a cosmic particle accelerator i.e. radio jets, superluminal plasmons, TeV photons, etc.

Like AGN, but much smaller...

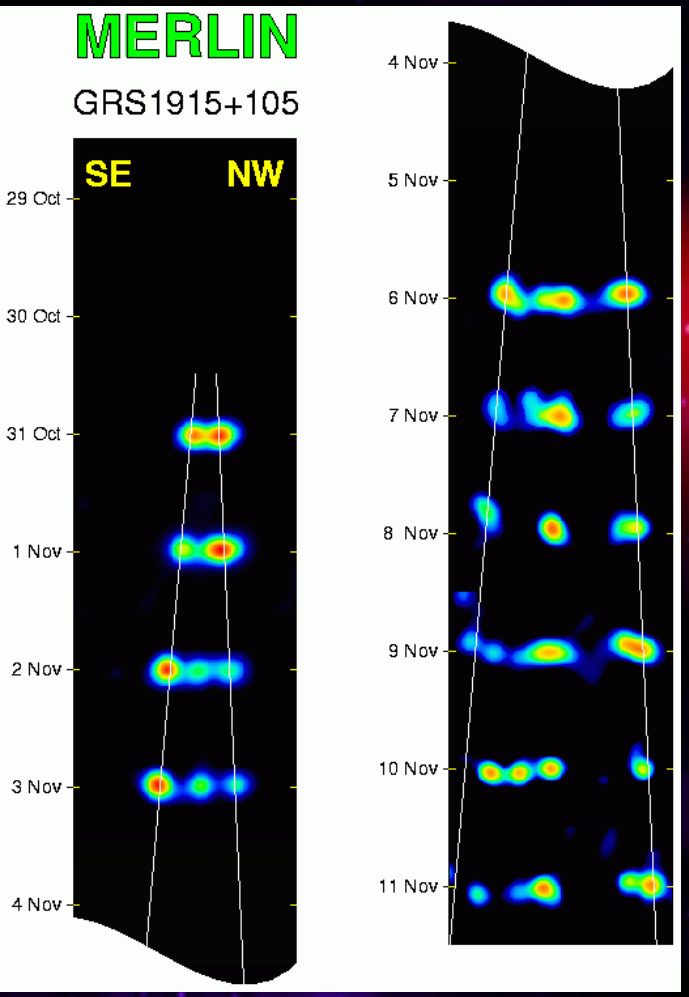
...so evolutionary time scales better suits the average Ph.D.



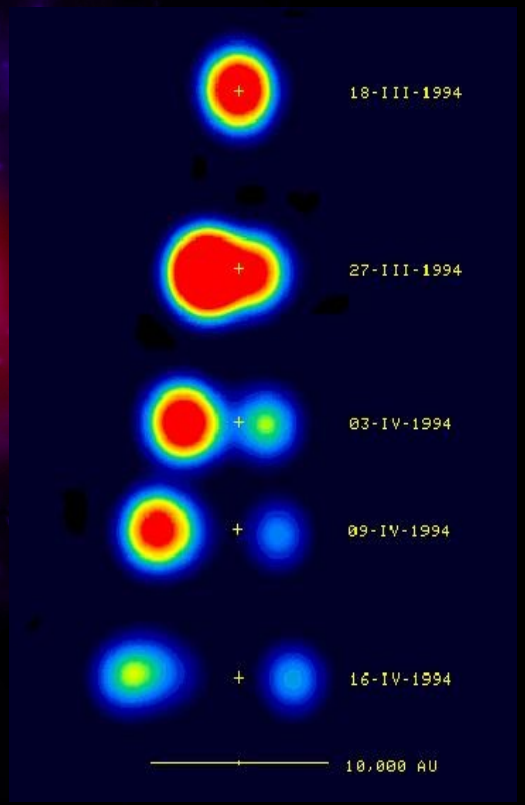
Credit: Dana Berry (CfA/NASA)

Introduction – GRS 1915+105

Fender et al. (1999)
MERLIN



Mirabel & Rodríguez (1994)
VLA



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Introduction – GRS 1915+105

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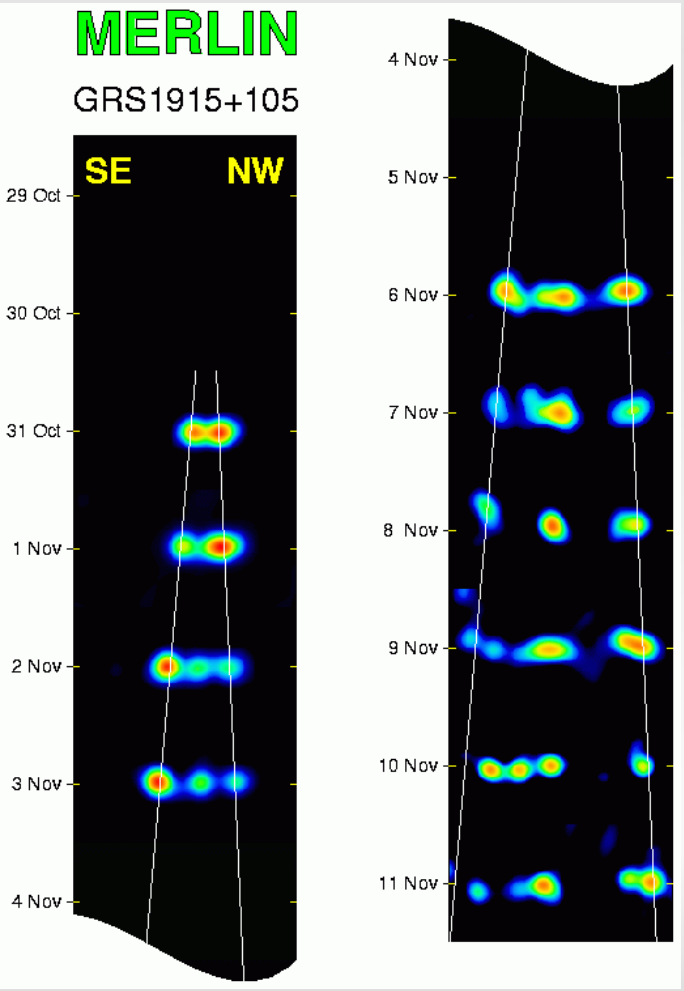


Superluminal motion

- Apparent fast than light ejections
- A good test of relativity

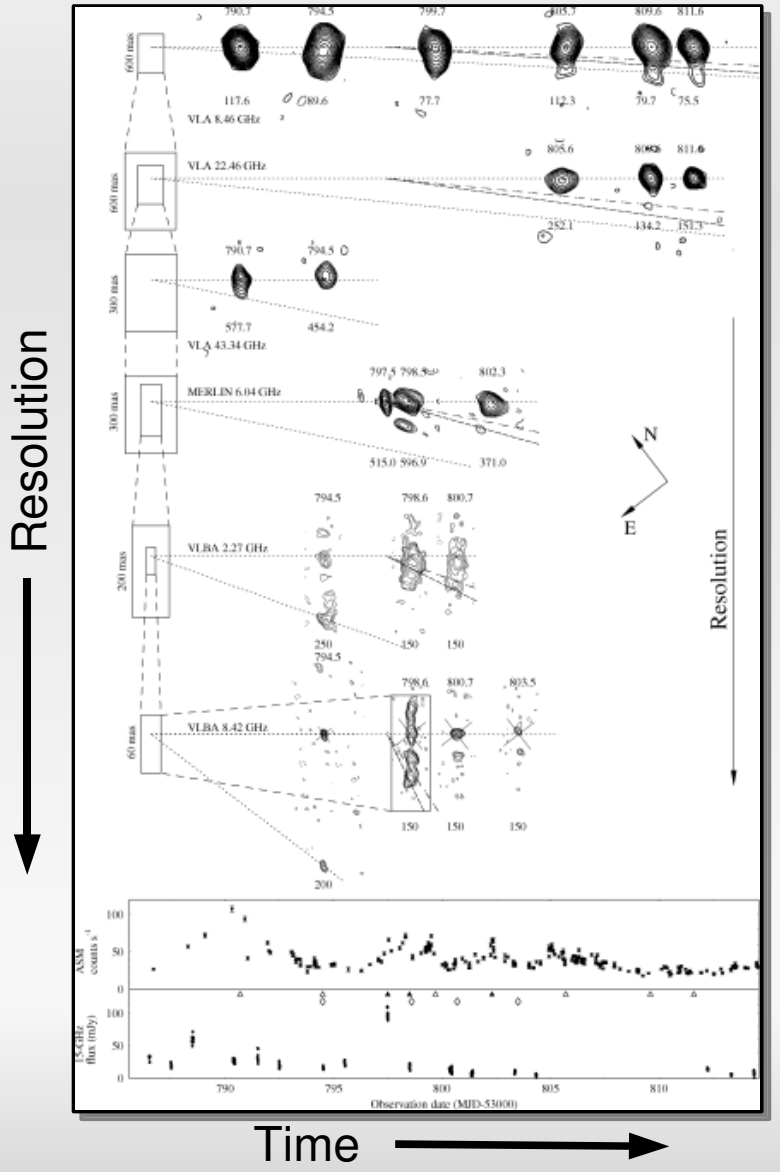
$$\mu_{r,a} = \frac{\beta \sin\theta}{(1 \pm \beta \cos\theta)} \frac{c}{D}$$

- Assuming a distance, D, of 12 kpc, the true velocity is about 0.92 c.

Evidenced for deceleration in the radio jet of GRS1915+105?

Miller-Jones, J., Rupen, M., Fender R., Rushton, A., Spencer, R. & Pooley, G.

- There is a discrepancy in the proper motion of the radio jet between VLBA, MERLIN and VLA resolution scales.
- Simultaneous multi-resolution campaign on a flare staring in 2006 February; Knot ejections were measured as 17.0 mas per day.
- No evidence for deceleration in jet knots, beyond **> 70 mas**.
- Differential velocity jets/ejections appear to be intrinsic.



Motivation

- The Rossi X-ray Timing Explorer (RXTE) and Ryle telescope (15 GHz) has now completed over a decayed of observations.

- It is now possible to do a comparative study between the X-rays and radio over a long period (1996 – 2007).

- How does the long term radio behaviour associate to changes in the X-ray state?

- How does the short (Intra-day) flares relate to the ejection of superluminal ejecta?

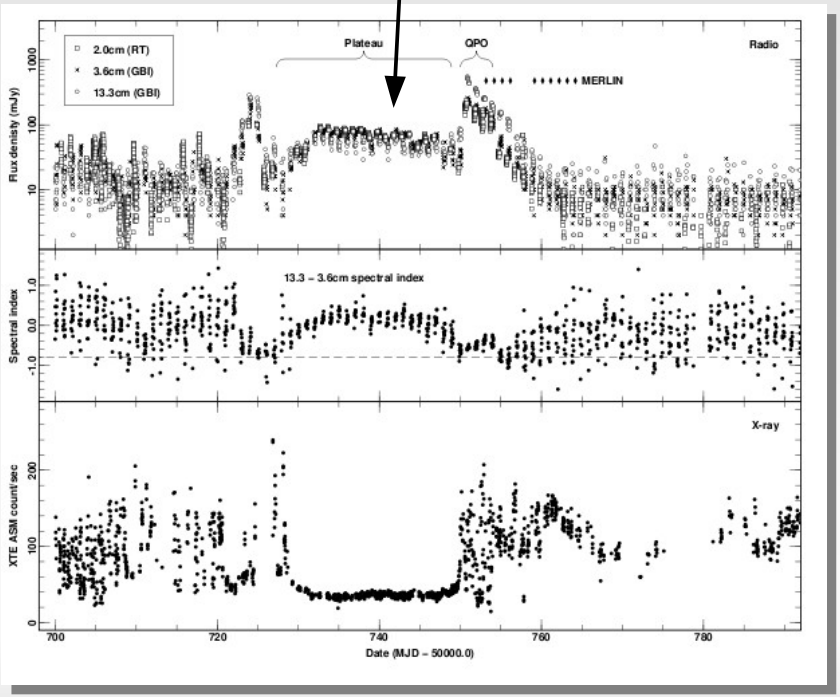
- Does the polarisation change during outburst?

Introduction – X-ray behaviour

Highly variable on very short time scales.

Quasi-periodic oscillation (QPO) believed to be associated with disk instabilities. (Chen et al. 1997)

The “Plateau state”



(Fender et al. 1999)

- Constant ASM count rate of ~ 20 counts per second

- X-rays are “harder”:

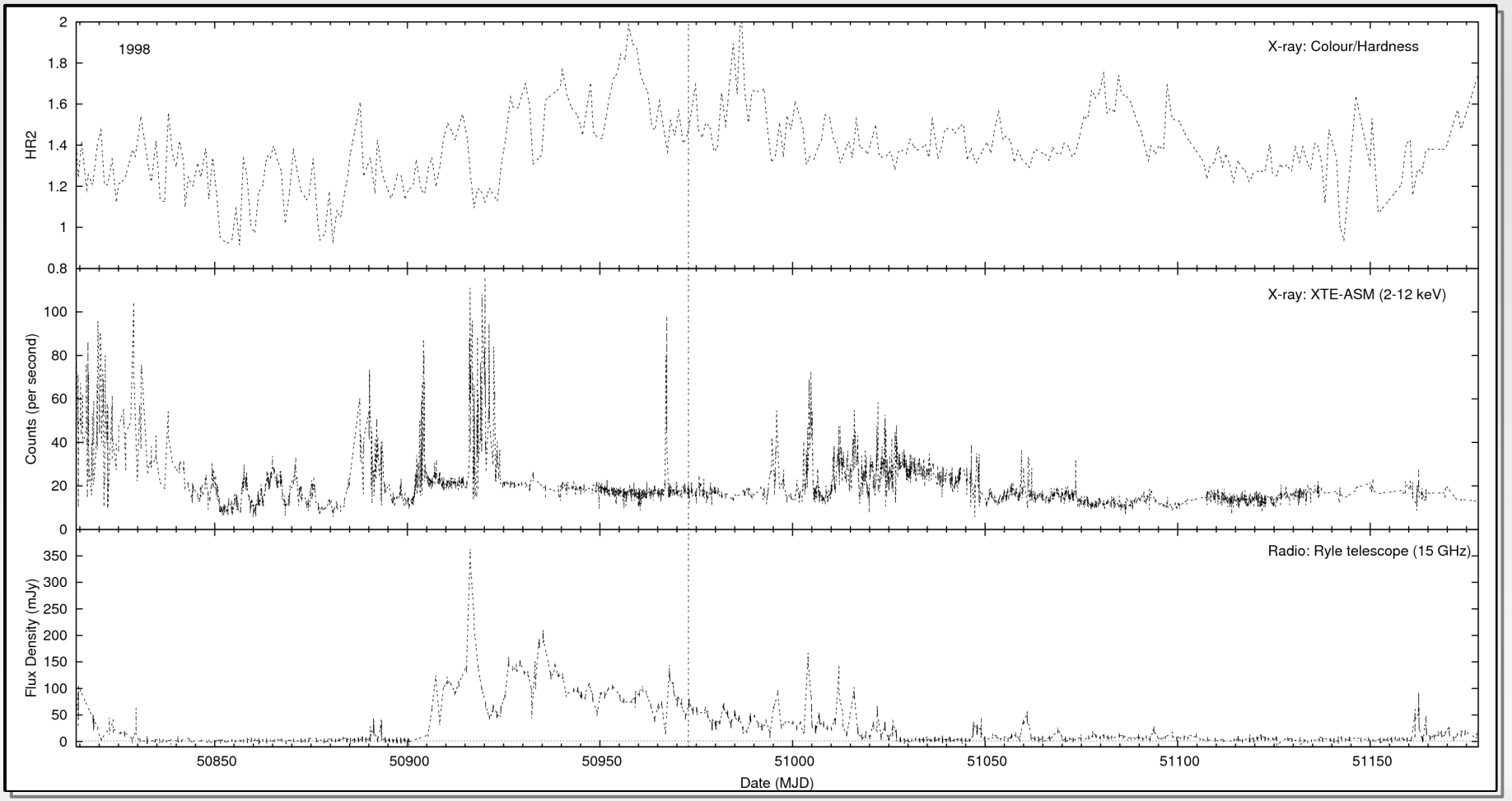
  none thermal

  not from the accretion disk?

- Strong radio emission

RXTE-ASM (2-12 keV)

and Ryle telescope (15 GHz)



Radio outburst rate

Between 1996 – 2007

“Major” events:

Date (MJD)	Duration (days)
50300	80
50730	20
50900	110
51350	60
52300	150
52700	150
53050	100
53400	100

- Defined as greater than 100 mJy at 15 GHz and lasting longer than 10 days.
- Over 10 years this has occurred approx. 8 times.
- RXTE-ASM measured ~ 20 counts / second.

→ GRS1915+105 outburst rate = 1.3 /yr.

MERLIN 1.4/1.6 GHz observations

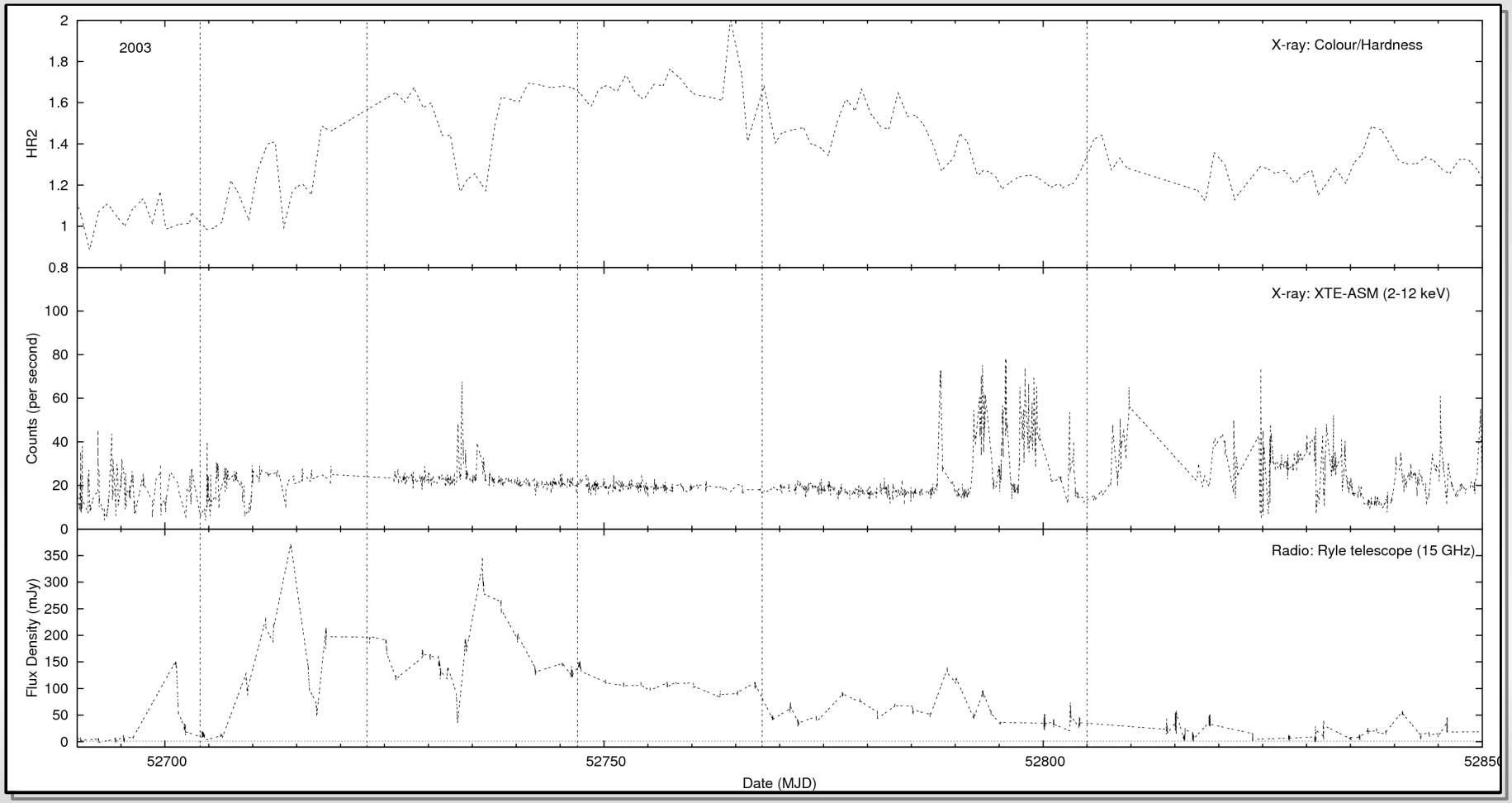
14 MERLIN epochs at 1.4 or 1.6 GHz between 1996 and 2007

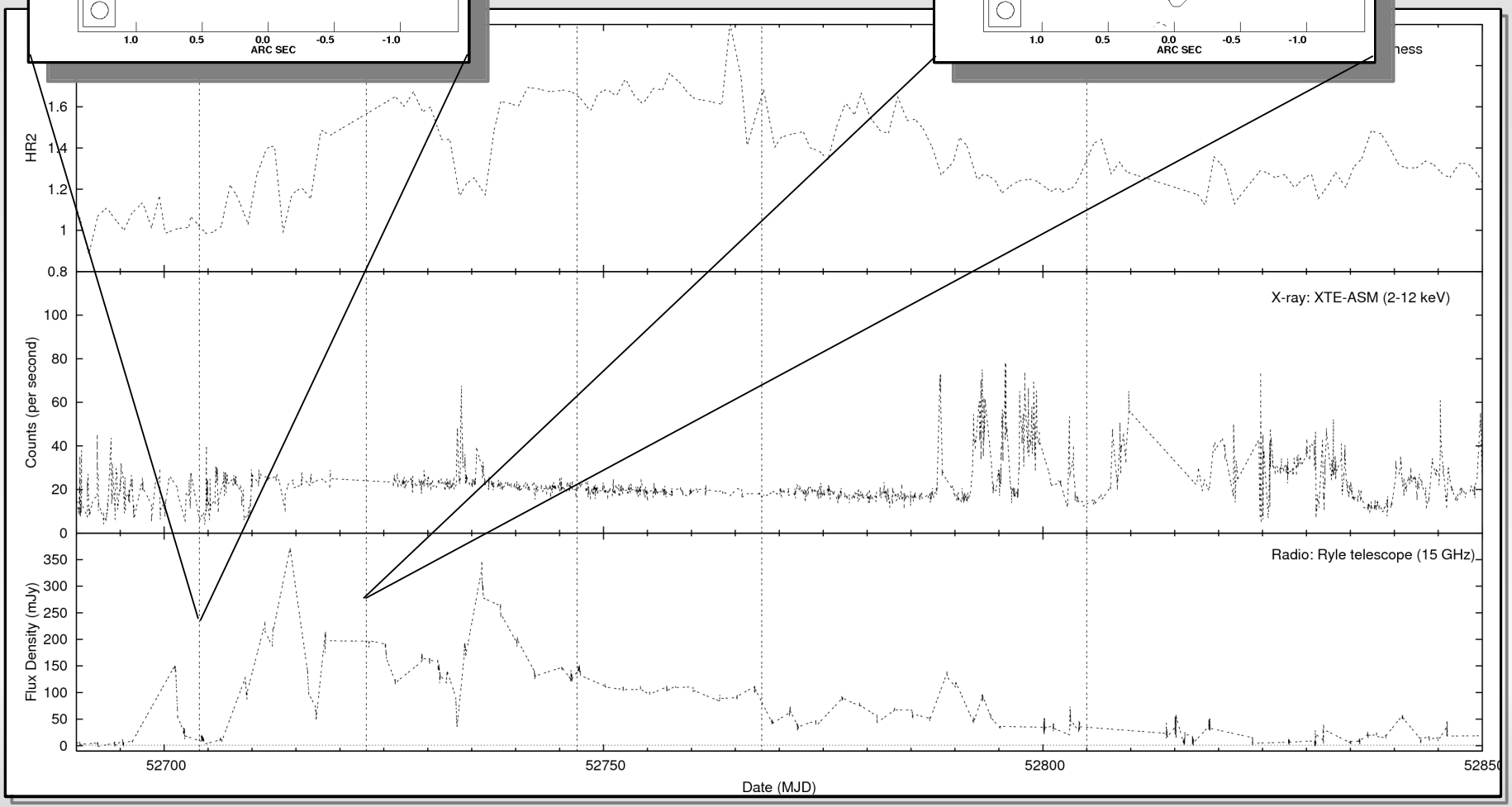
Epoch (MJD)	Frequency/Array (GHz)	I_{peak} (mJy/beam)	I_{total} (mJy)	$3\sigma\times$ rms (mJy)	LP_{peak} (mJy/beam)	LP_{total} (mJy)	Fraction (%)
†1997 October 31 (50752) -core	2.27 / VLBA	24.0 ± 0.4	105 ± 2	1.3	$\leqslant 0.1^1$	$\leqslant 0.1^1$	$\leqslant 0.5^1$
†1997 October 31 (50752) -jet	2.27 / VLBA	63.7 ± 0.4	226 ± 2	1.3	2.6 ± 0.1	5.6 ± 0.3	2.5
†1997 October 31 (50752) -core	8.3 / VLBA	23.5 ± 0.5	33 ± 1	1.4	$\leqslant 0.1^1$	$\leqslant 0.1^1$	$\leqslant 0.5^1$
†1997 October 31 (50752) -jet	8.3 / VLBA	15.0 ± 0.5	65 ± 3	1.4	1.1 ± 0.1	4.7 ± 0.3	7.2
1998 June 9 (50973)	1.6 / MERLIN	95.1 ± 0.2	145.1 ± 0.4	0.90	4.2 ± 0.1	9.5 ± 0.3	6.9 ± 0.2
1999 April 2 (51270)	1.6 / MERLIN	221.7 ± 0.1	238.4 ± 0.3	1.6	0.80 ± 0.1	3.5 ± 0.3	1.5 ± 0.2
1999 November 18 (51500)	1.6 / MERLIN	194.8 ± 0.4	221.3 ± 0.8	2.6	0.50 ± 0.1	6.9 ± 0.3	3.2 ± 0.2
1999 November 22 (51504)	1.6 / MERLIN	31.1 ± 0.4	37.1 ± 0.7	0.9	$\leqslant 0.1^1$	$\leqslant 0.1^1$	$\leqslant 0.4^1$
1999 December 28 (51540)	1.6 / MERLIN	49.2 ± 0.3	89.1 ± 0.7	1.2	1.0 ± 0.1	12.7 ± 1.6	14.1 ± 0.2
2003 March 6 (52704)	1.6 / MERLIN	22.3 ± 0.2	31.3 ± 0.3	0.73	0.5 ± 0.1	1.6 ± 0.3	5.2 ± 1.0
2003 March 25 (52723)	1.6 / MERLIN	110.3 ± 0.1	125.8 ± 0.1	0.42	2.1 ± 0.1	7.1 ± 0.2	5.6 ± 0.2
2003 April 18 (52747) -core	1.6 / MERLIN	84.9 ± 0.2	135.4 ± 0.4	0.822	2.4 ± 0.1	3.5 ± 0.2	2.6 ± 0.2
2003 April 18 (52747) -jet	1.6 / MERLIN	20.1 ± 0.2	20.0 ± 0.3	0.822	1.3 ± 0.1	1.3 ± 0.1	6.5 ± 0.5
2003 June 15 (52805) -core	1.6 / MERLIN	23.3 ± 0.4	41.4 ± 0.1	1.18	$\leqslant 0.1^1$	$\leqslant 0.1^1$	$\leqslant 0.2^1$
2003 June 15 (52805) -jet	1.6 / MERLIN	50.5 ± 0.4	67.5 ± 0.1	1.18	6.1 ± 0.2	7.6 ± 0.4	11.9 ± 0.6
2006 December 24 (54093)	1.4 / MERLIN	144.5 ± 0.3	145.0 ± 0.5	1.14	2.1 ± 0.1	7.7 ± 0.6	5.3 ± 0.4
2006 December 24 (54093)	1.6 / MERLIN	149.7 ± 0.7	156.9 ± 1.2	1.7	1.5 ± 0.1	11.5 ± 0.5	7.3 ± 0.5
2006 December 27 (54096)	1.4 / MERLIN	17.7 ± 0.2	20.7 ± 0.5	0.69	$\leqslant 0.1^1$	$\leqslant 0.1^1$	$\leqslant 0.5^1$
2006 December 27 (54096)	1.6 / MERLIN	17.0 ± 0.2	27.0 ± 0.5	0.69	$\leqslant 0.1^1$	$\leqslant 0.1^1$	$\leqslant 0.5^1$
2006 December 28 (54097)	1.4 / MERLIN	19.9 ± 0.2	25.8 ± 0.4	0.64	$\leqslant 0.1^1$	$\leqslant 0.1^1$	$\leqslant 0.4^1$
2006 December 28 (54097)	1.6 / MERLIN	18.3 ± 0.2	26.2 ± 0.4	0.64	$\leqslant 0.1^1$	$\leqslant 0.1^1$	$\leqslant 0.4^1$
2007 January 04 (54104)	1.4 / MERLIN	15.1 ± 0.2	21.0 ± 0.5	0.78	$\leqslant 0.1^1$	$\leqslant 0.1^1$	$\leqslant 0.5^1$
2007 January 04 (54104)	1.6 / MERLIN	13.9 ± 0.2	22.2 ± 0.5	0.78	$\leqslant 0.1^1$	$\leqslant 0.1^1$	$\leqslant 0.5^1$

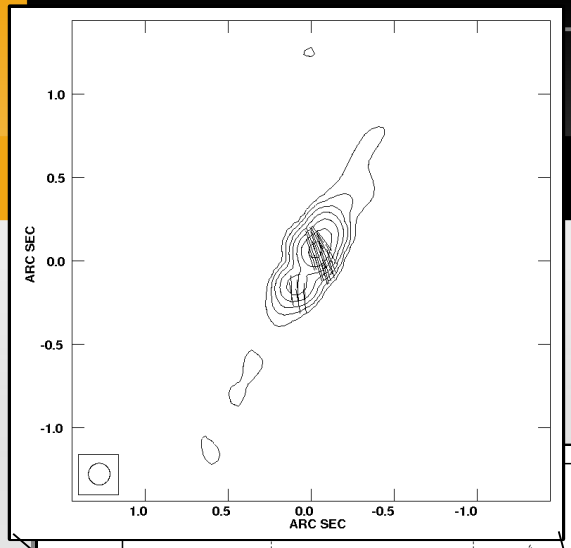
The large flare of 2003

Duration ~ 150 days.

Five MERLIN observations taken over this period.




ARC SEC
1.0
0.5
0.0
-0.5
-1.0
HR2
1.6
1.4
1.2
1
0.8
X-ray: XTE-ASM (2-12 keV)
Counts (per second)
100
80
60
40
20
0
Radio: Ryle telescope (15 GHz)
Flux Density (mJy)
350
300
250
200
150
100
50
0
52700
52750
52800
52850
Date (MJD)


ARC SEC
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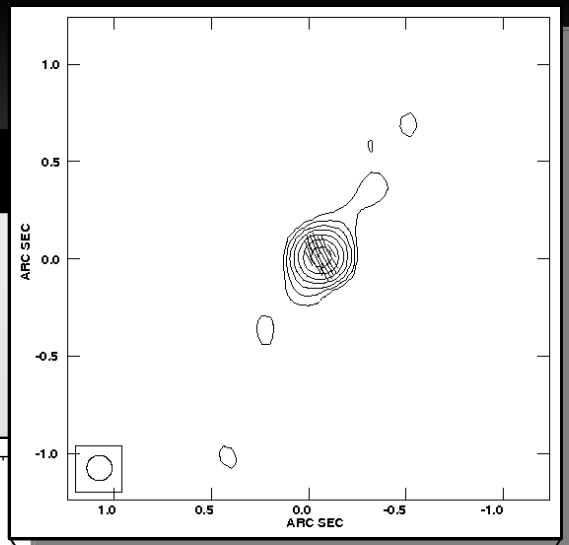
ARC SEC
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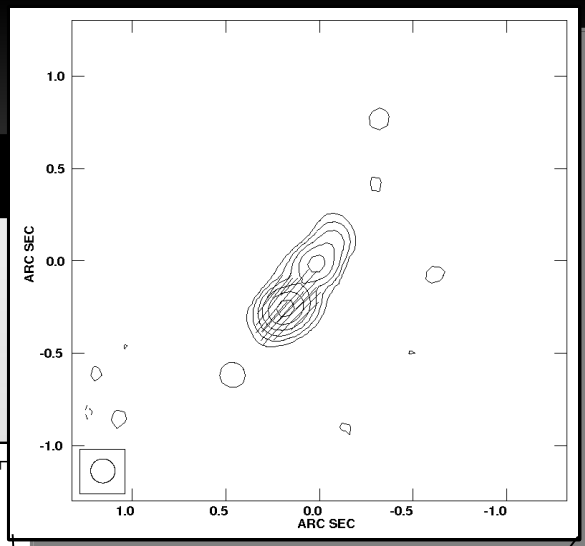
ARC SEC
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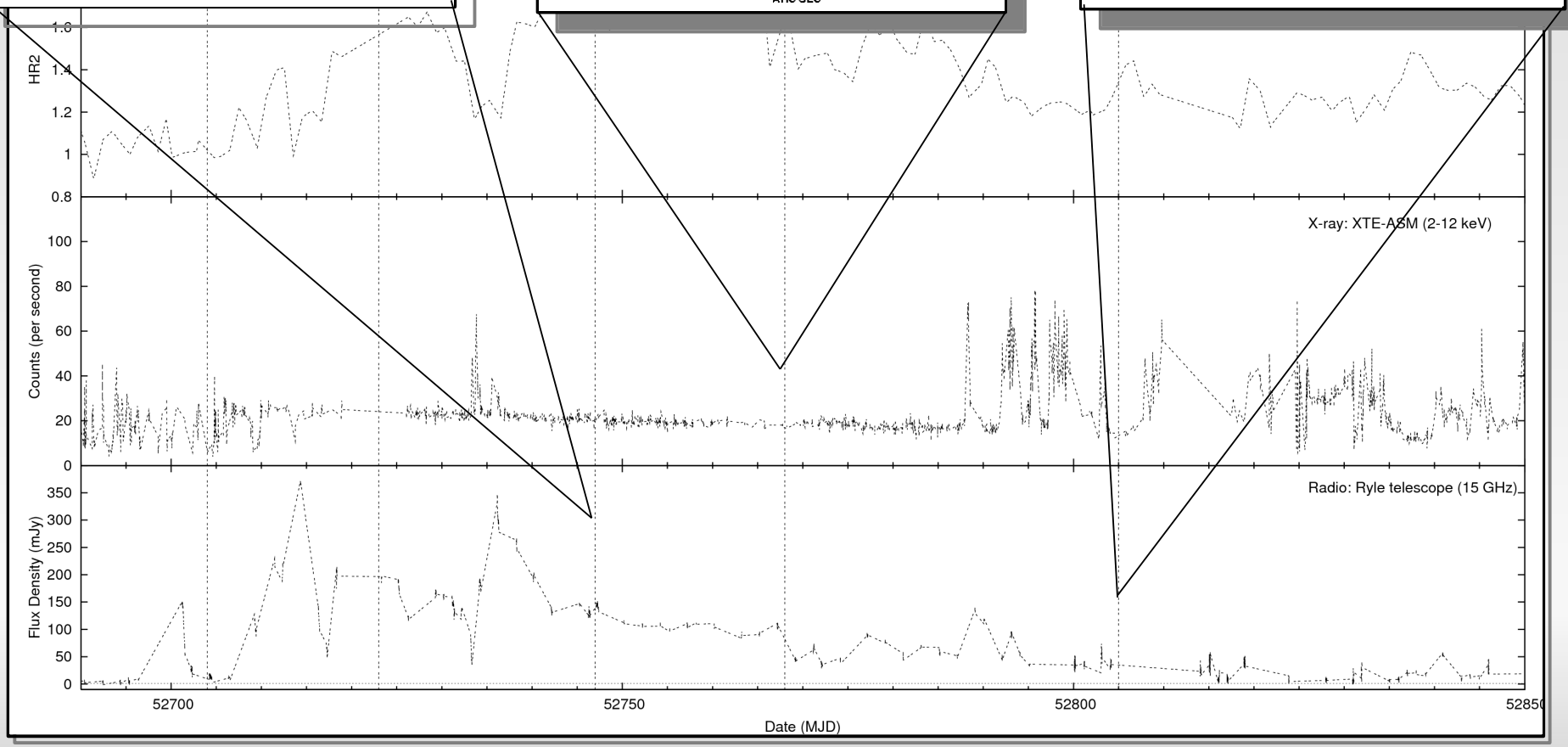
HR2
X-ray: XTE-ASM (2-12 keV)
Counts (per second)
Radio: Ryle telescope (15 GHz)
Flux Density (mJy)
52700
52750
52800
Date (MJD)

Conditions for superluminal ejection

Epoch of radio obs.	Plateau state?	Soft X-ray Flare?	Ejection?
1997 October 31	✓	✓	Plasmon
1998 June 09	✓	✓	Jet/Plasmon
1999 April 02	✗	✗	No
1999 November 18	✗	✓	No
1999 November 22	✗	✓	No
1999 December 28	✗	✓	Jet
2003 March 06	✗	✗	Jet
2003 March 24	✓	✗	No
2003 April 18	✓	✓	Plasmon
2003 June 15	✓	✓	Plasmon
2006 December 24	✗	✗	No
2006 December 27	✗	✗	Jet
2006 December 28	✗	✗	Jet
2007 January 04	✗	✗	Jet

Conditions for superluminal ejection

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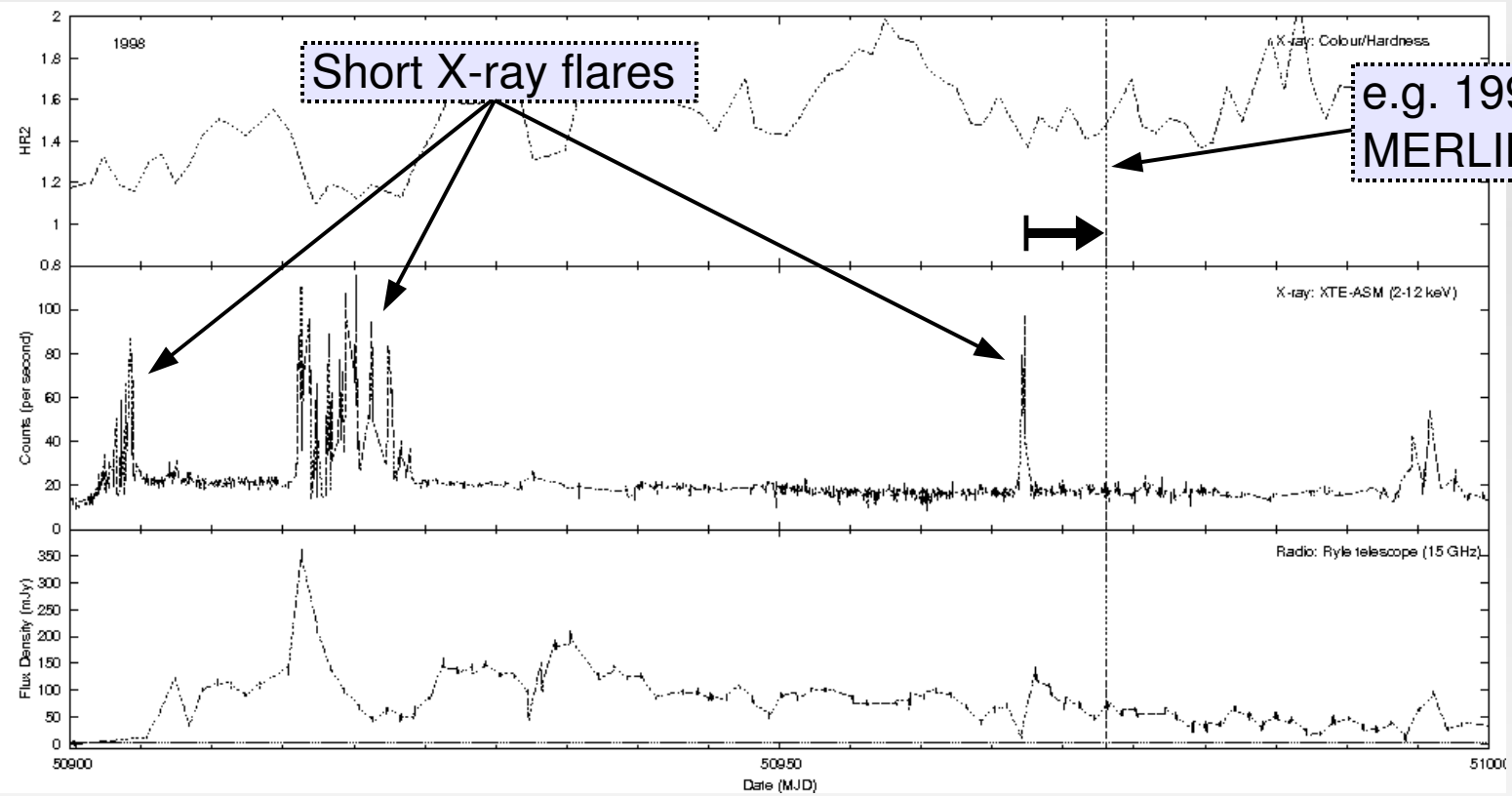
1997 October 31	✓	✓	Plasmon
1998 June 09	✓	✓	Jet/Plasmon
1999 April 02	✗	✗	No
1999 November 18	✗	✓	No
1999 November 22	✗	✓	No
1999 December 28	✗	✓	Jet
2003 March 06	✗	✗	Jet
2003 March 24	✓	✗	No
2003 April 18	✓	✓	Plasmon
2003 June 15	✓	✓	Plasmon
2006 December 24	✗	✗	No
2006 December 27	✗	✗	Jet
2006 December 28	✗	✗	Jet
2007 January 04	✗	✗	Jet

Identification of the X-ray progenitor?

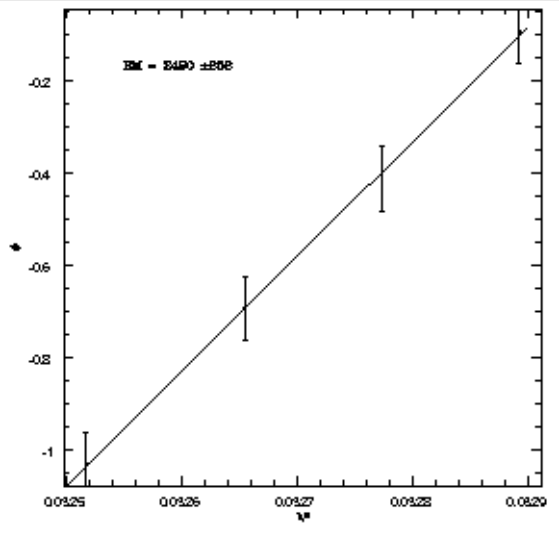


Epoch of radio observation	Proper motion (mas per day)
1997 October 31	23.6 ± 0.5
1998 June 09	21.6 ± 2.1
2003 April 18	21± 1.8
2003 June 15	18.2 ± 1.9

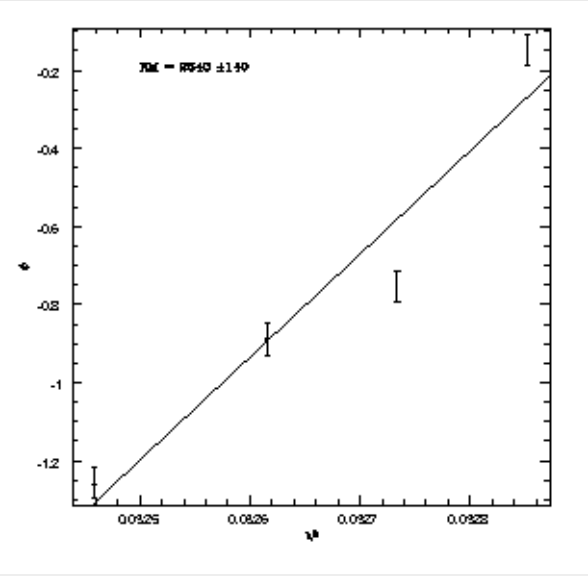
Rotation measure found?

- How does the position angle change with frequency?
- Brown (2004) compared MERLIN data across 1650-1665 MHz:

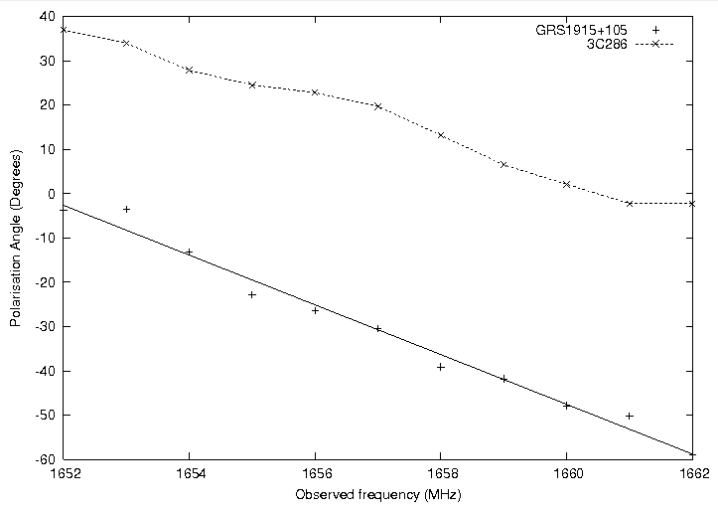
Epoch: 2003 June 15
RM ~ 2400 rad/m^2



Epoch: 2003 March 06
RM ~ 2600 rad/m^2



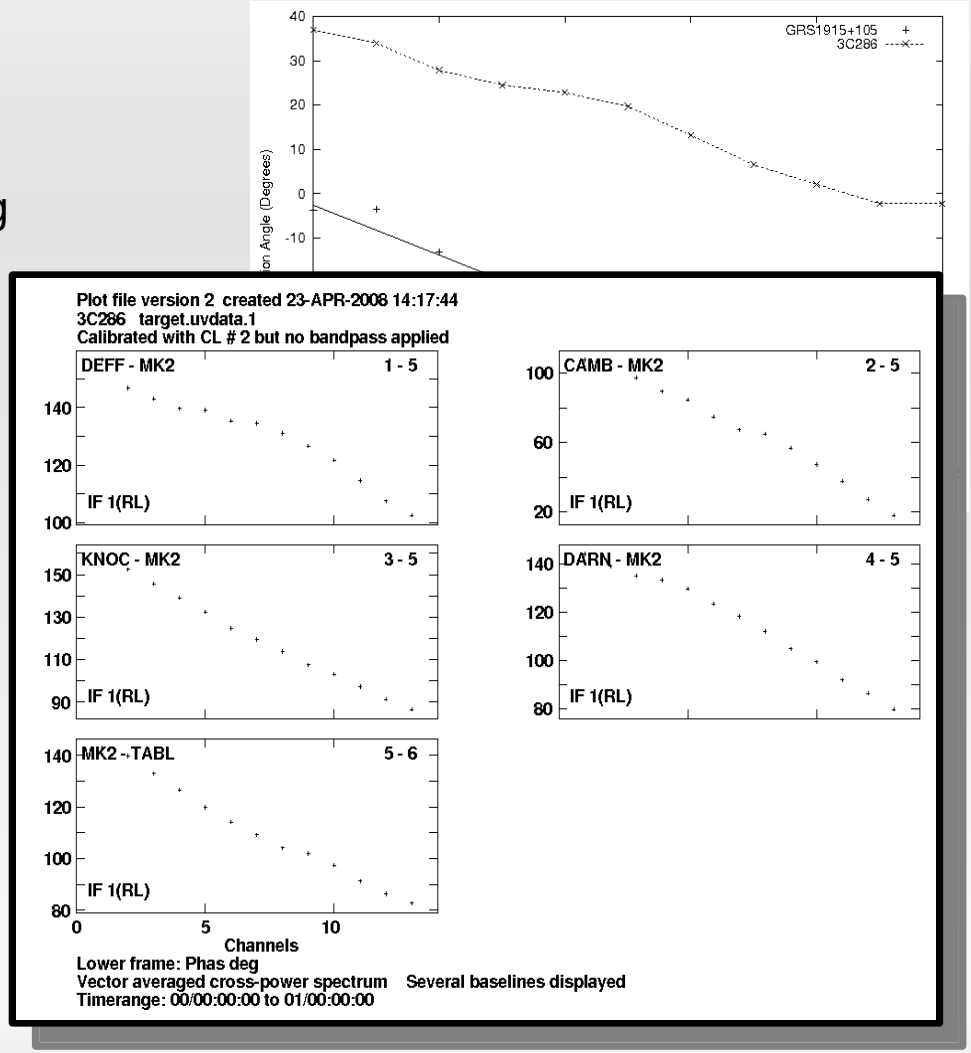
Position angle across the band



Before calibration

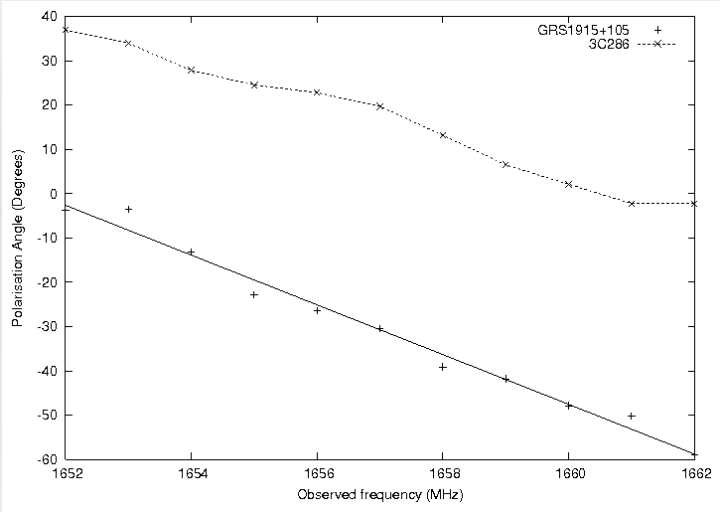
Position angle across the band

- Initially this was calibrated using VLBACPOL.
- Due to the microwave link there are additional phase error in the cross hands

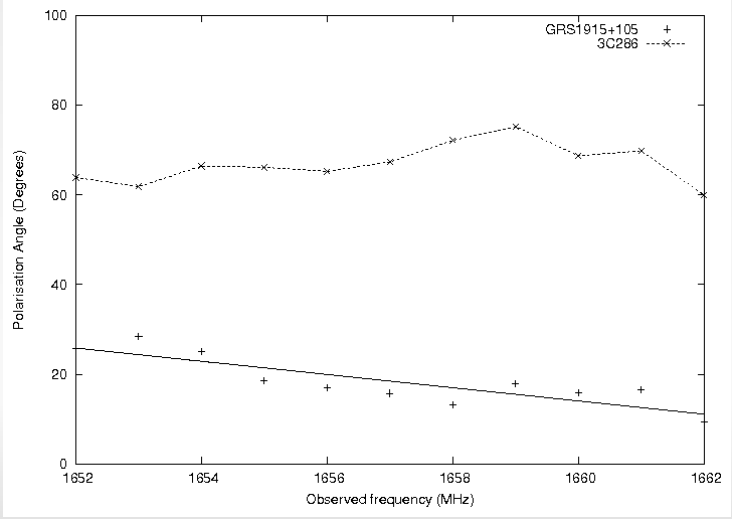


Position angle across the band

- Initially this was calibrated using VLBACPOL.
- Due to the microwave link there are additional phase error in the cross hands
- We corrected this channel-by-channel using CLCOR and the known PA of 3C286.
- Across the 15 MHz band **no rotation measure** was detected above > 600 rad/m^2



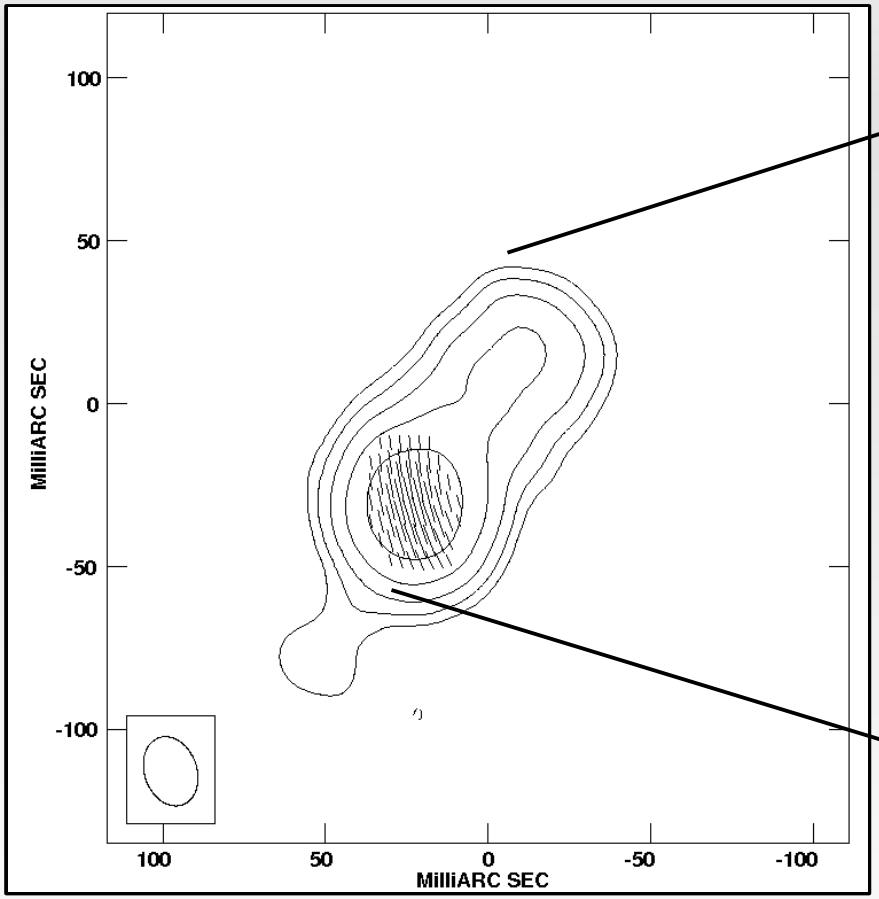
Before calibration

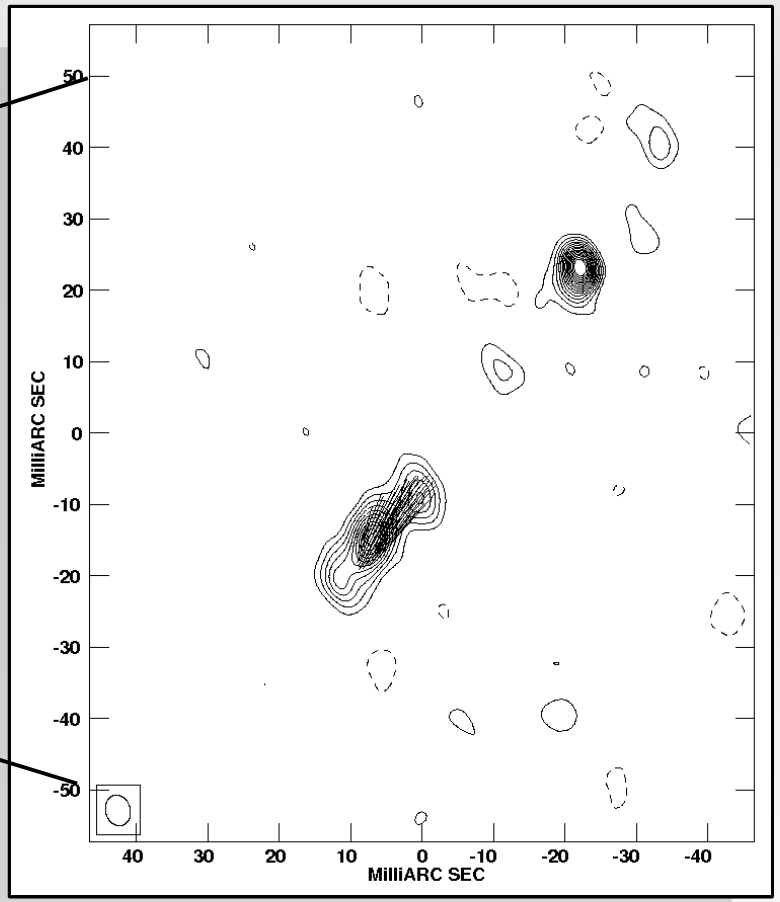


After calibration

Fractional LP increases with frequency

VLBA (originally presented in Dhawan et al. 2000)





2.27 GHz

Fraction = 2.5 %

8.3 GHz

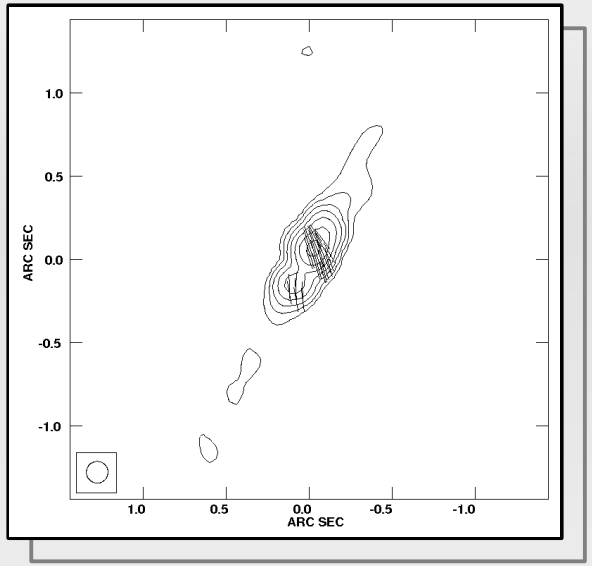
Fraction = 7.2 %

Core depolarisation

- MERLIN observations measured a large variation of linear polarisation: < 1% – 14%
- Core depolarisation occurred during ejection.
- One observation was interleaved between 1.4 and 1.6 GHz, showing a slightly higher LP at the higher frequency.

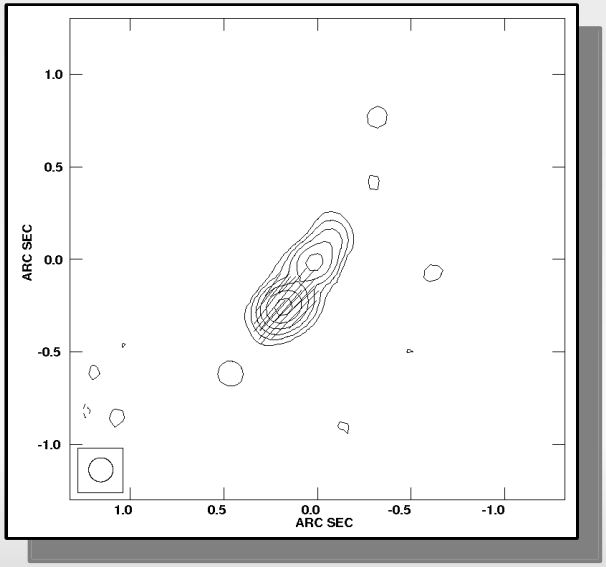
Core – 2.6 %

Jet – 6.6 %



Core - < 1 %

Jet - 12 %



Conclusions

- Large ejections only occur following the plateau state and short X-ray flares.
- No deceleration beyond > 70 mas.
- We believe to have identified the beginning ejection.
- When correcting for the right/left phase off-set across the MERLIN band, we found no rotation measure.
- Core depolarisation occurs during ejection.
- Fractional linear polarisation increases with frequency.