Global evolution of XRBs in outburst: observation

Rob Fender

UNIVERSITY OF OXFORD

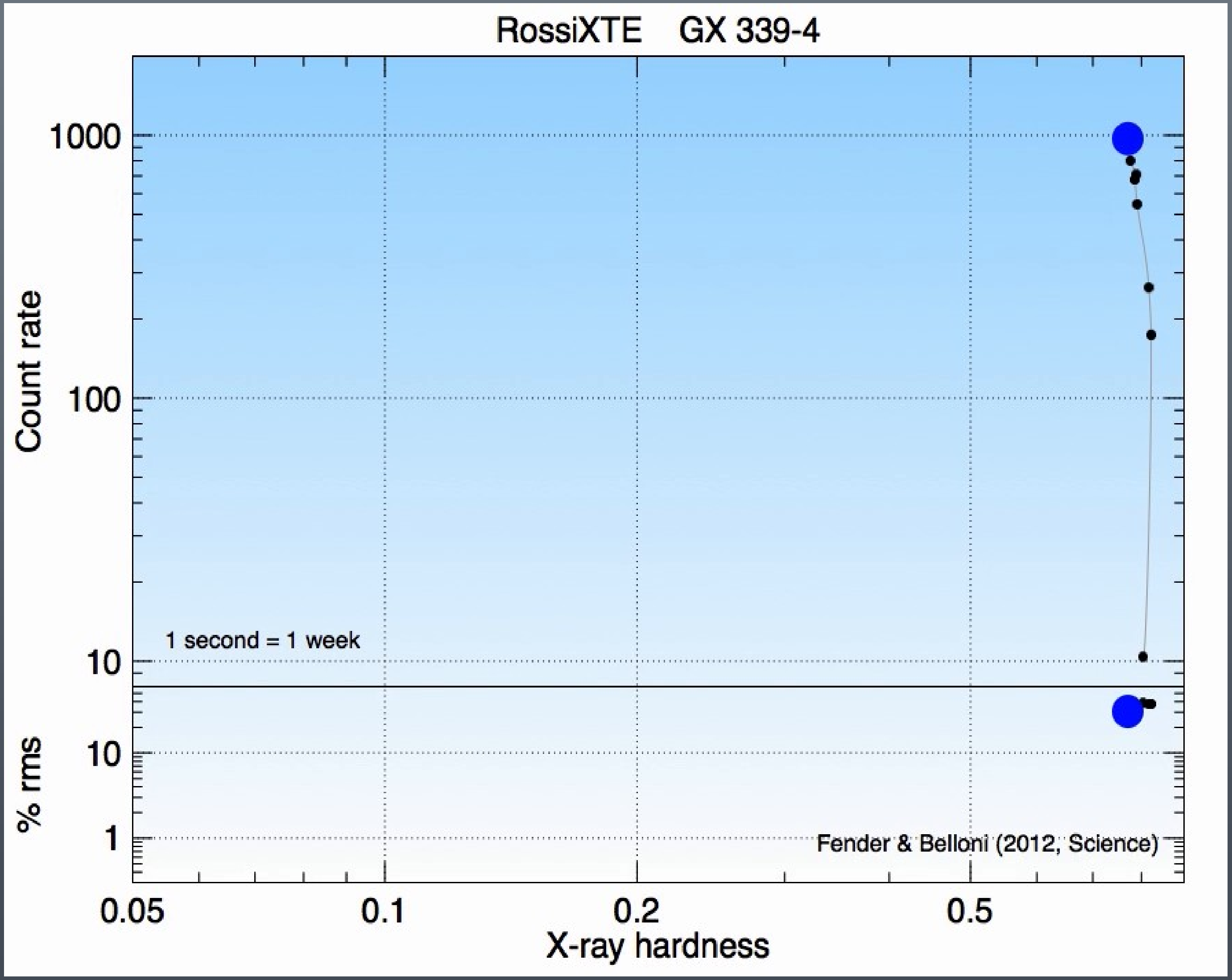
1. Summary of the empirical picture: disc-jet coupling in black hole XRBs

2. The nature of the radio-quiet hard state black holes

3. New puzzles from neutron star XRBs

4. V404 Cyg: our clearest-ever view of black hole jet production

Accretion states and connection to feedback



Flat spectrum radio emission: Stable/hard Jet/no wind

Unstable Erratic jet

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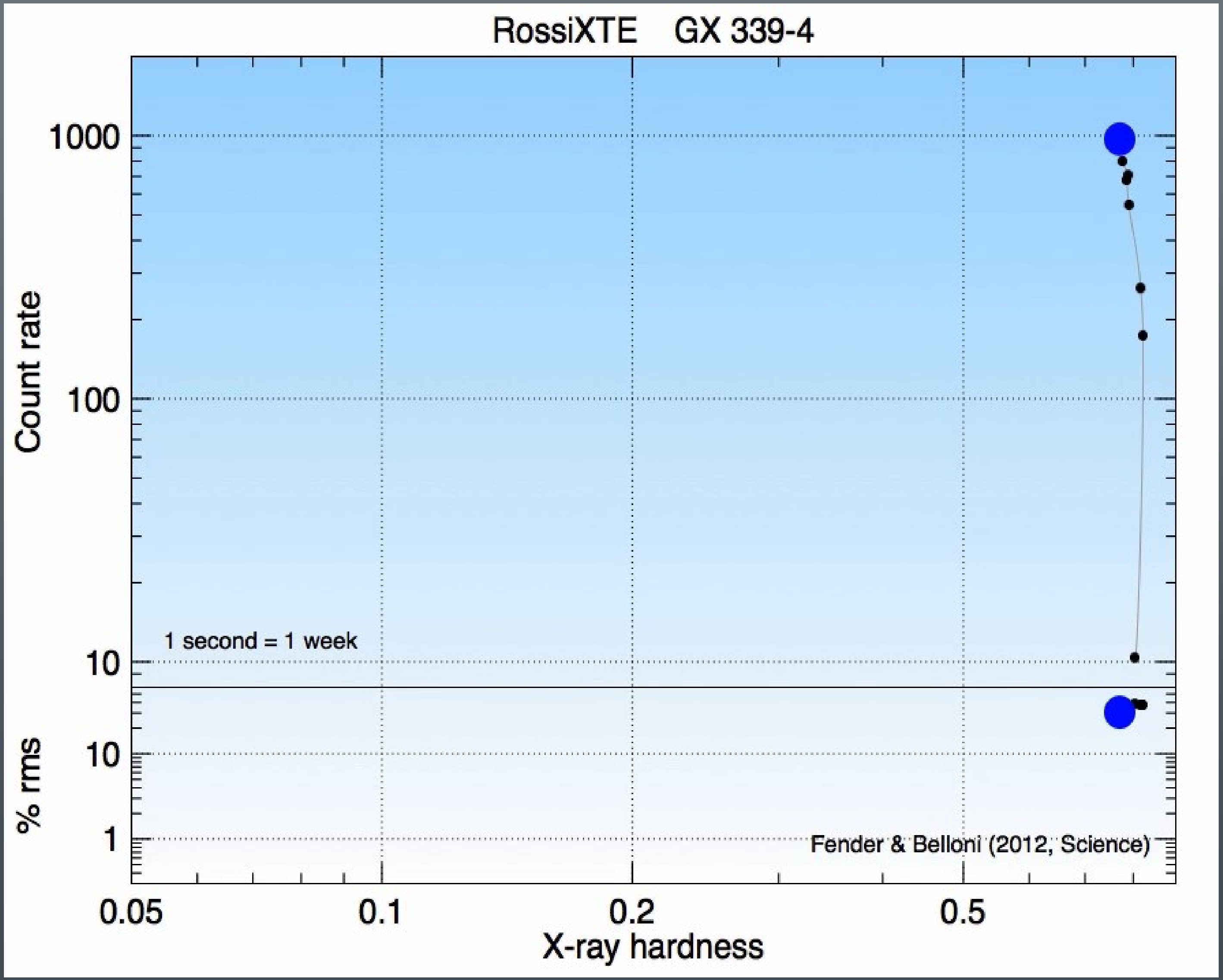

Flat spectrum radio emission: Stable/hard Jet/no wind

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Radio flare - Relativistic ejection

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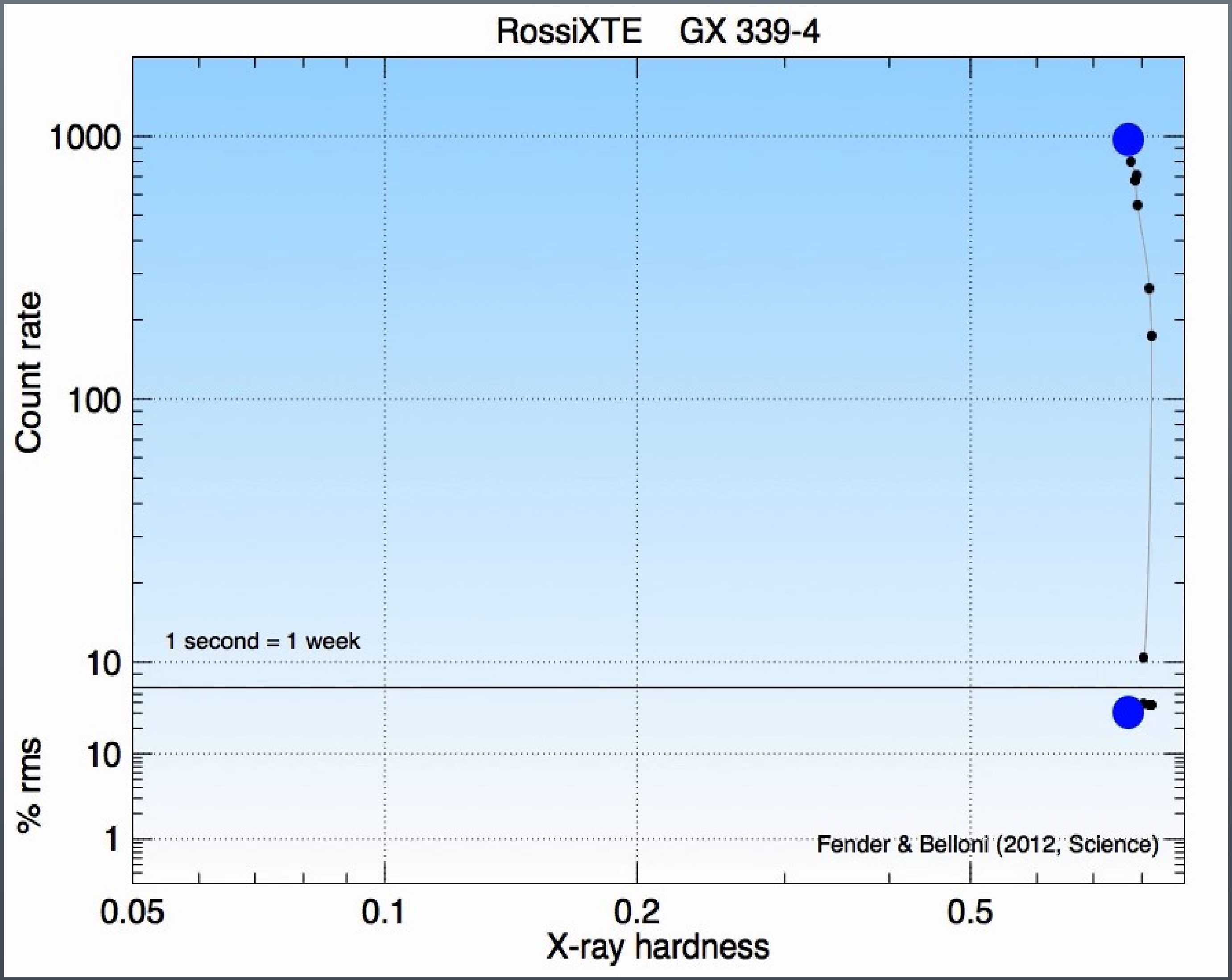


Flat spectrum radio emission: Stable/hard Jet/no wind?

Unstable Erratic jet

Radio flare - Relativistic ejection

No core radio emission: Stable/soft Wind/no jet?

What does this observational picture mean?

– Does the flaring / peak of transition really occur as disc reaches ISCO?

There are opposing views…

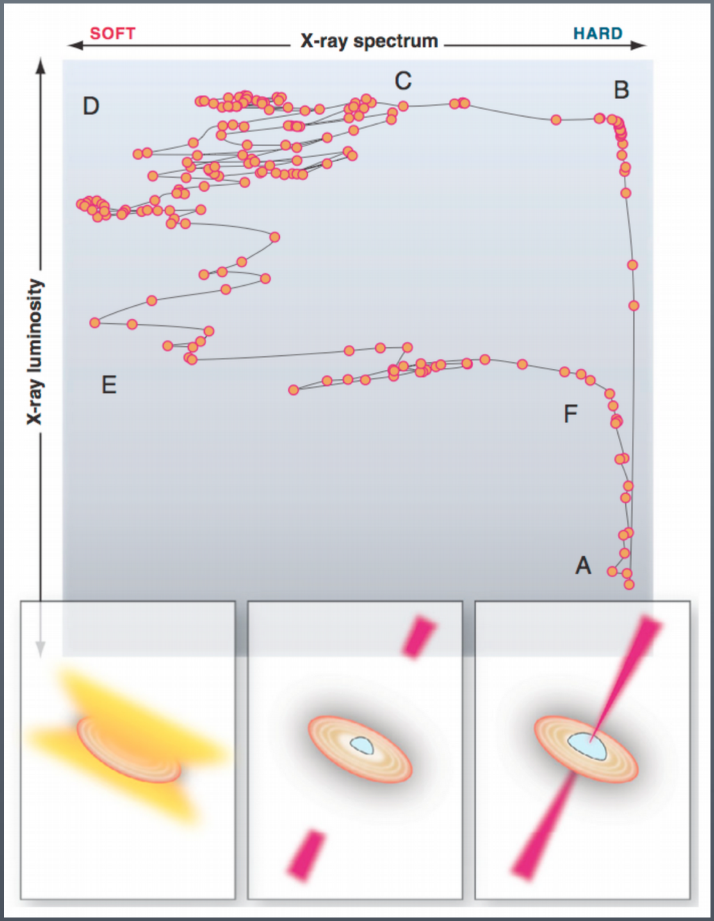
– Do the jets really disappear in the soft state?

This is the easiest interpretation. Perhaps, however, they are boosted out of the line of sight, or radiate less due to fewer shocks (Drappeau et al. 2017). What consequence for radio-quiet AGN?

– Do the winds really disappear in the hard state?

I'm not sure… see talk by Bianchi

NB Homan et al. (2017) have found evidence for simultaneous winds and jets in NS XRBs at very high luninosities (and this is probably also seen in GRS 1915+105)



Is the type-B QPO the smoking gun of jet formation?

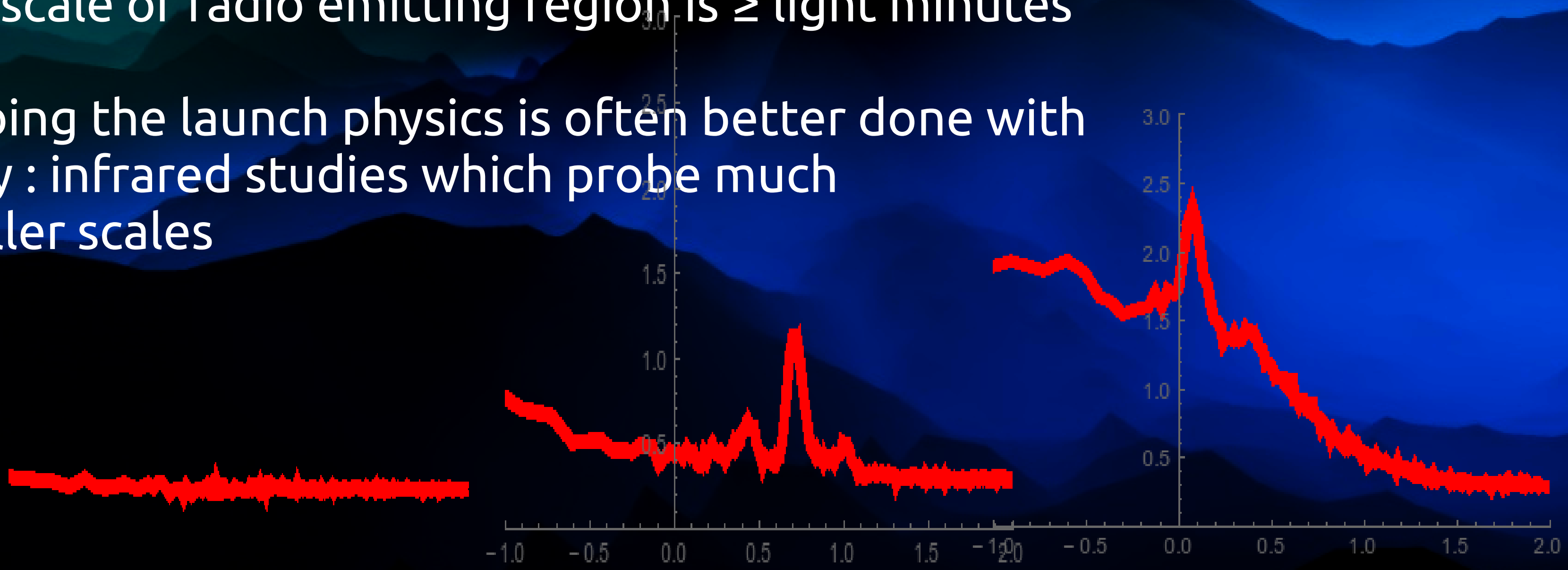
It happens around the same time… (‘a few hours..’)

… but the smoking gun has **not** been found
(Fender et al. 2009, Miller-Jones et al. 2013)

[NB a few hours = 10 ks = 2 000 000 dynamical timescales at the ISCO
of a 10 solar mass Schwarzschild black hole]

Size scale of radio emitting region is ≥ light minutes

Probing the launch physics is often better done with
X-ray : infrared studies which probe much
smaller scales



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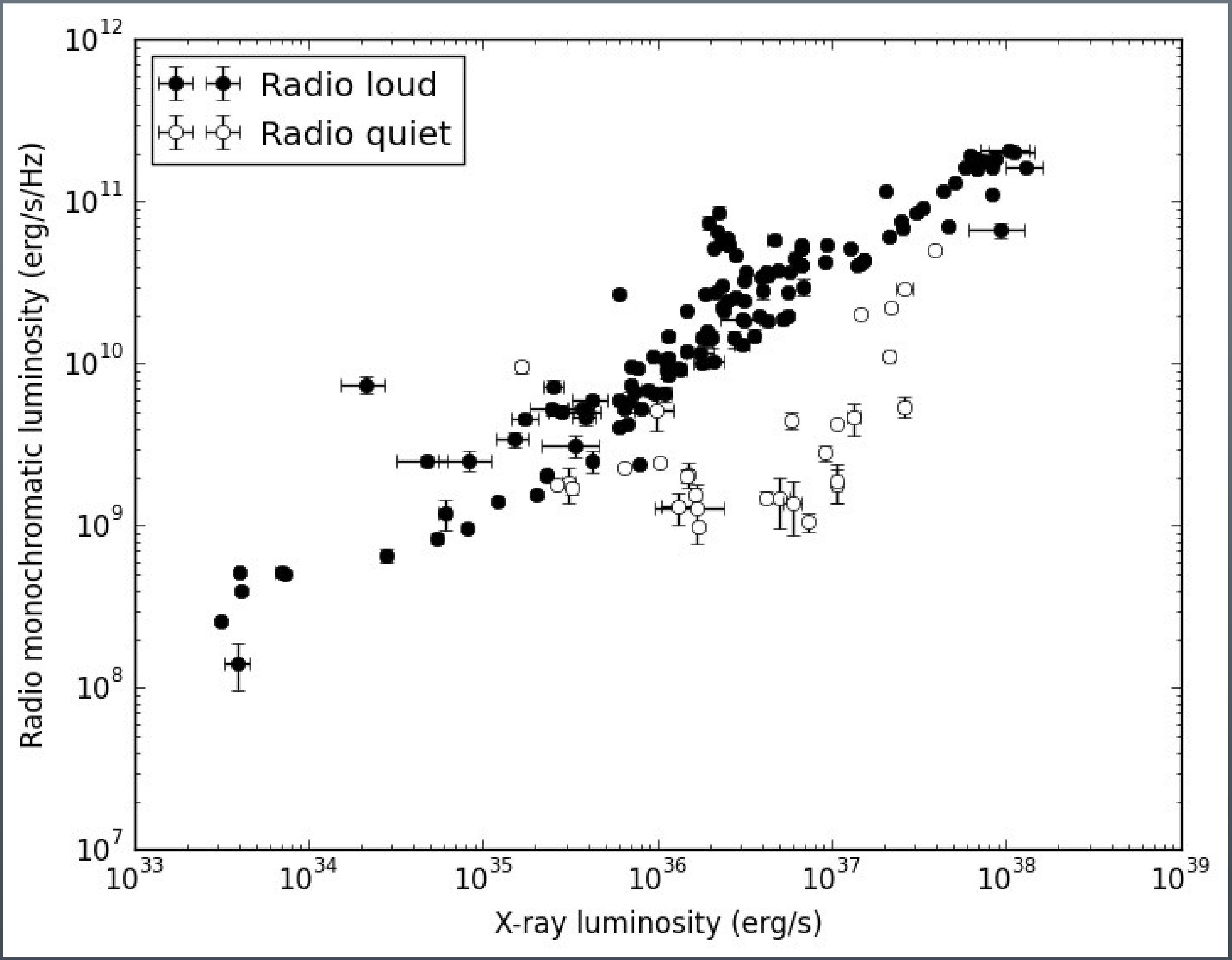
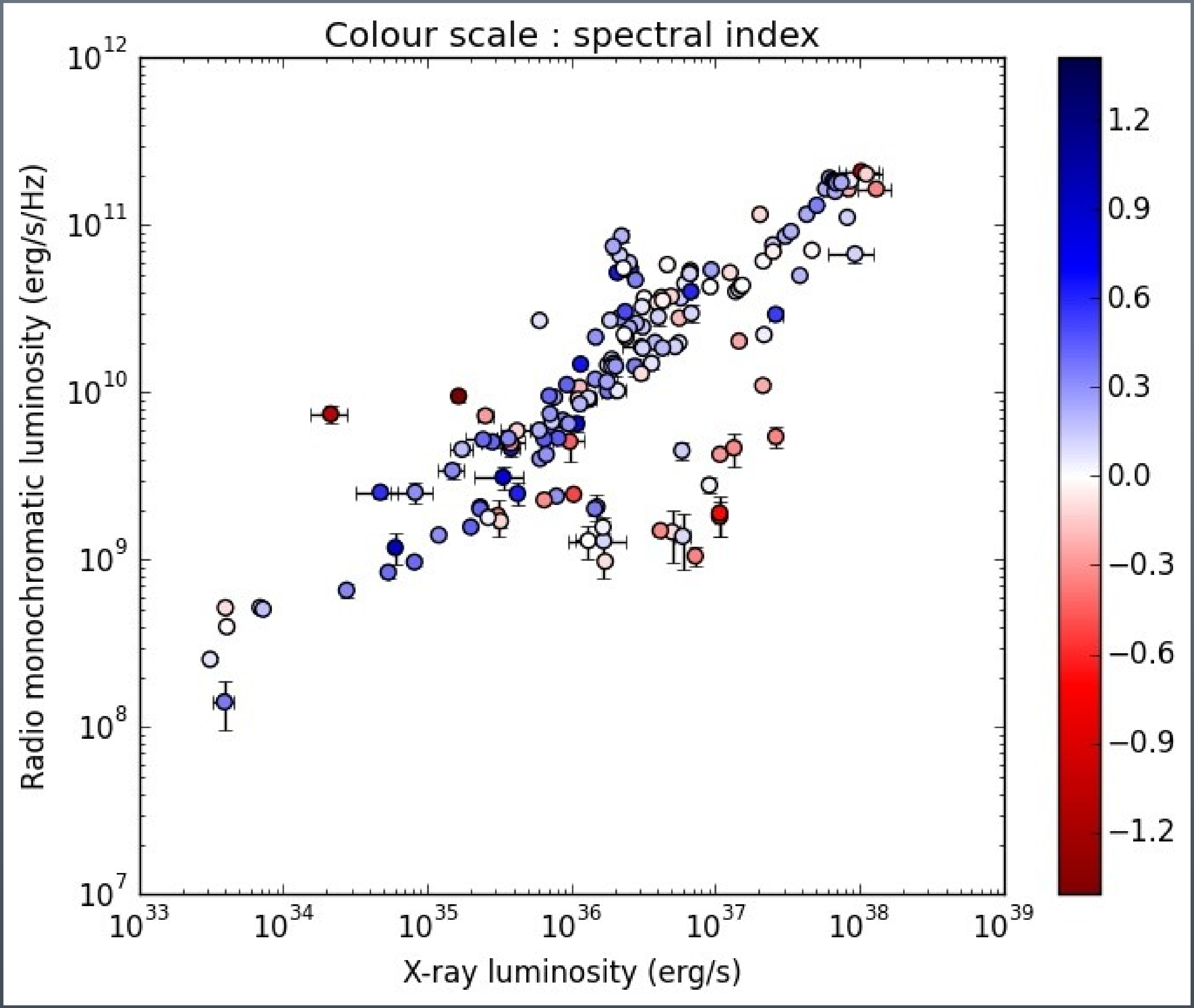
Radio loud and radio quiet hard state BH XRBs



Espinasse & Fender (2017), see also Corbel et al., Gallo et al. papers



We measured GHz spectral index wherever possible

Only previous reported difference is in PDS: radio quiet sources may have lower rms

(Dincer et al. 2014)

Espinasse & Fender (2017)

Radio loud and radio quiet hard state BH XRBs

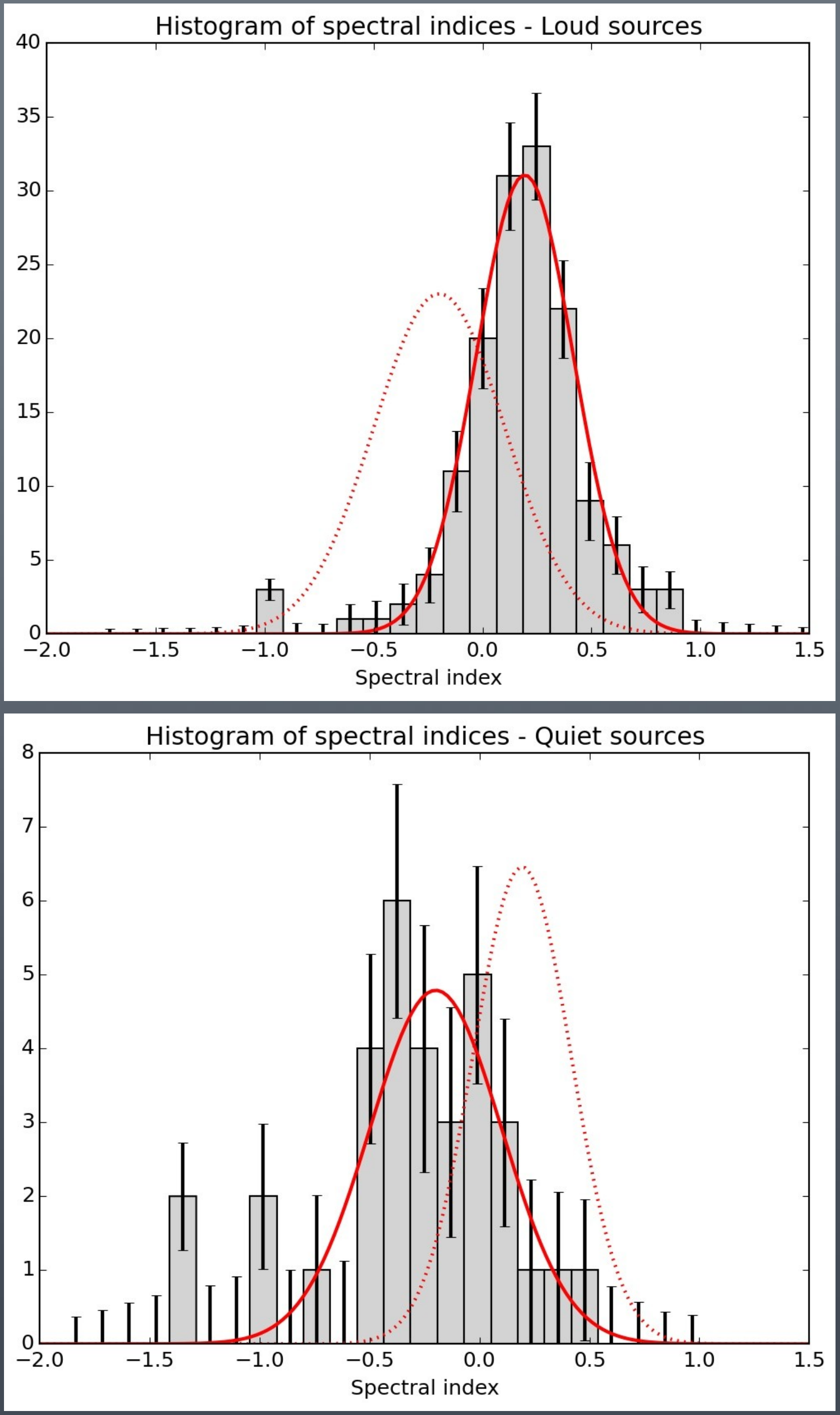
‘Radio loud’ BH XRBs have +0.2 mean spectral index

‘Radio quiet’ BH XRBs have -0.2

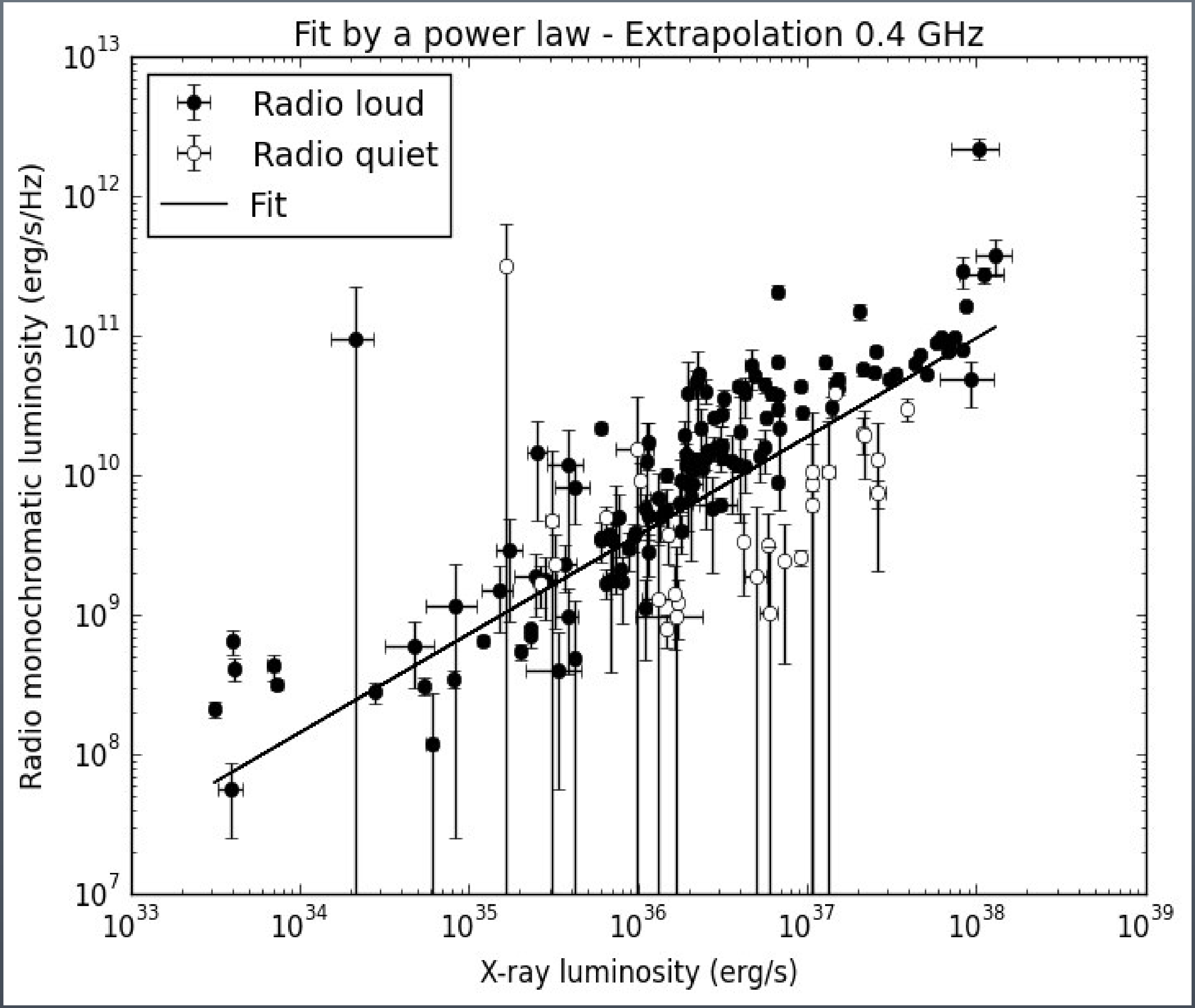
The difference is highly statistically significant

GX 339-4 distribution – the best sampled – is the same as that for the overall radio loud population

The effect is not due to inclination → physics of jets is different



Espinasse & Fender (2017)



At low frequencies (e.g. 400 MHz) we would only have observed a single track..

Espinasse & Fender (2017) – see poster for more details

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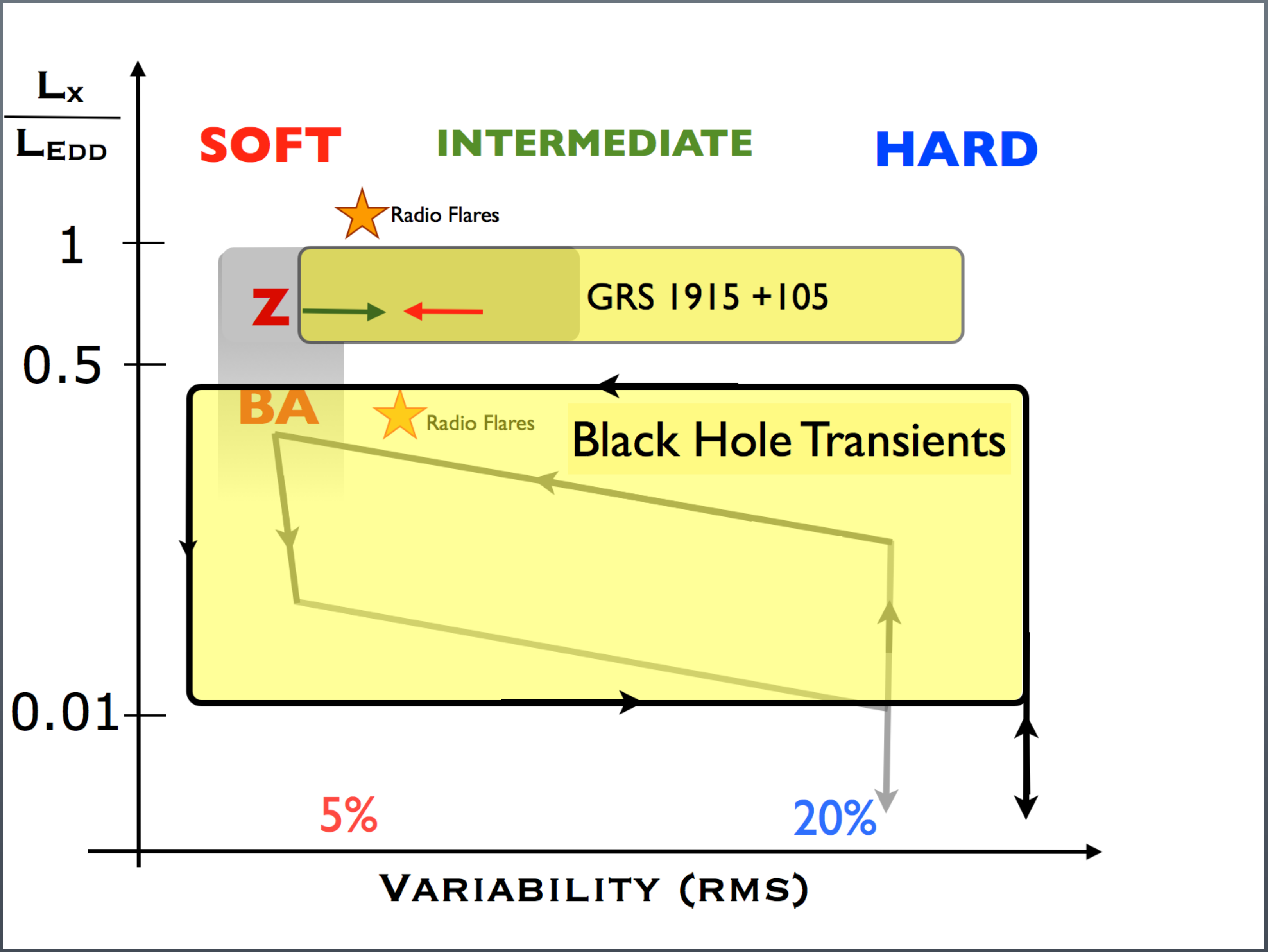
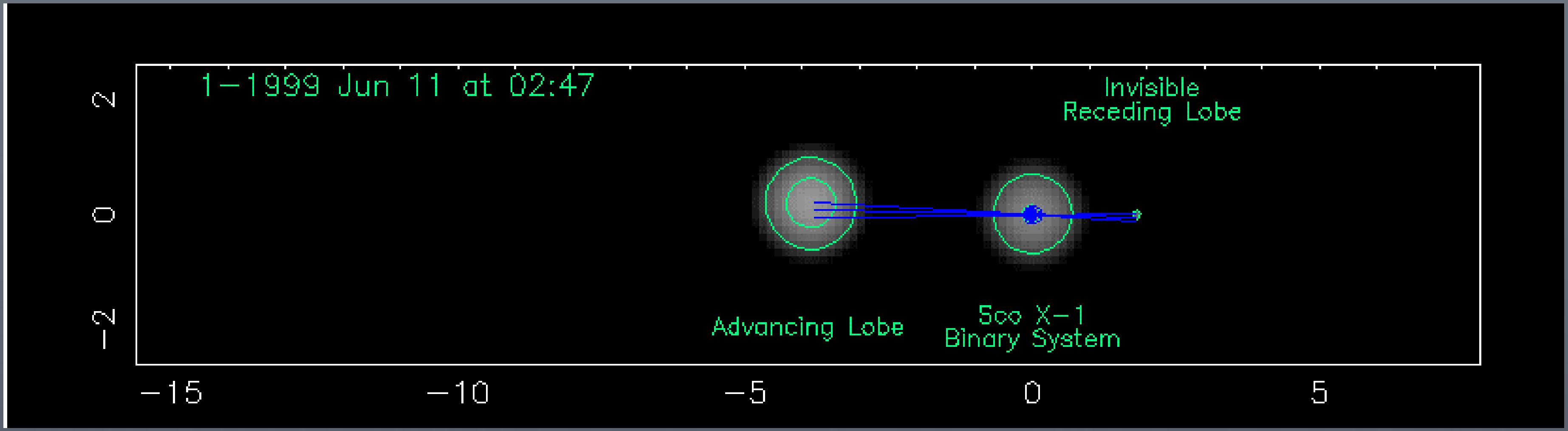
Neutron stars play like black holes (mostly)



Muňoz-Darias et al. (2014)

The ultrarelativistic jet of Sco X-1

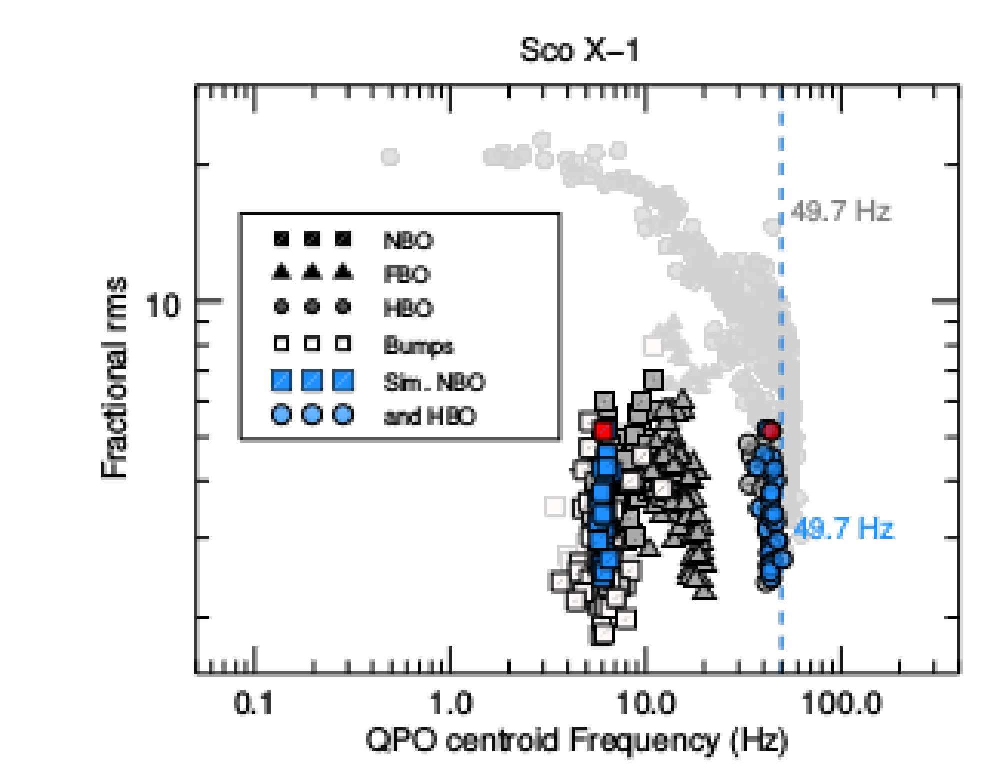


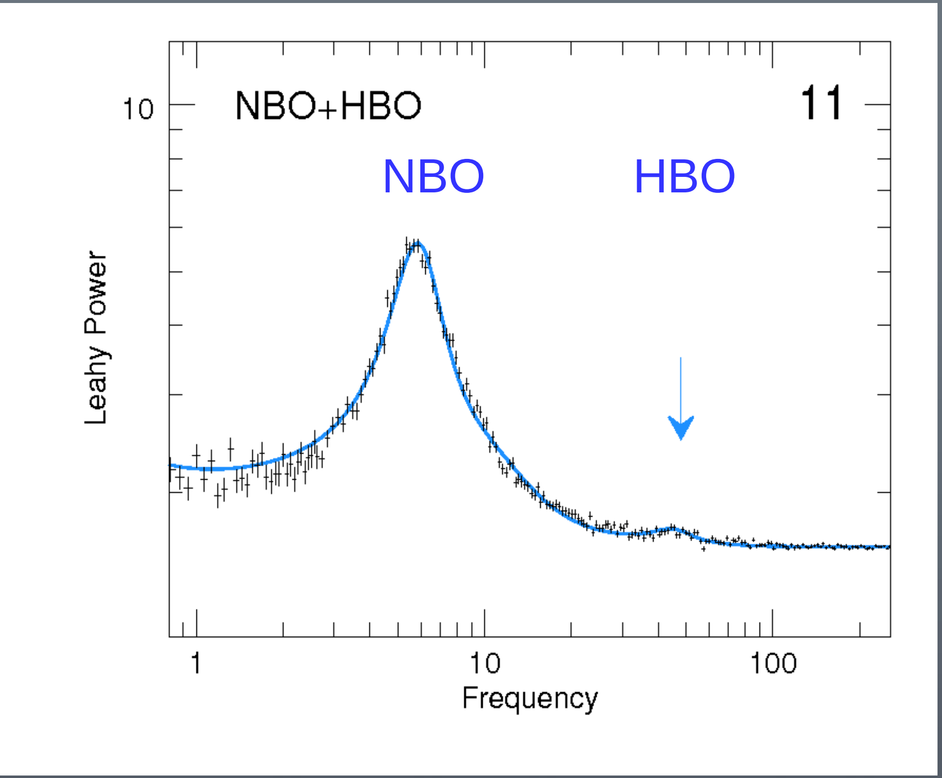
Fomalont et al. (2001a,b)

Evidence for a similar effect in Cir X-1 and SS 433
(Fender et al. 2004, Migliari et al. 2005)

This effect has not been seen in confirmed BH XRB

The ultrarelativistic jet of Sco X-1: clues...

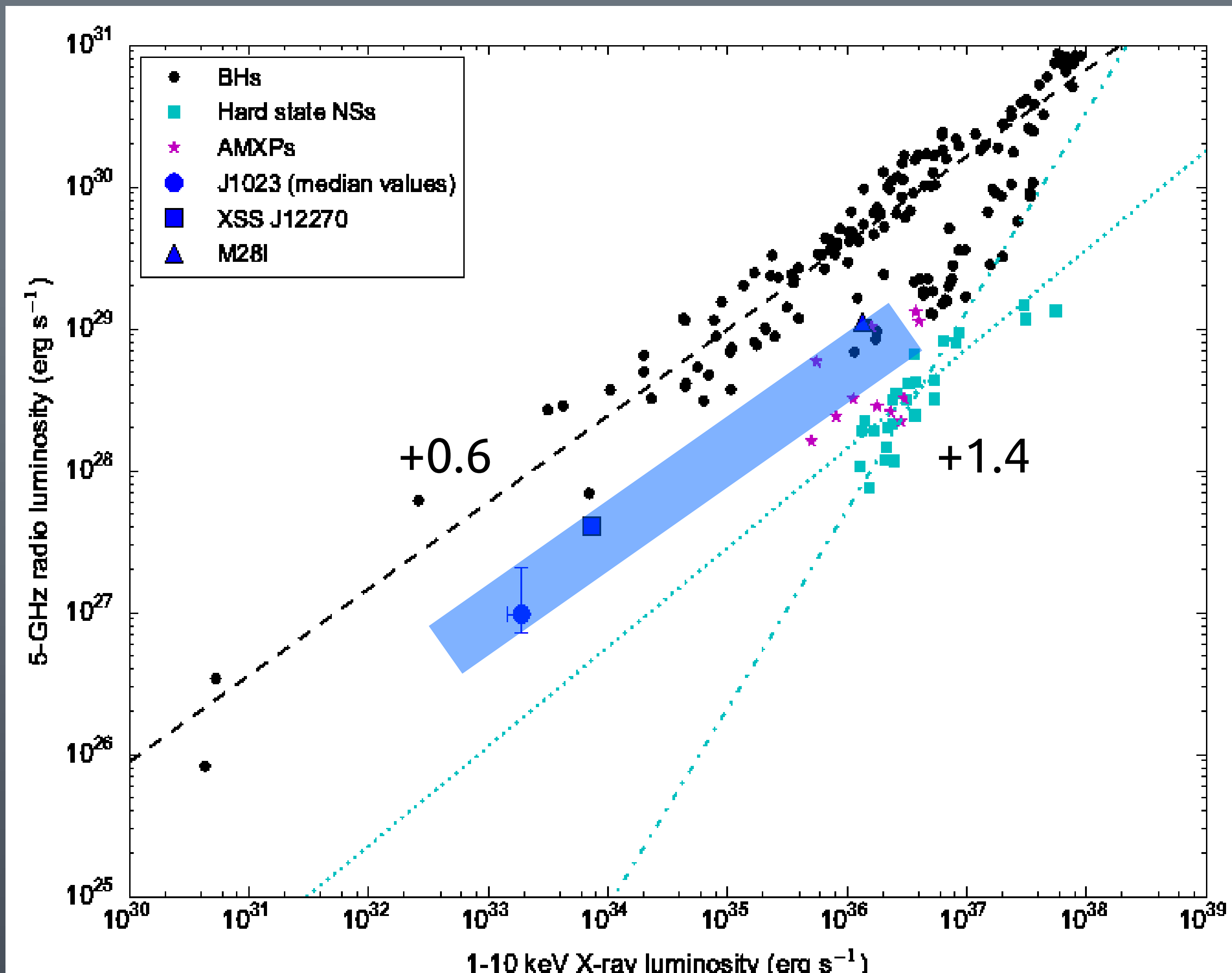




Ultrarelativistic ‘invisible’ flows occur around the time of simultaneous NBO+HBO in X-ray PDS → inner disc at r_{min}

Motta & Fender (in prep), radio data from Fomalont et al. (2001a,b)

The radio:X-ray plane with neutron stars added



Transitional msXRPs appear to follow the same global correlation as black holes! What does that mean for radiative efficiency?

$$L_R \propto P_J^{?}$$

$$P_J \propto \dot{m}^{?}$$

Deller et al. (2015), also Gallo & Degenaar (in prep)

van den Eijnden et al. (submitted): radio detection GX 1+4

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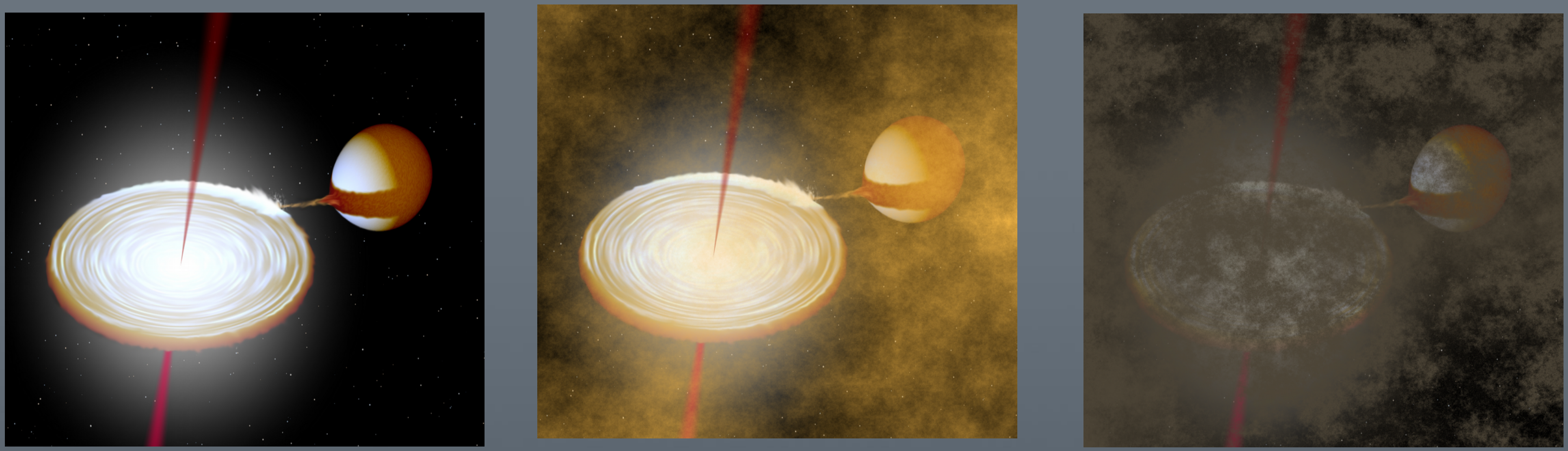
The pathological case of V404 Cyg



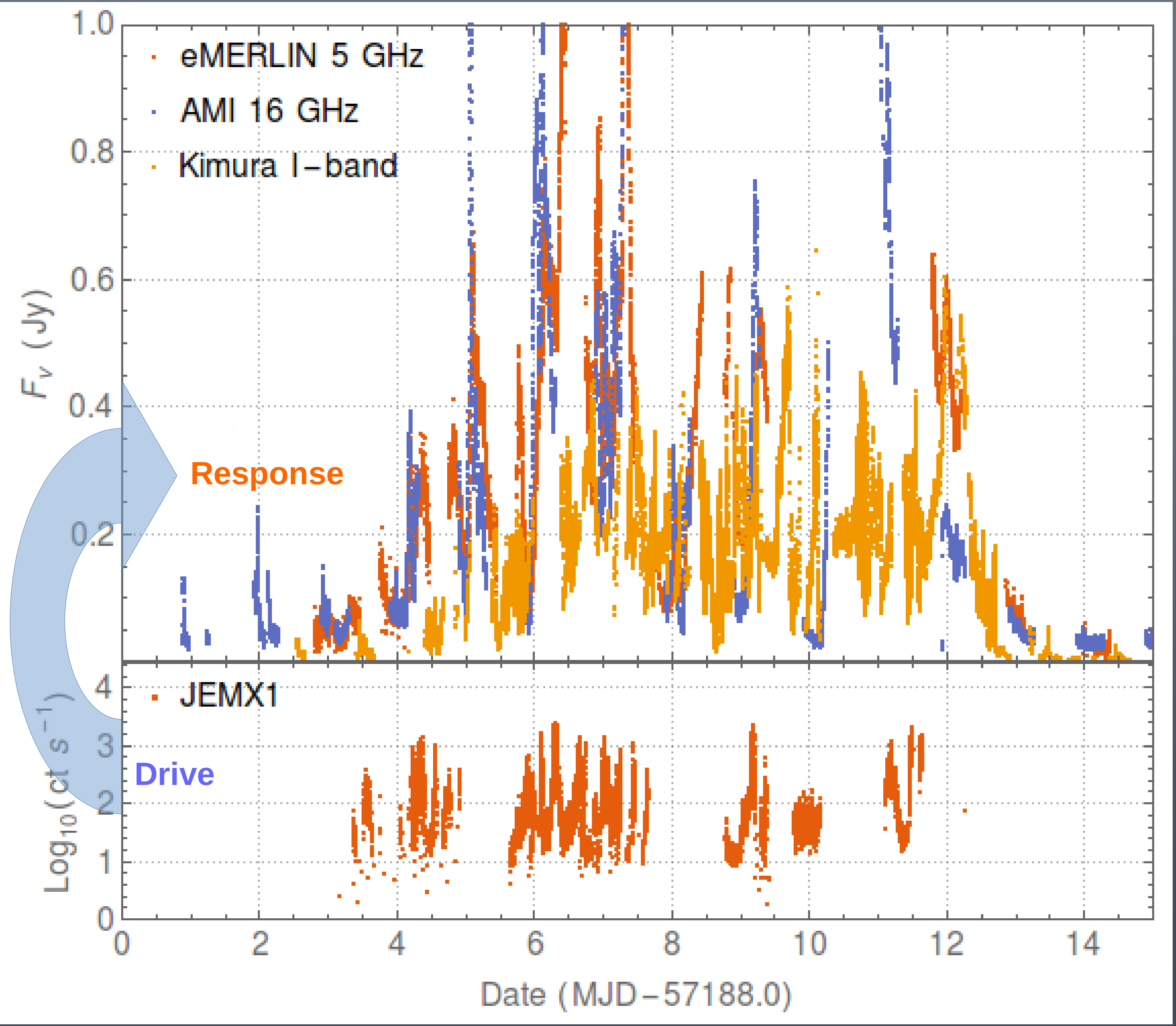
In June 2015 V404 Cyg underwent a very bright, short-lived outburst

Large amout of mass ejected from the disc

This matter resulted in huge and highly variable absorption

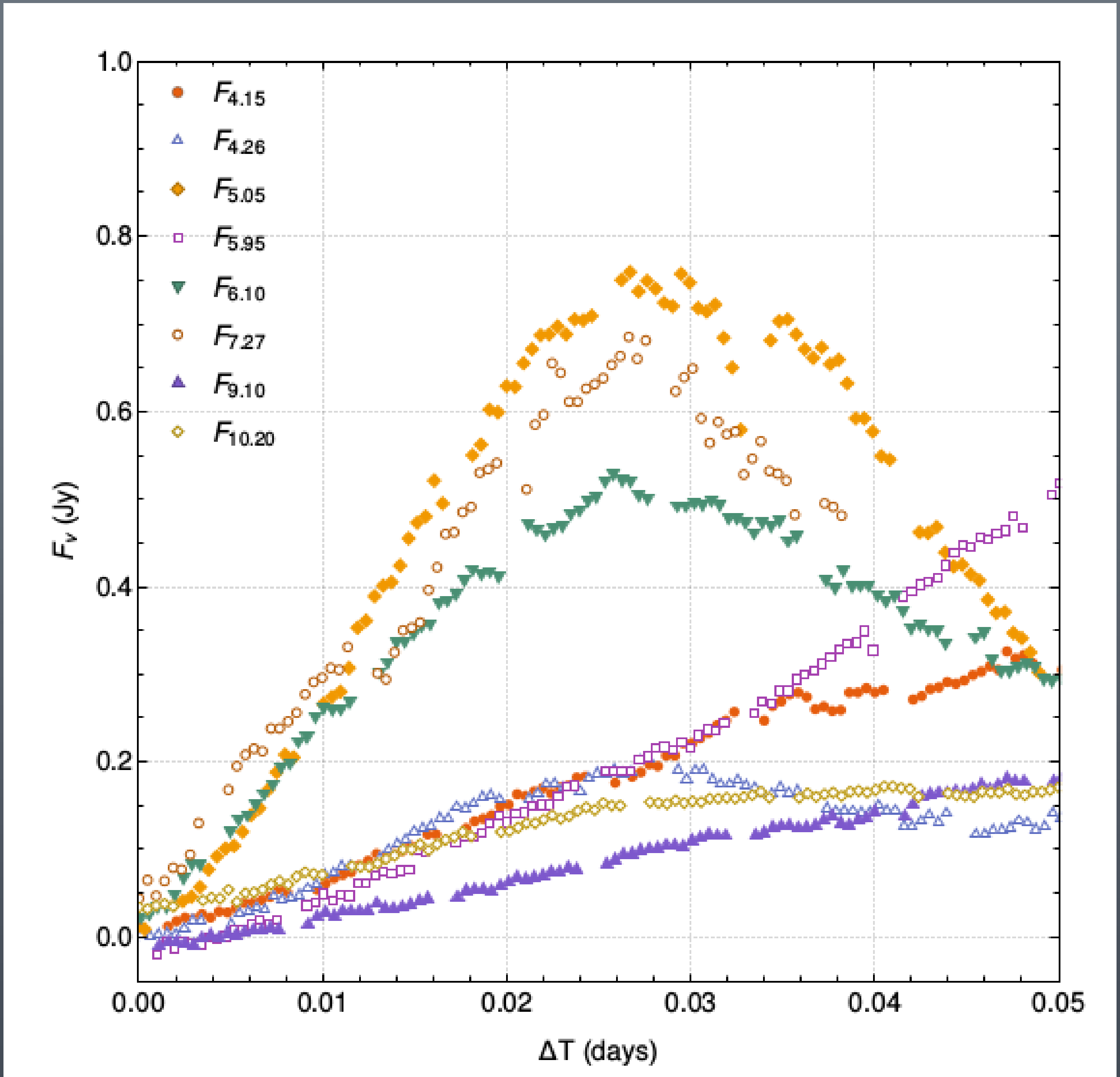
Pathological.. and yet, radio coverage best ever obtained for a black hole outburst

Muňoz-Darias et al. (2016), Motta et al. (2017) and many other papers



eMERLIN 5 GHz
AMI 16 GHz
Kimura I−band
F_ν (Jy)
Response
Drive
JEMX1
Log10(ct s−1)
Date (MJD−57188.0)

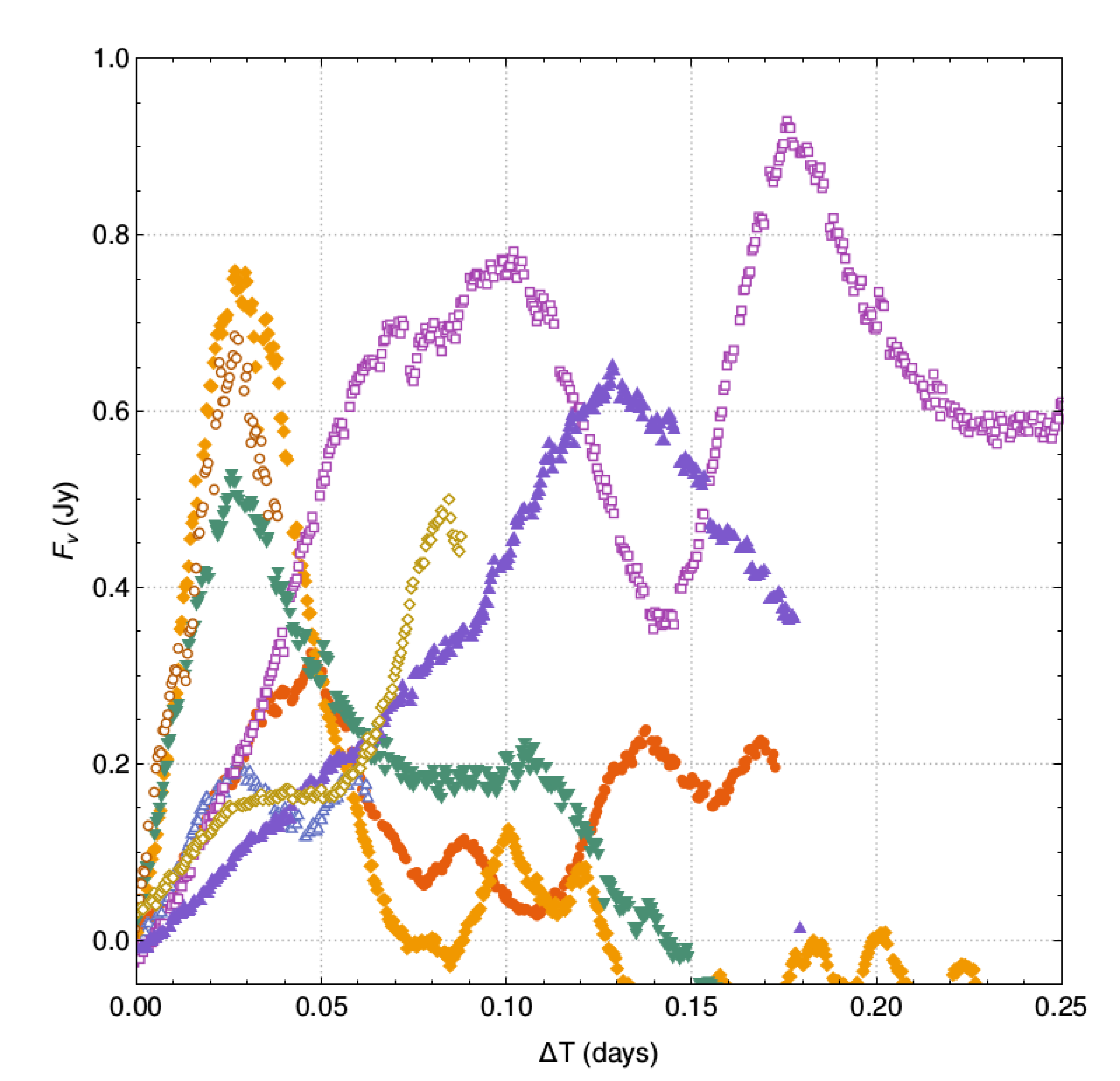
V404 Cyg June 2015



Inspection of individual radio flare events appears to reveal a dichotomy in flare rise times

Fender et al. (in prep)

V404 Cyg June 2015



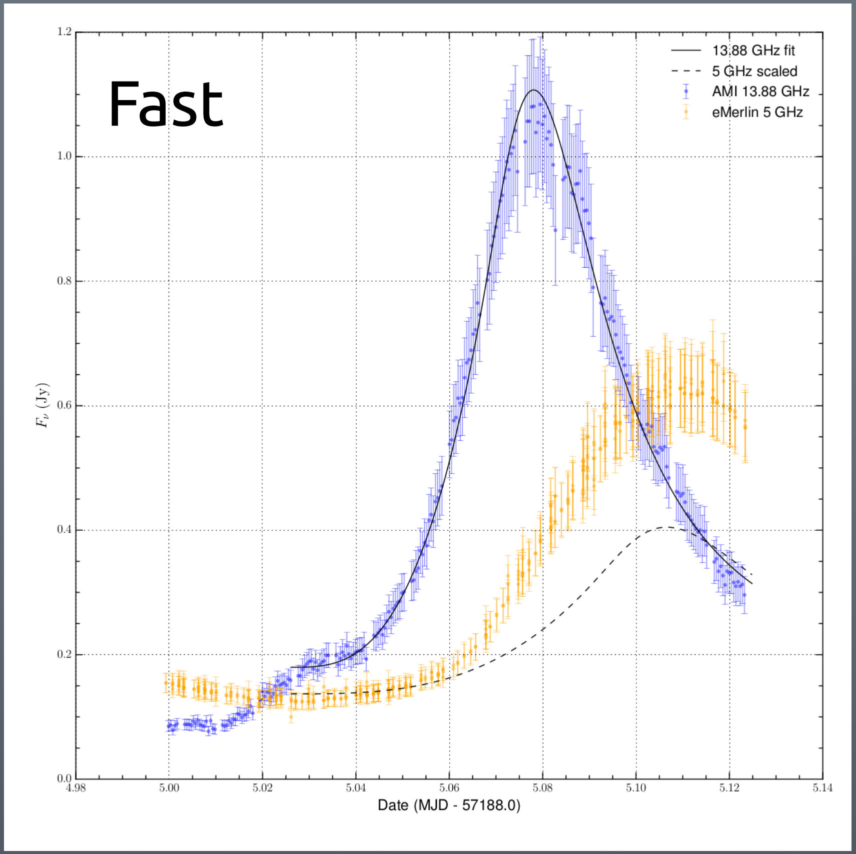
The faster-rising events tend to look like isolated flares.

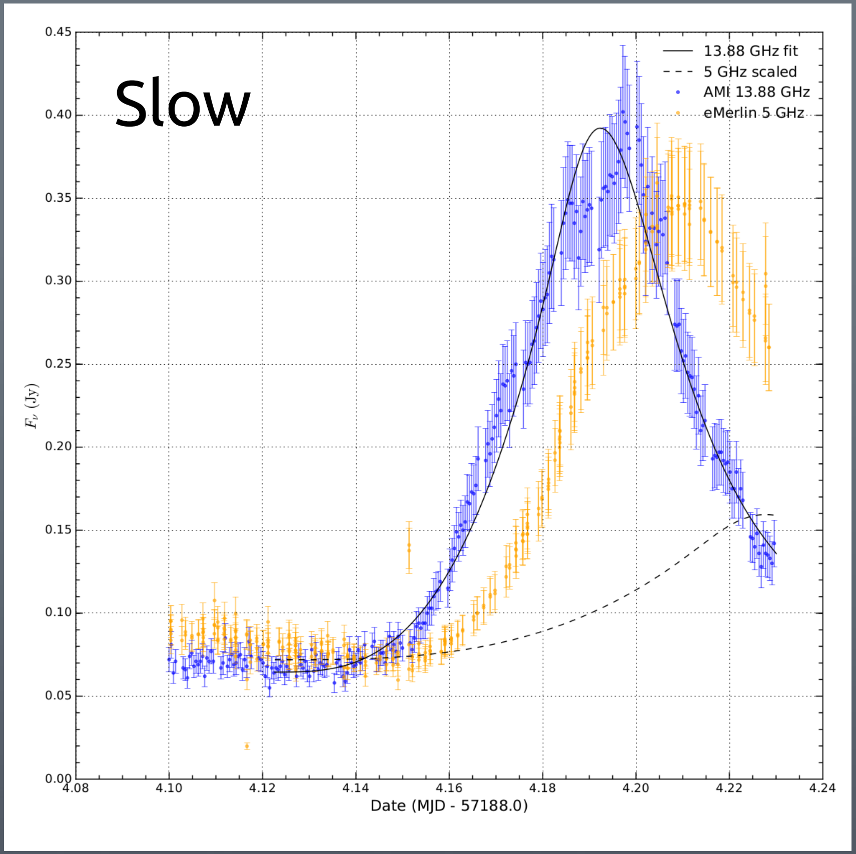
The slower-rising events tend to be associated with prolonged periods of activity and changes in rise rate

Fender et al. (in prep)

V404 Cyg June 2015

Fits by Joe Bright



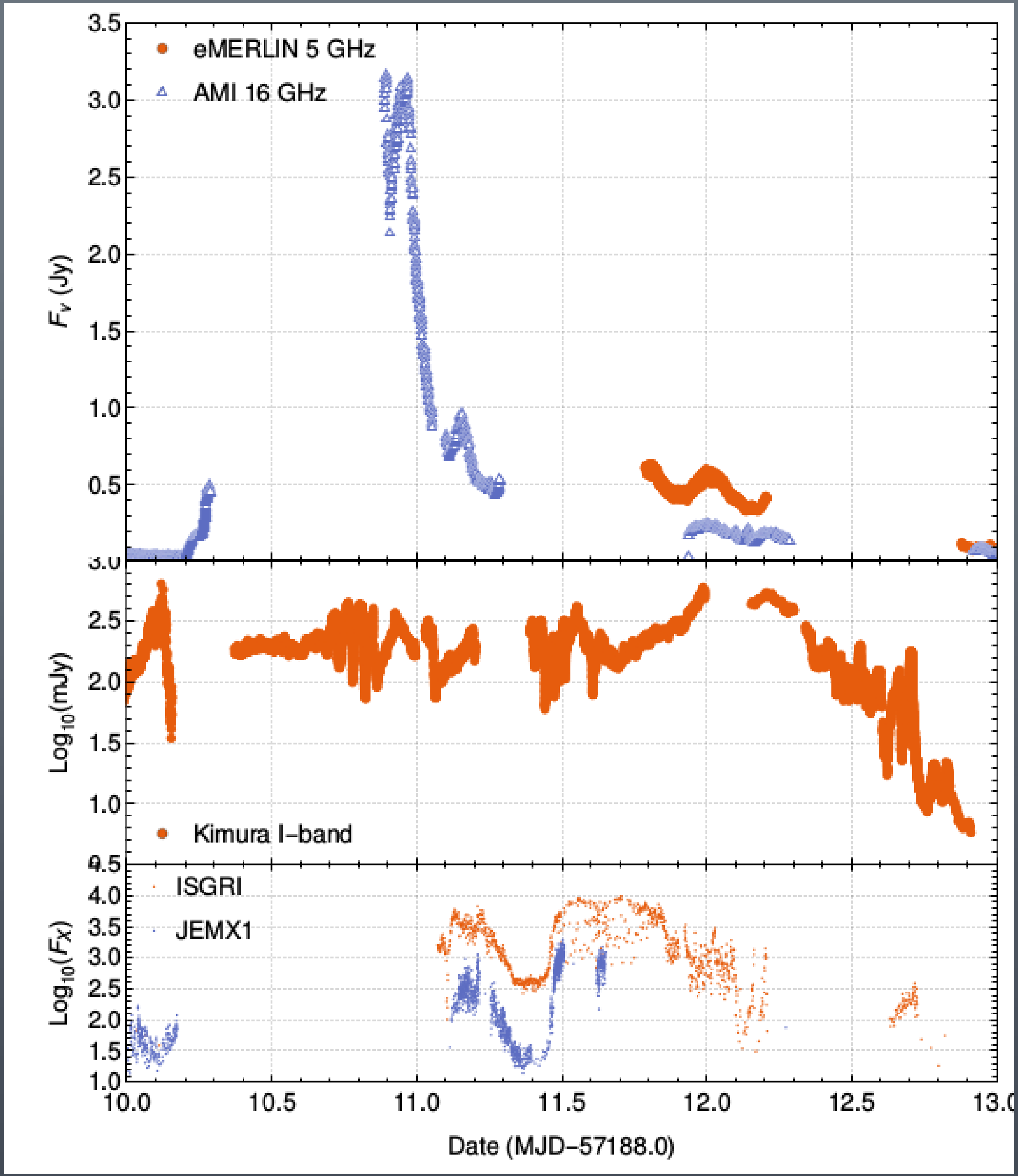


The faster-rising events are much better (abeit not well) fit by van der Laan-style synchrotron ejecta models. The slower-rising events cannot be fit by these simple models

Proposal: fast events are ~discrete ejections, in the slower events we are resolving compact jet growth [?]

Fender et al. (in prep), see also Tetarenko et al. (2017)

A third mode: optically thin flares



Following the main flare there is a ~200 mJy event which is optically thin throughout

This implies

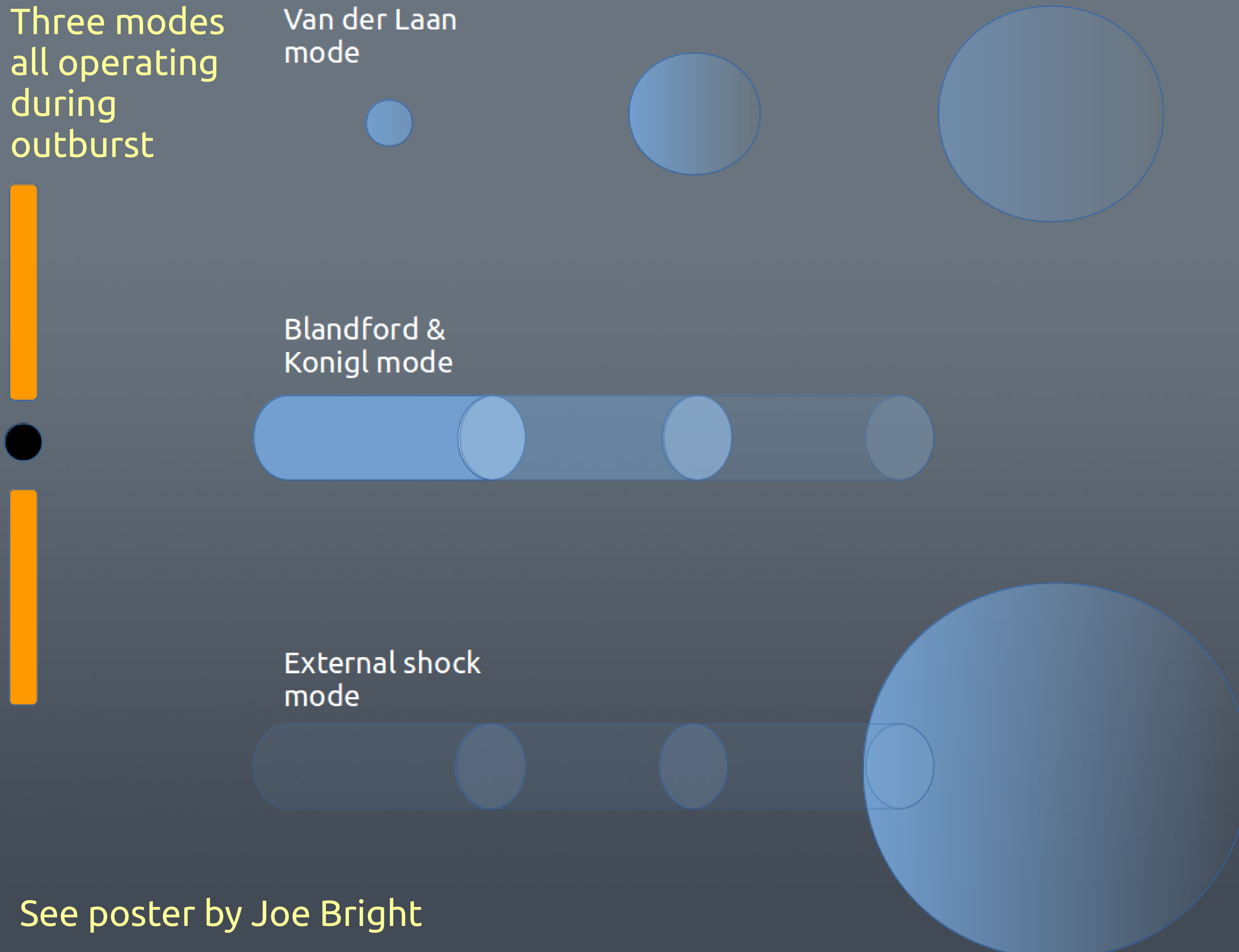
1. We are temporally resolving the particle acceleration process

2. Particle acceleration is going on in a low optical depth environment → extended jet-matter interaction

Previously seen in Cyg X-3 and directly shown to be the case for large-scale jet-ISM interactions from XTE J1550-564

(Corbel et al. 2002)

Three modes all operating during outburst



See poster by Joe Bright

Conclusions...

An enormous body of observational and theoretical work has built up around accretion and feedback from stellar mass black holes.

However, many aspects remain unproved and **everything** needs to be viewed with a critical eye. Subjectively, such aspects include:

– does the jet really disappear in the soft state, and the wind in the hard state? Does the disc really move in and out?

– how well do we understand the radio emission and particle acceleration mechanisms at play? Is there a mixture of internal and external shocks, or non-shock mechanisms at play?

– is there really a clear divide in radiative efficiency between hard and soft states?

The future:

Physics of jet launching: high time resolution studies, quantitative comparison of sizes and timescales (X-ray:IR, reverberation and time lags)

Feedback: more radio monitoring and direct imaging of jets (looks to MeerKAT/SKA), better understanding of winds

Relevance: AGN, CVs, jetted supernovae and GRBs, TDEs

Fin