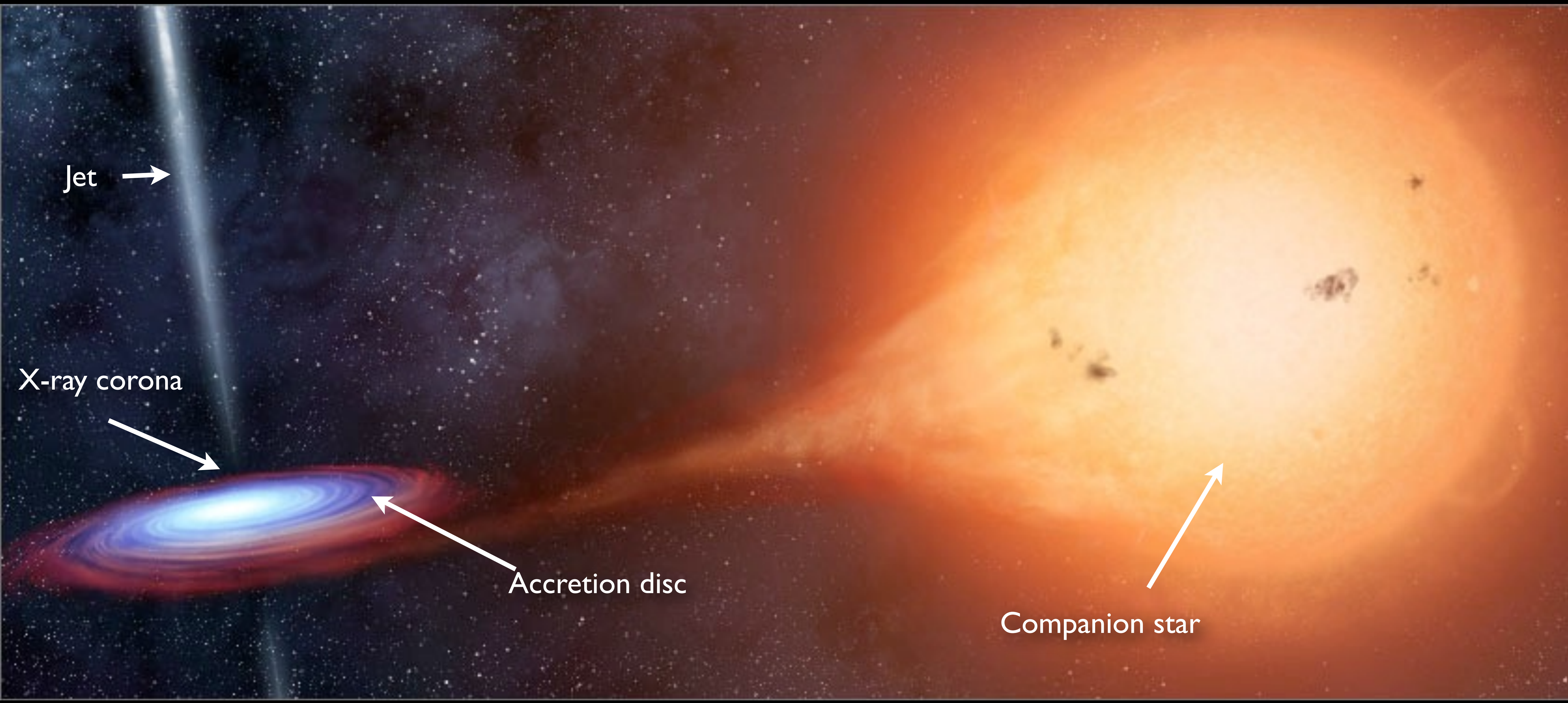
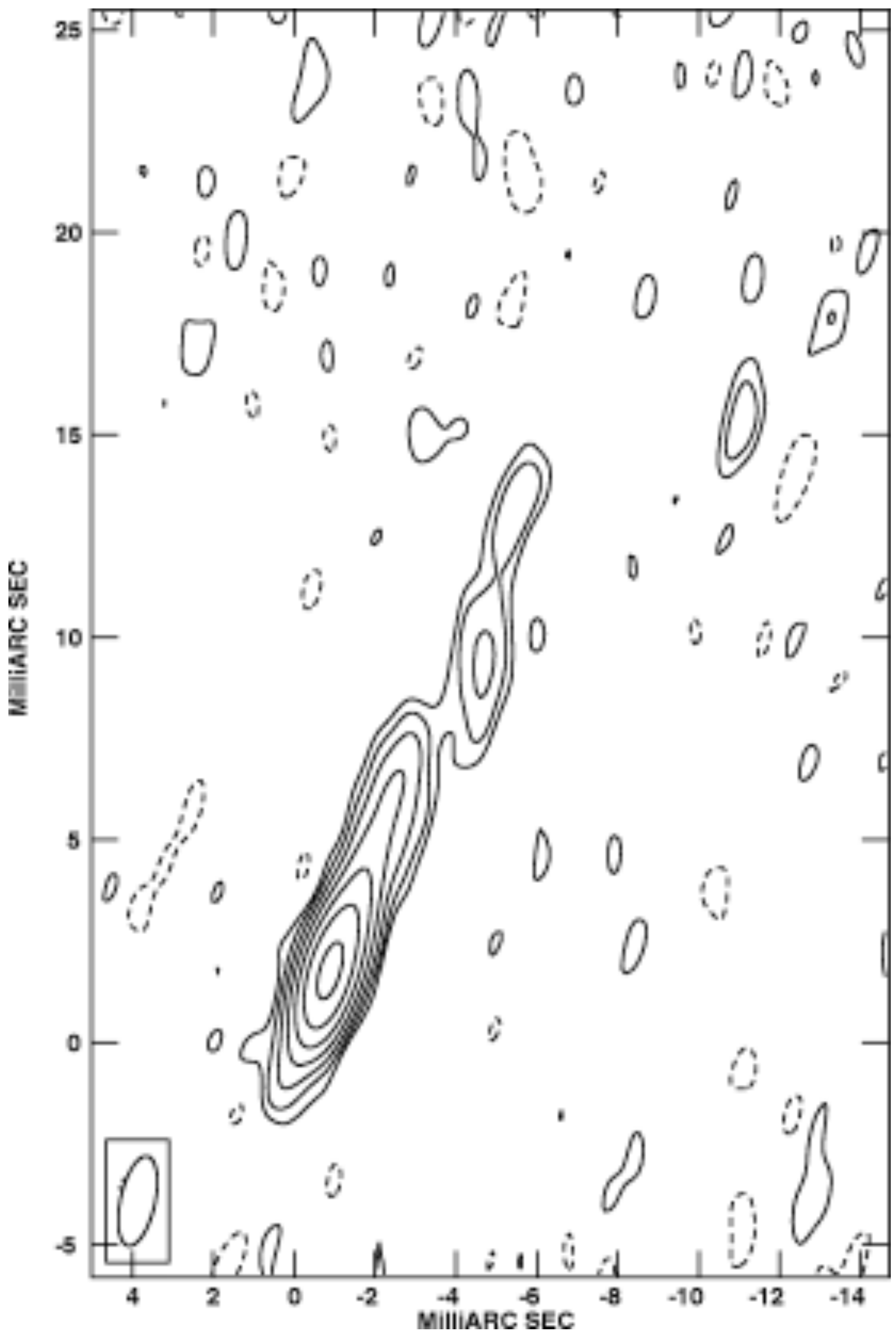
Emission of compact jets powered by internal shocks

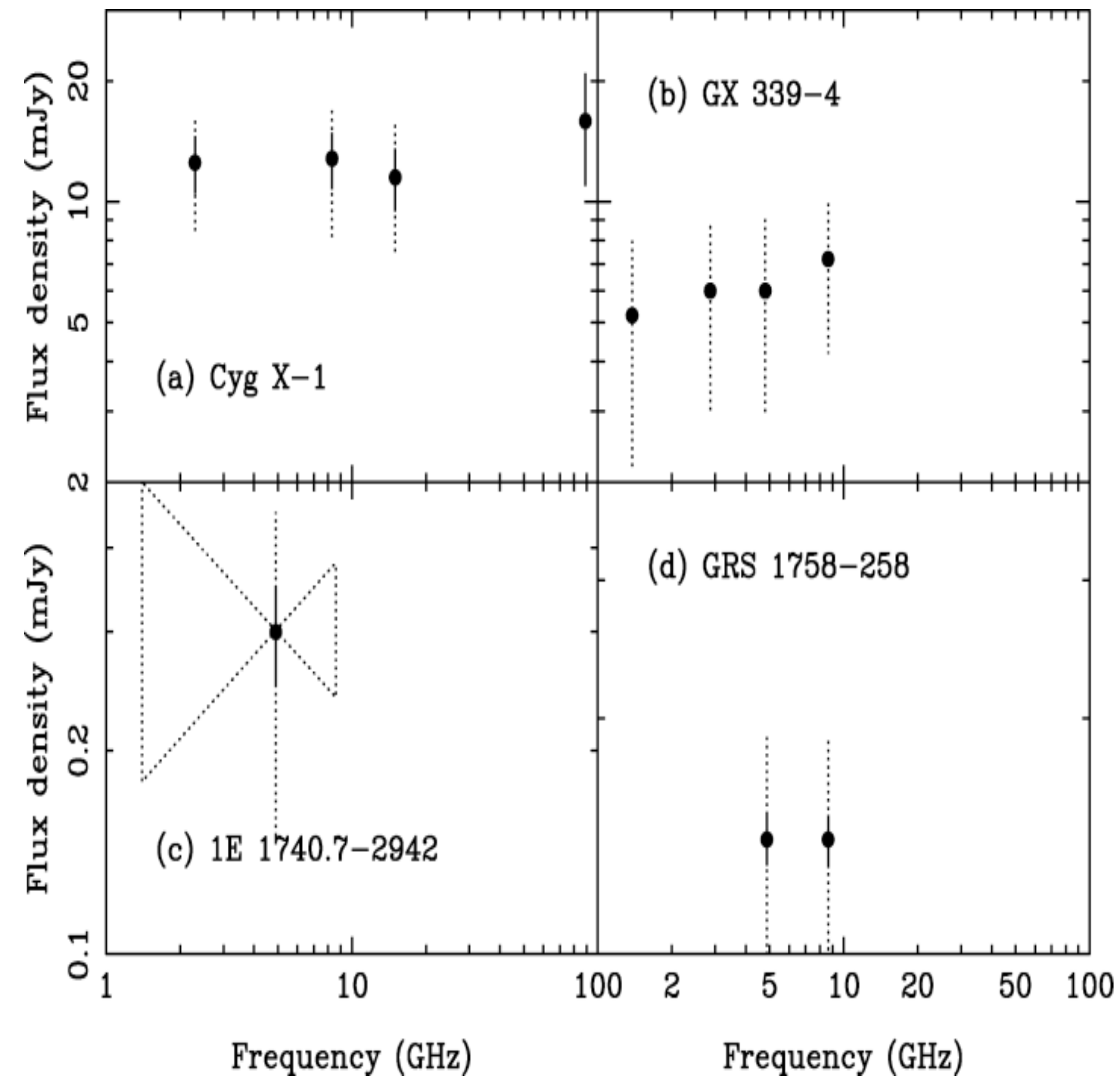


Julien Malzac

Evidence for compact radio jets in XRBs in the hard spectral state

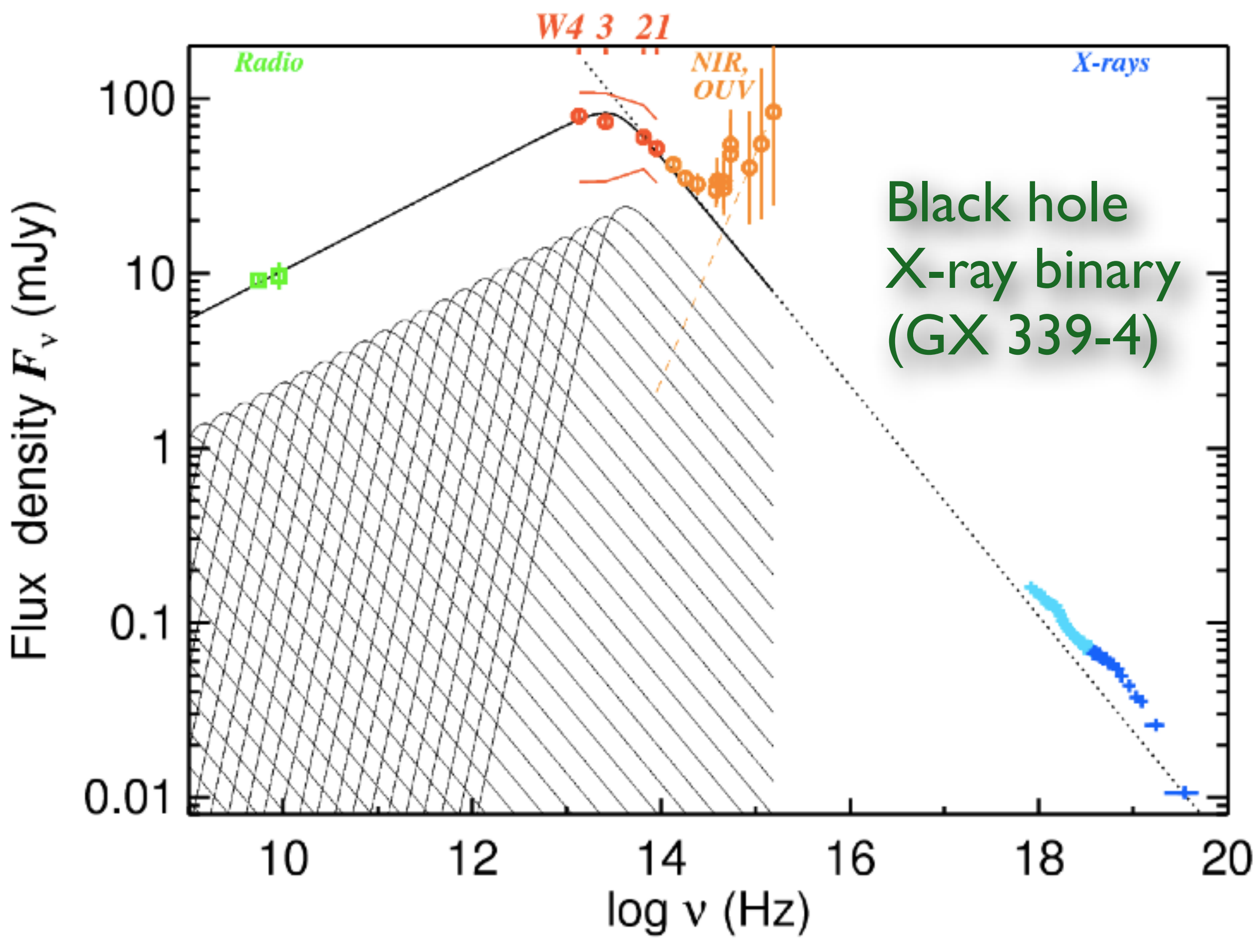


Cygnus X-1
(Stirling et al. 2001)

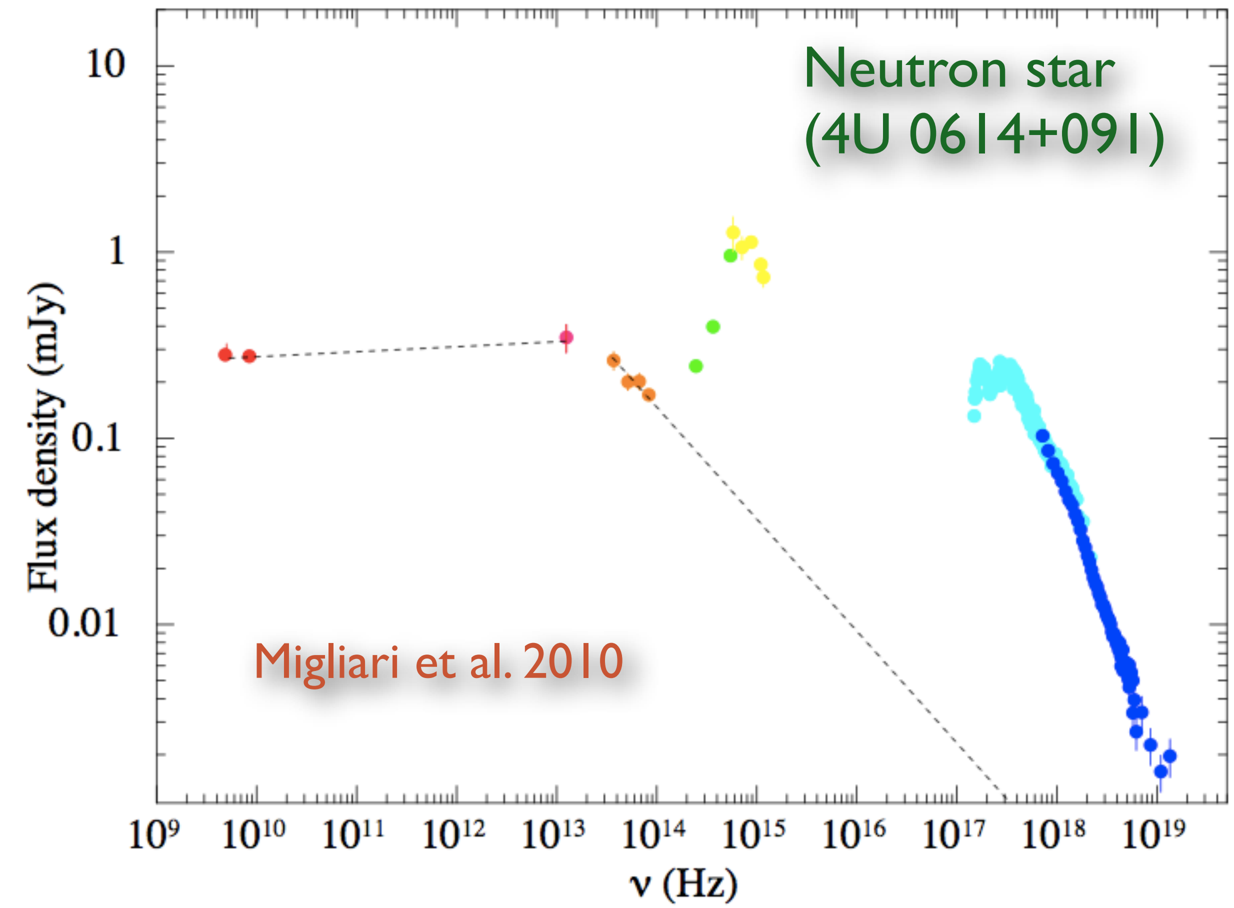


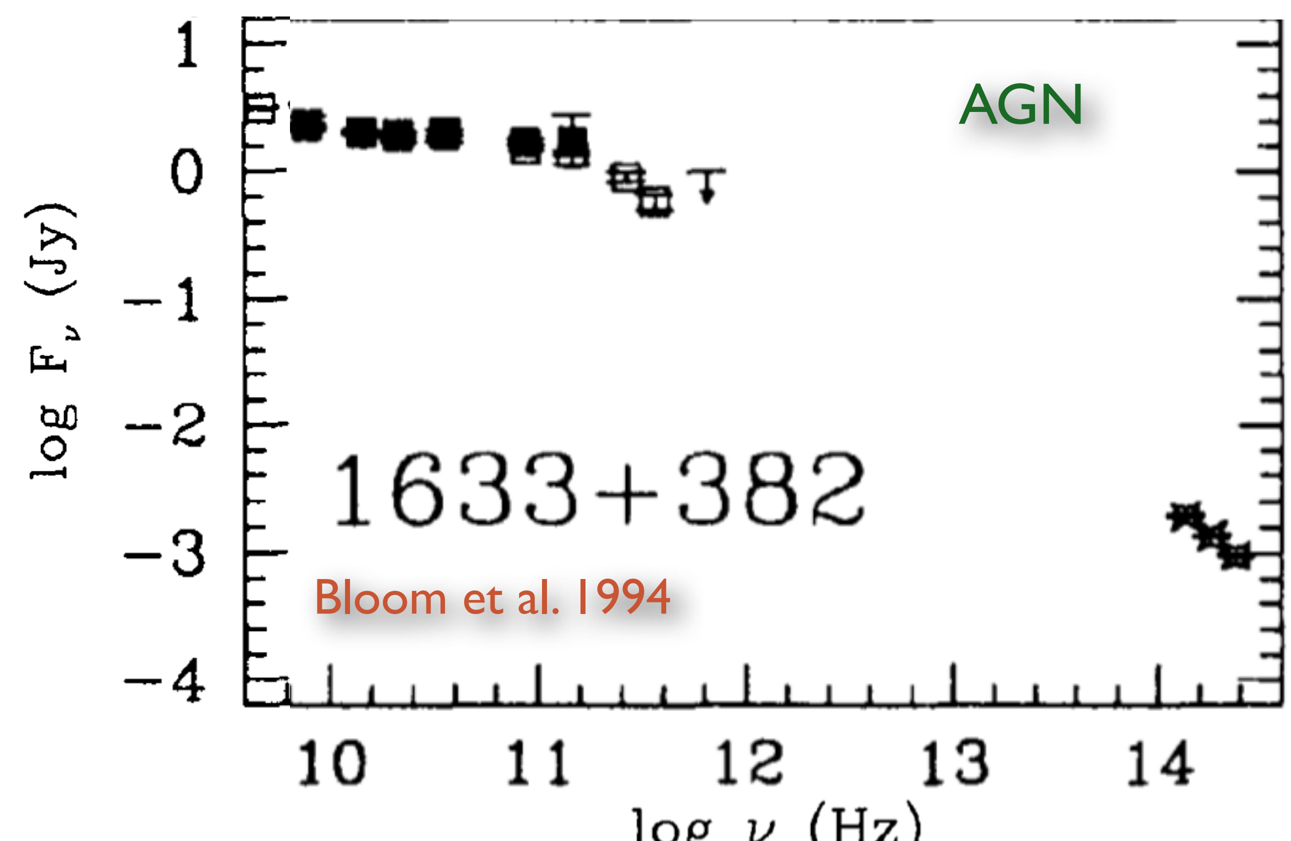
Flat/inverted radio spectra
(Fender 2001)

Observed Spectral Energy Distribution of Compact Jets



Gandhi et al. 2011
see also Corbel & Fender 2002, Chaty et al. 2011; Rahoui et al 2012; Corbel et al. 2013; Russell et al. 2013...



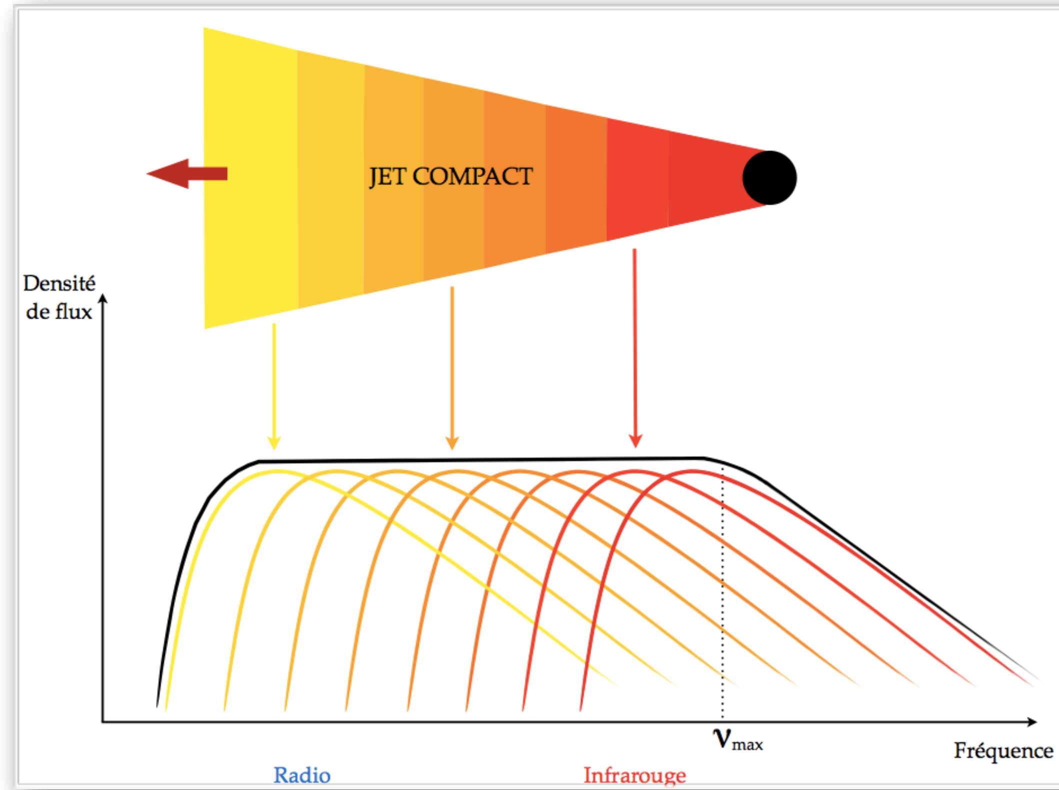


Standard conical jet emission model (Blandford & Koenigl 1979)

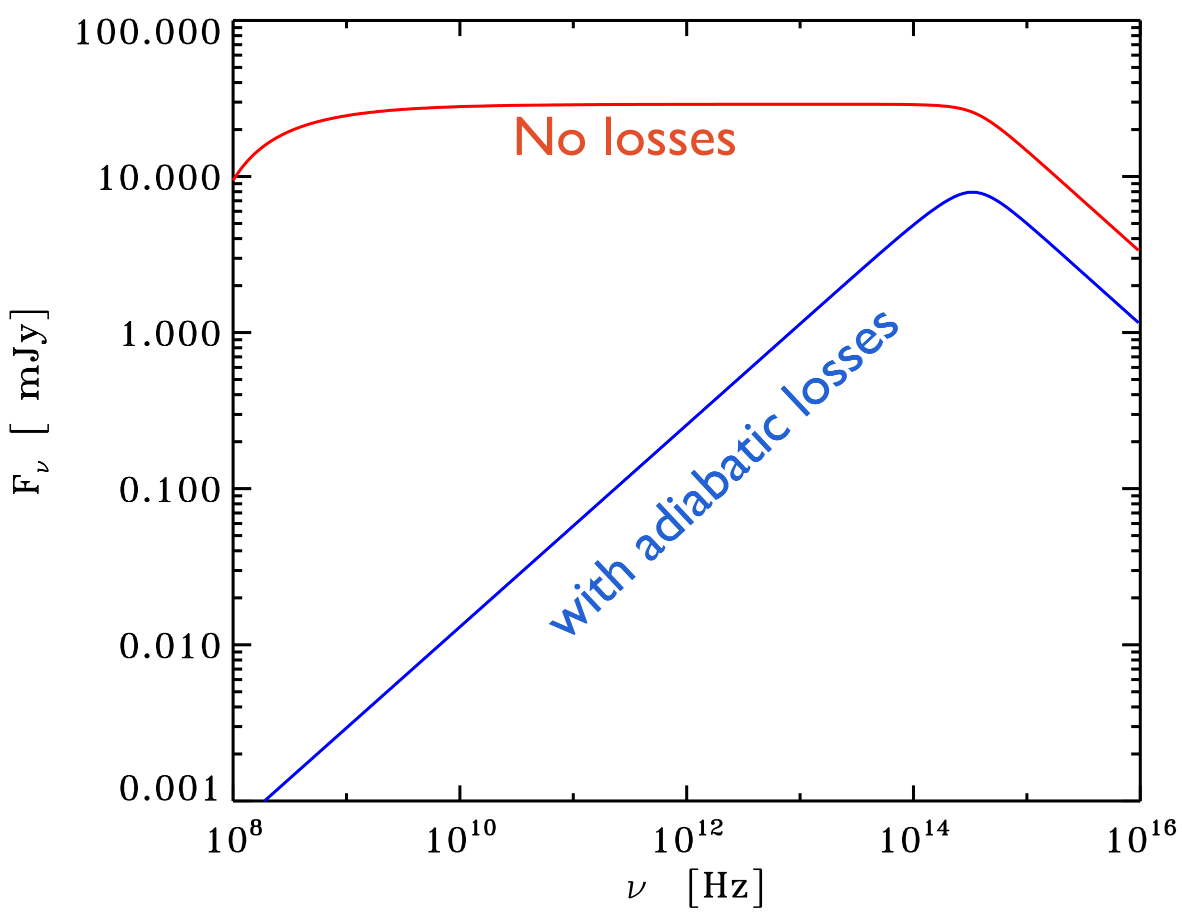
- Synchrotron radiation from a population of relativistic leptons travelling down the jet

$$n_e(\gamma_e) \propto \gamma_e^{-p}$$

- Energy losses neglected



(M. Coriat)



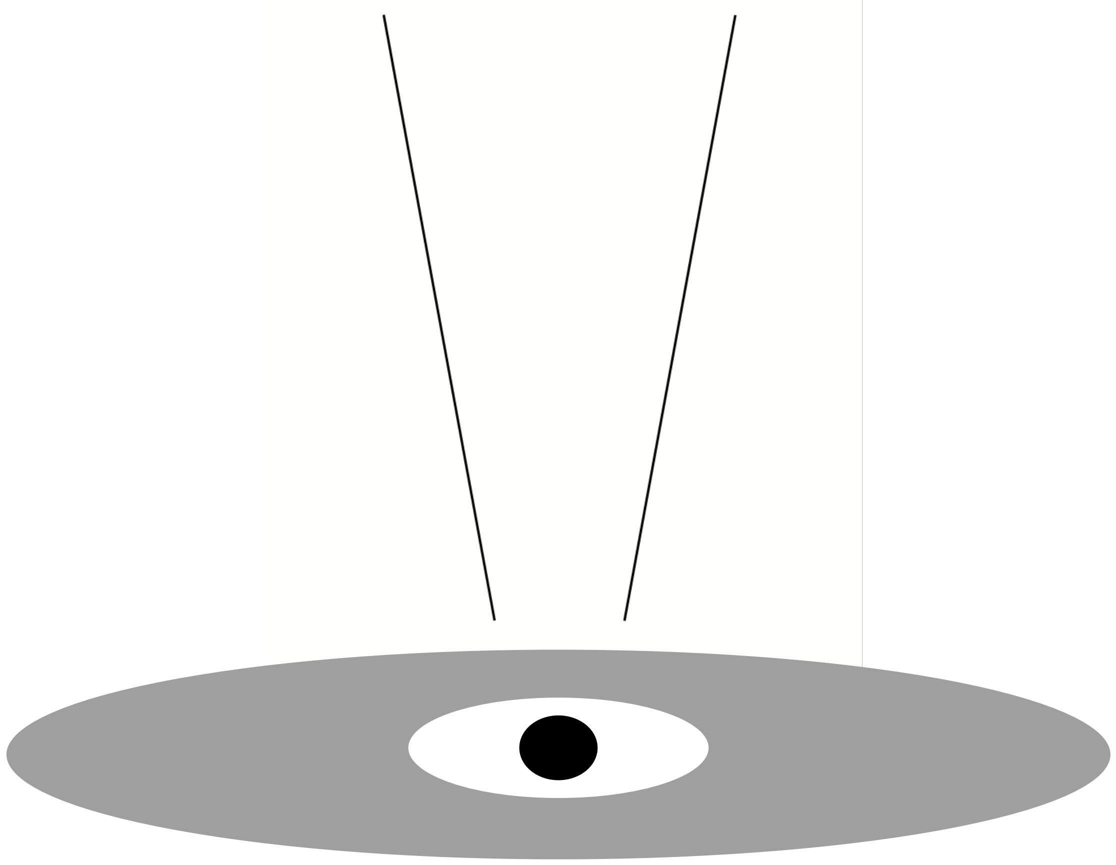
Adiabatic expansion energy losses:

➡ strongly inverted SED

➡ need to compensate for losses

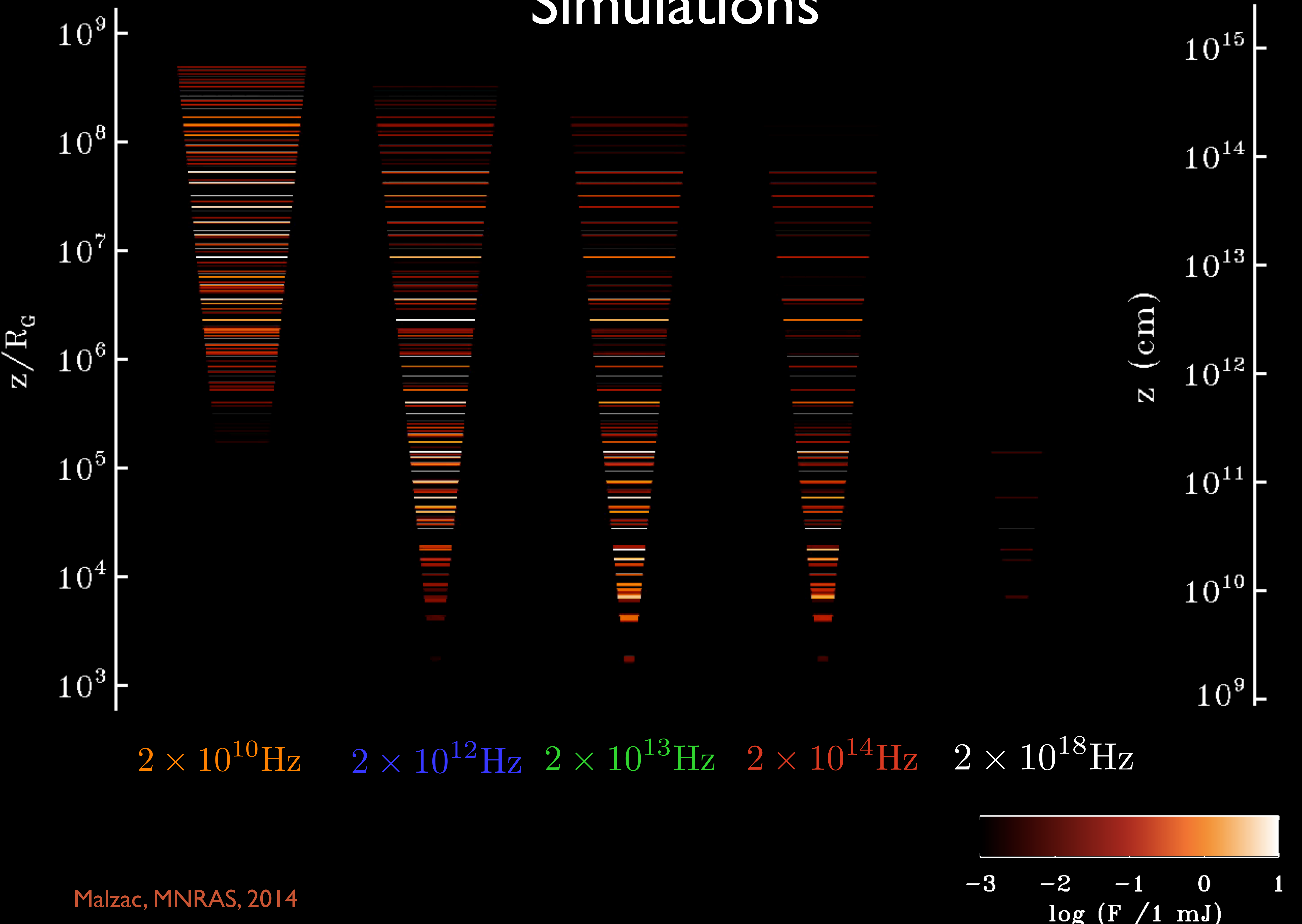
Internal shock model

- Jet= ‘shells‘ ejected a time intervals ~ t_{dyn} with randomly variable Lorentz factors
- Faster shells catch up will slower shells and collide
- Shocks, particle acceleration, and emission of synchrotron radiation
- Hierarchical merging process



Jamil et al. 2010

Simulations



Malzac, MNRAS, 2014

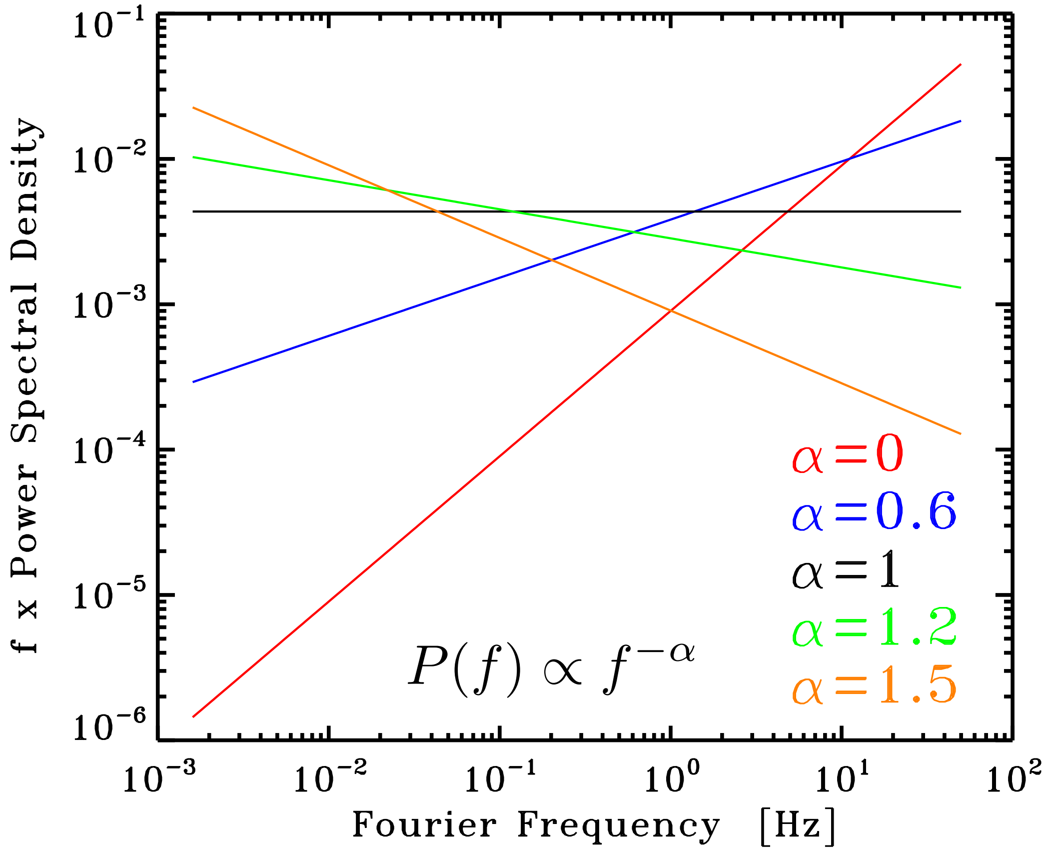
Can shock dissipation balance energy losses ?

- Dissipation profile depends on the properties of Lorentz factor fluctuations:

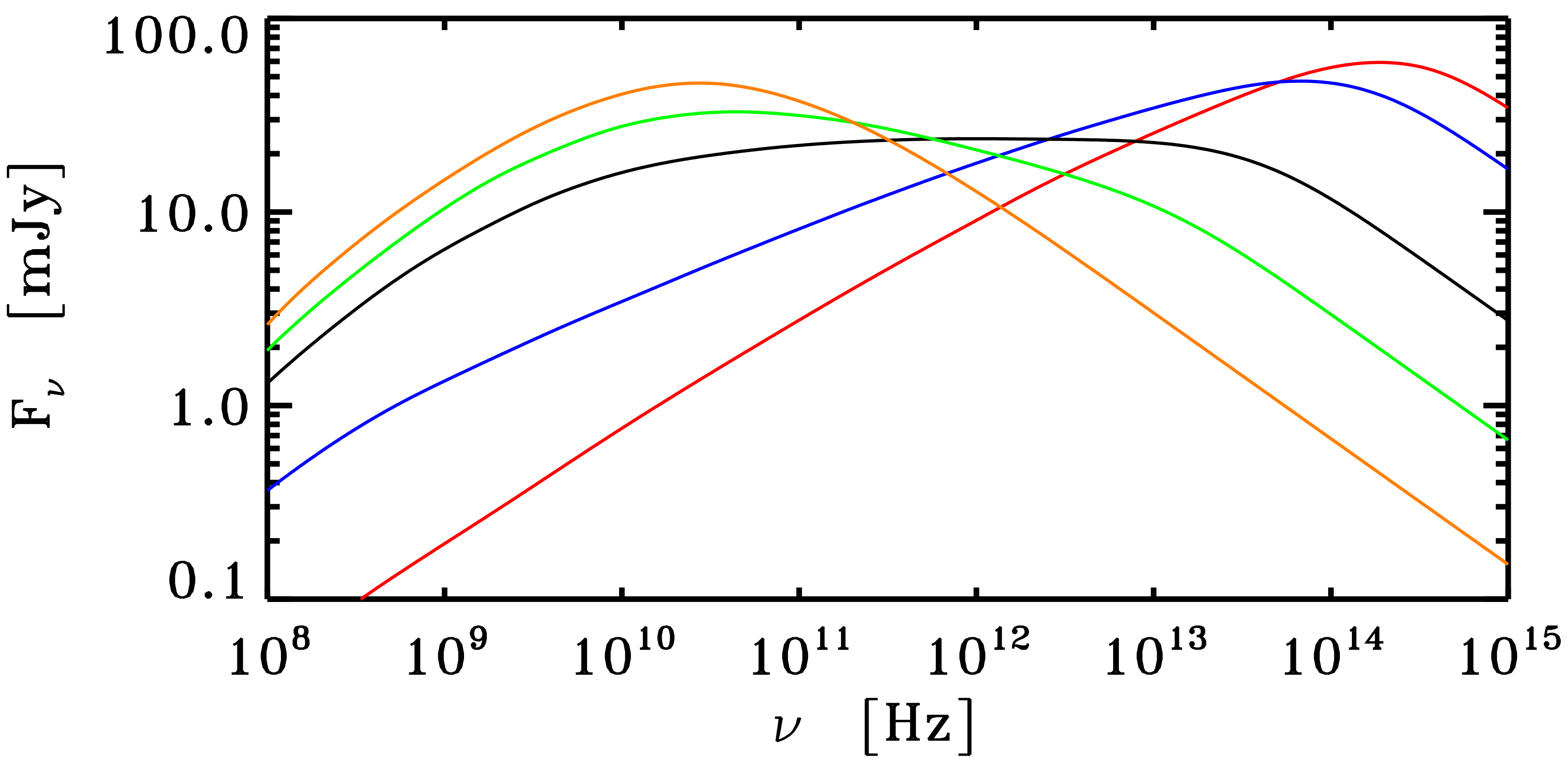
  Longer time scales and lower amplitudes ➡ collisions at larger distances

  ➡ emission at longer wavelength

➡ SED sensitive to Fourier PSD of input Lorentz factor fluctuations



PSD of Lorentz factor fluctuations



Spectral energy distribution

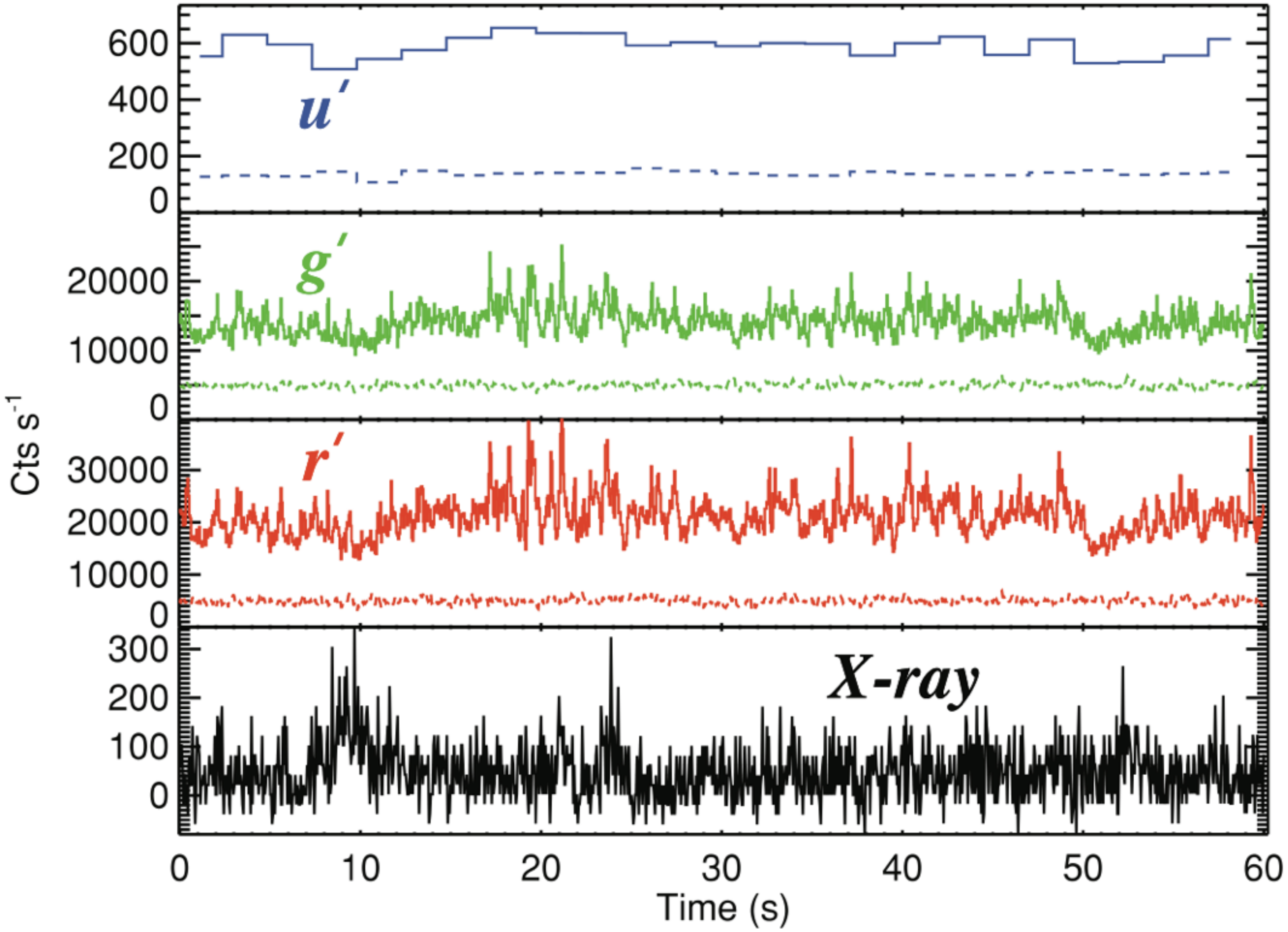
➡Flat radio-IR spectra produced for flicker noise Lorentz factor fluctuations

Malzac, MNRAS, 2013

Fast Jet Variability

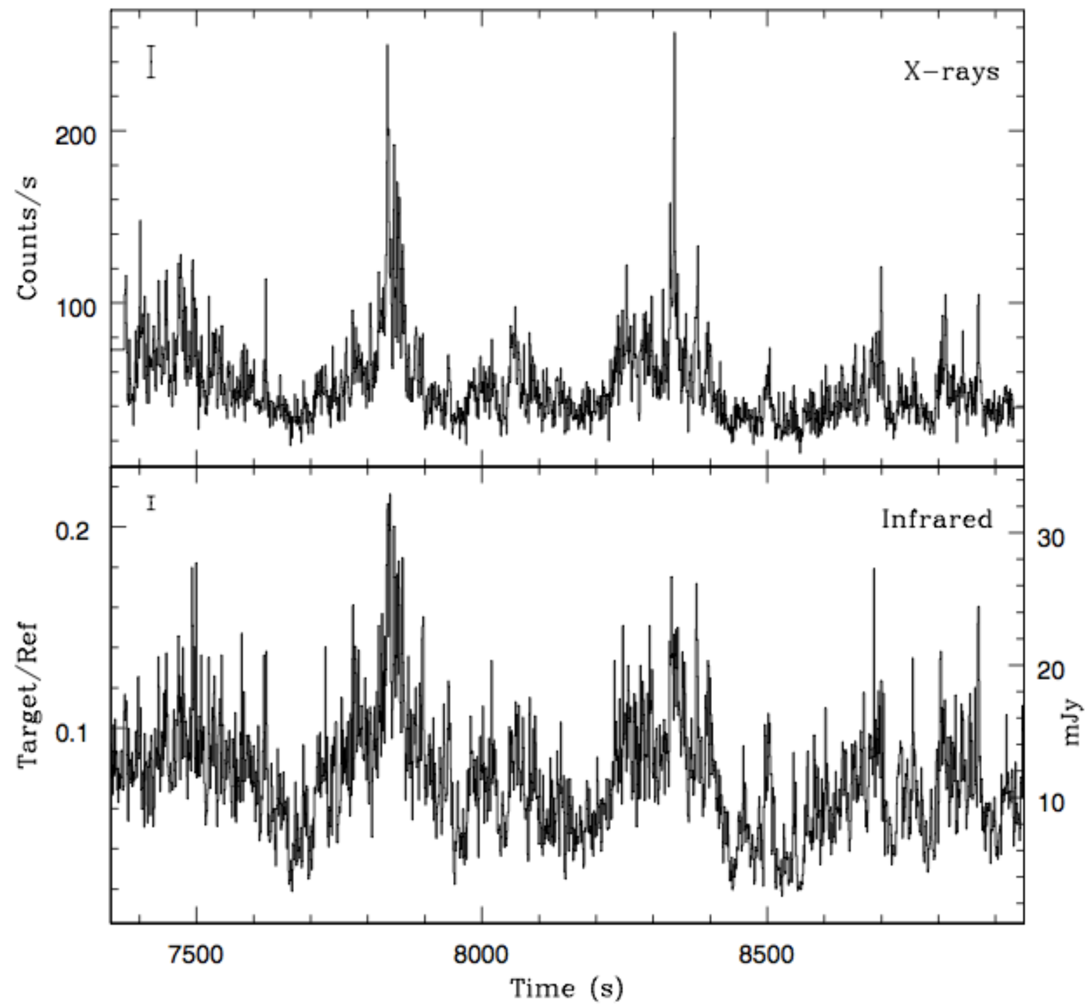
Observations of GX 339-4

Optical



Gandhi et al. 2010

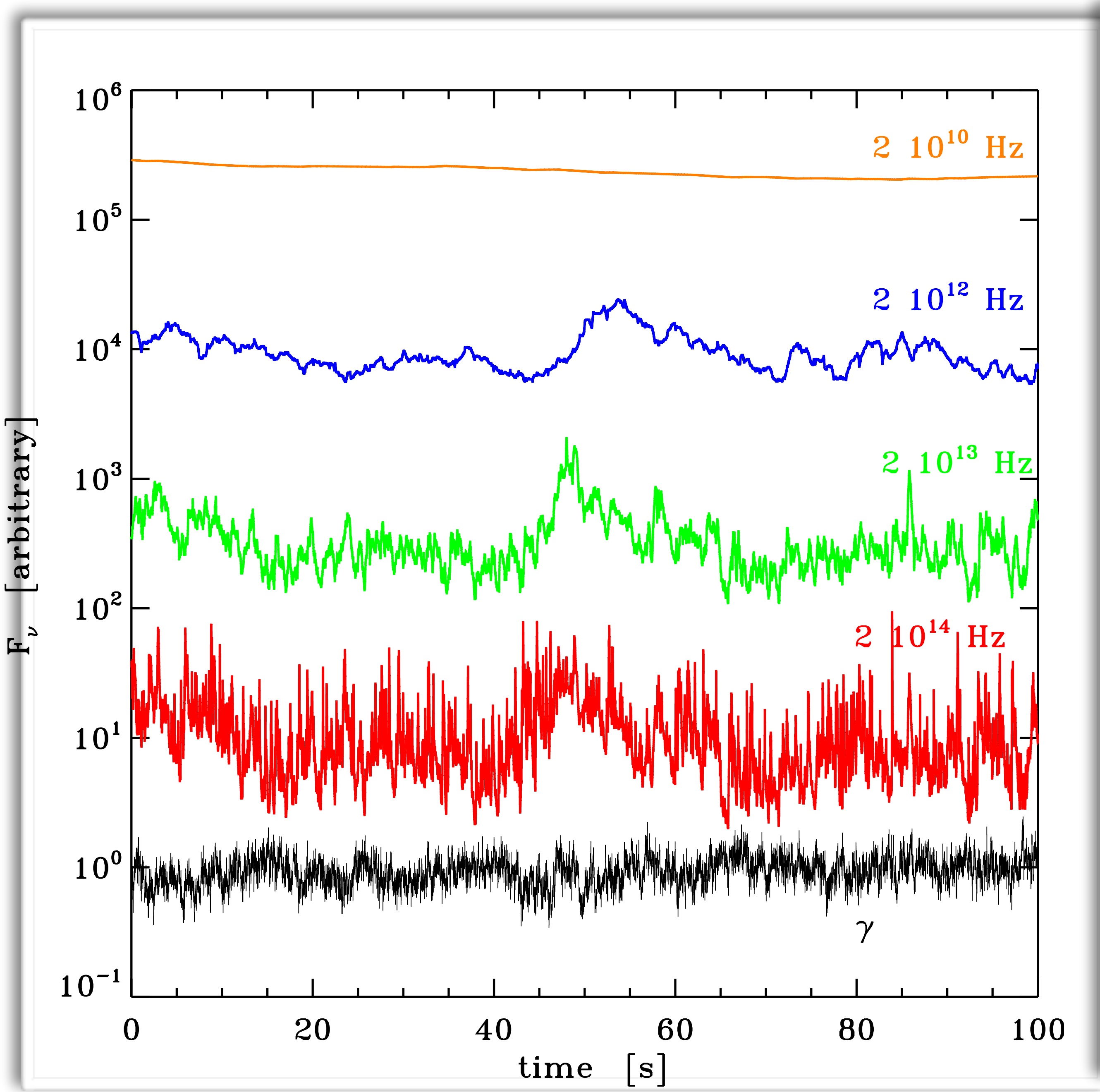
Infrared

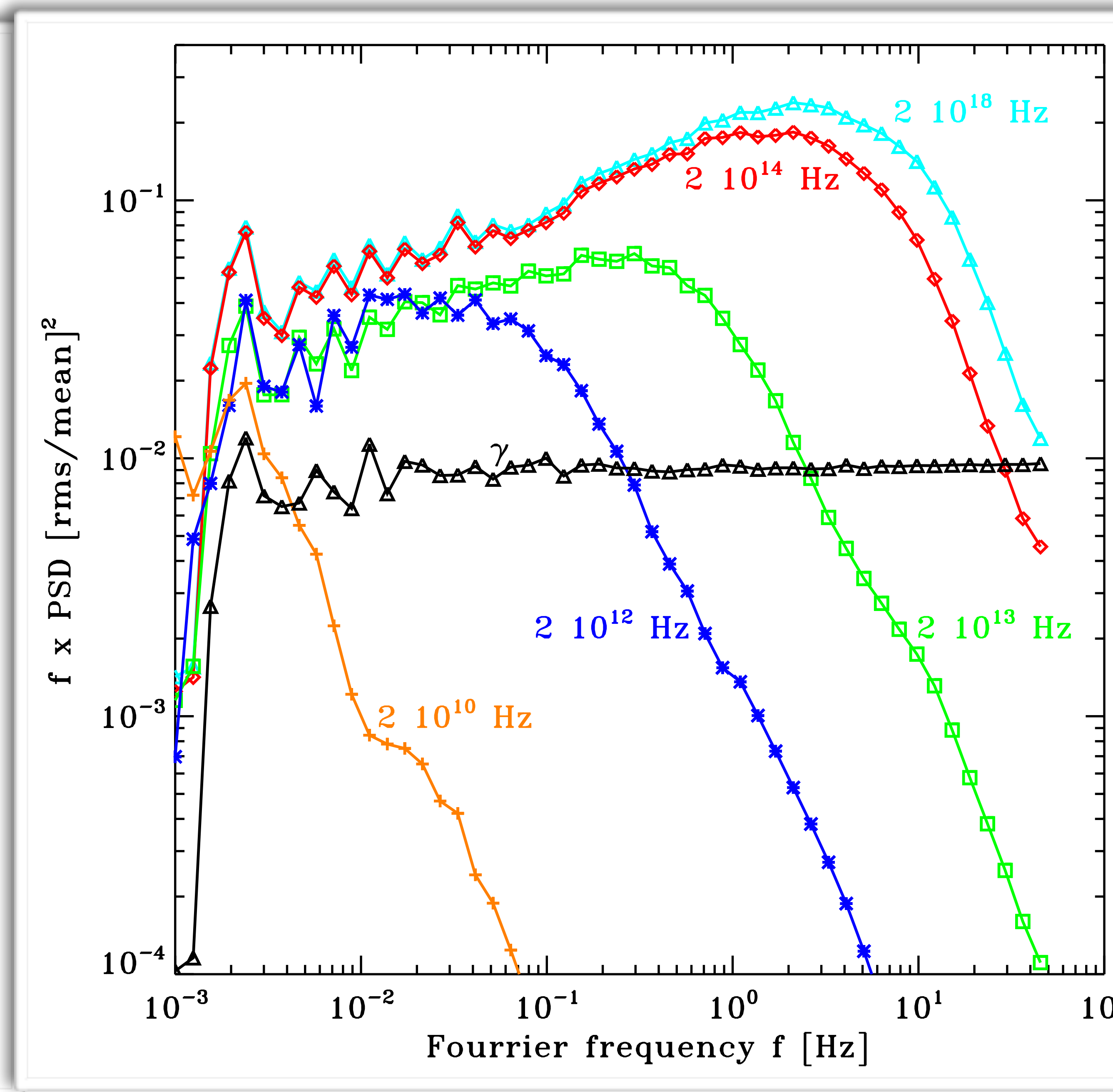


Casella et al. 2010

Fast Jet Variability

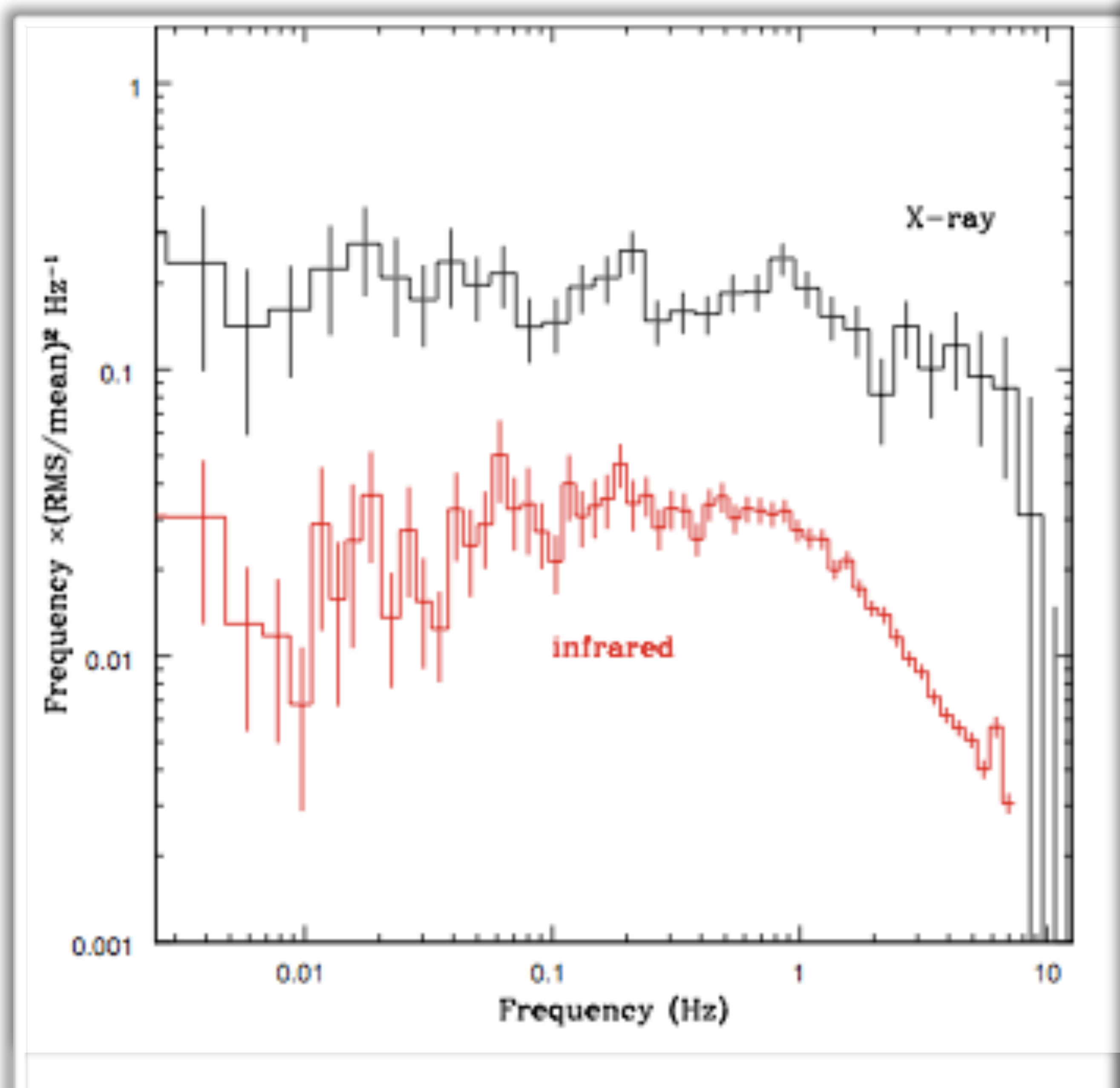
Model



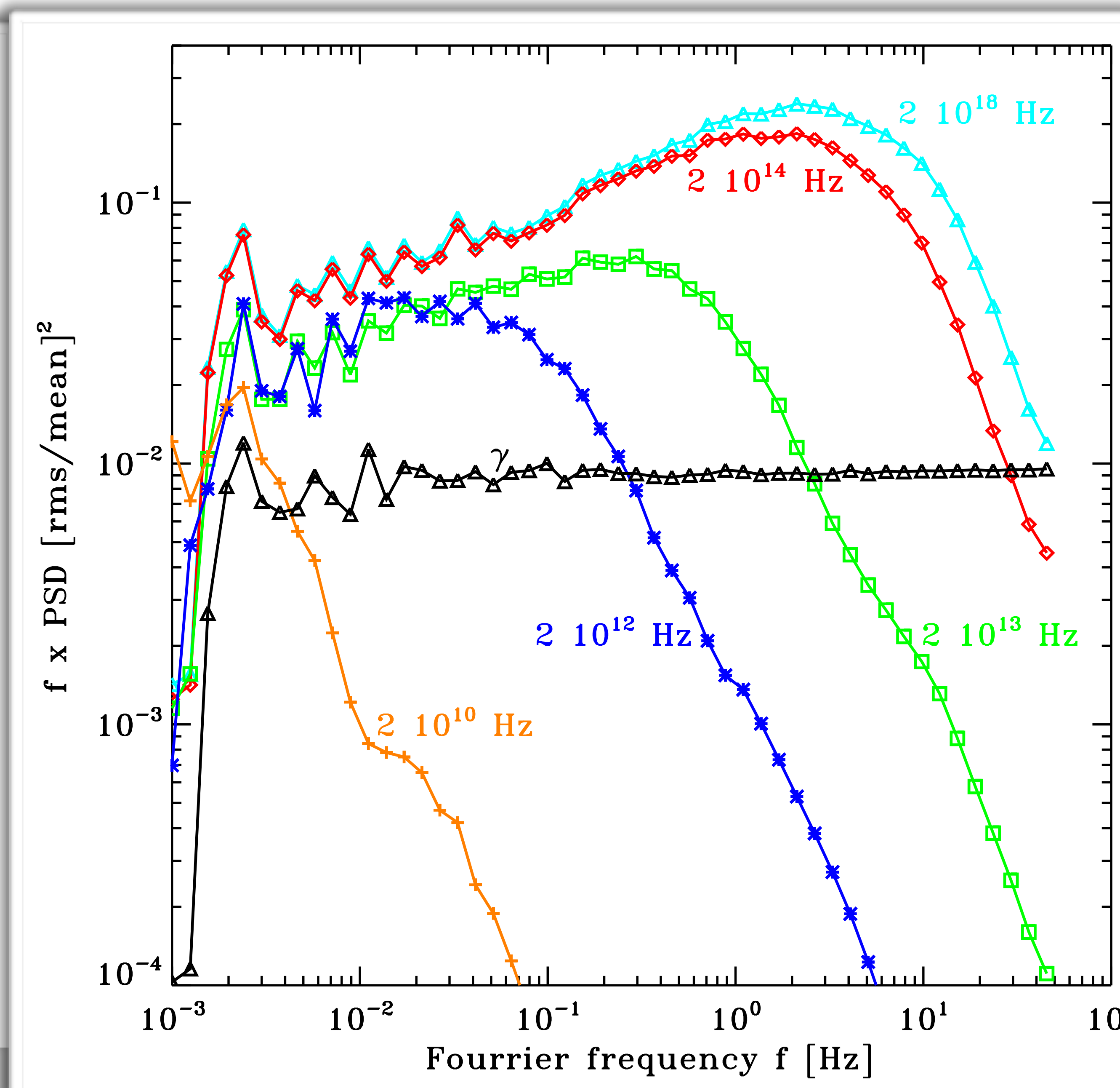


Malzac, MNRAS, 2014

Fast Jet Variability



Casella et al. 2010

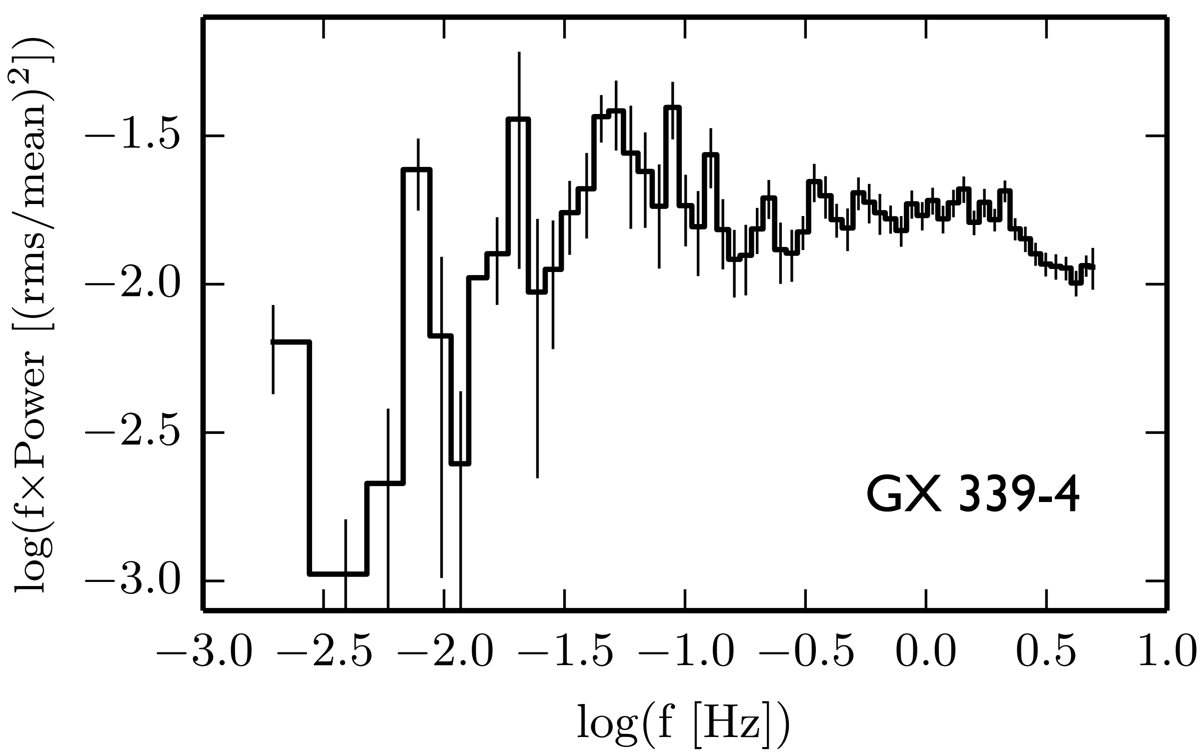


Malzac, MNRAS, 2014

Why flicker noise ?

- Independently of launching mechanism, jet variability likely to be driven by the accretion flow

- Accretion flow variability best traced by X-ray fluctuations:



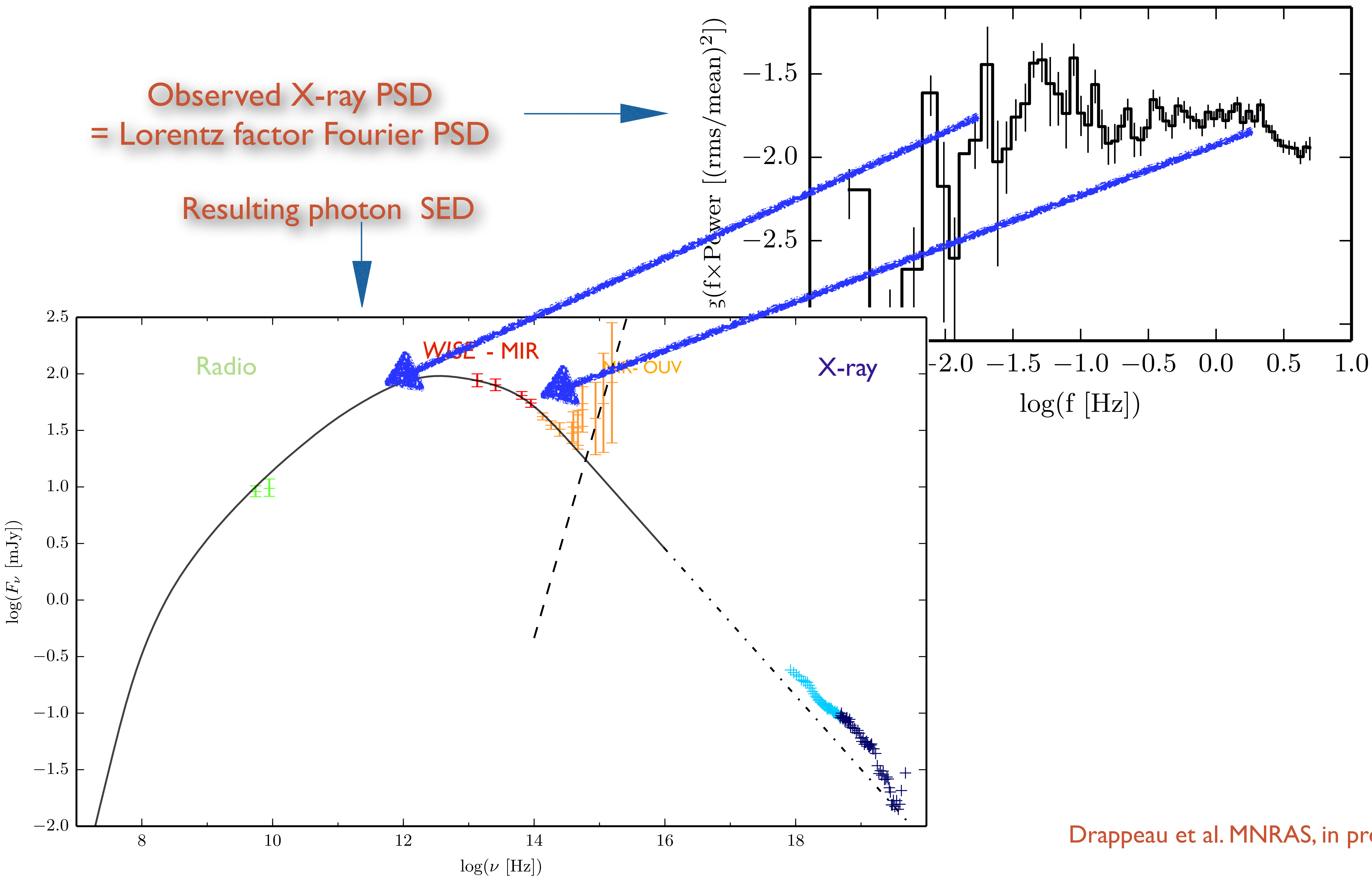
- X-ray power spectra of X-ray binaries close to flicker noise

➡Jet Lorentz factor fluctuations expected to be close to 1/f noise

Using observed X-ray PSD as input PSD of jet Lorentz factor fluctuations

Observed X-ray PSD
= Lorentz factor Fourier PSD

Resulting photon SED

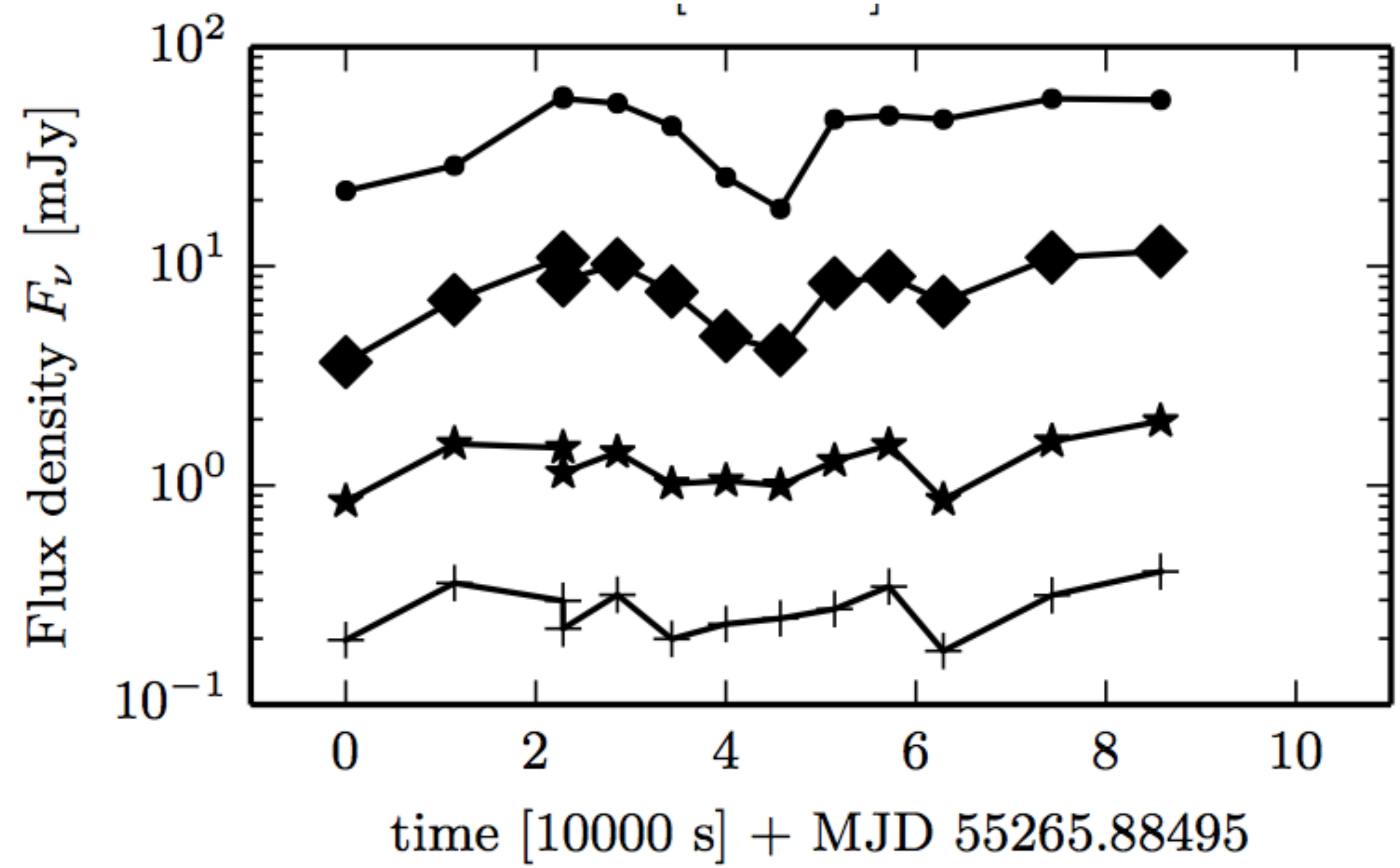


Drappeau et al. MNRAS, in press

Observation

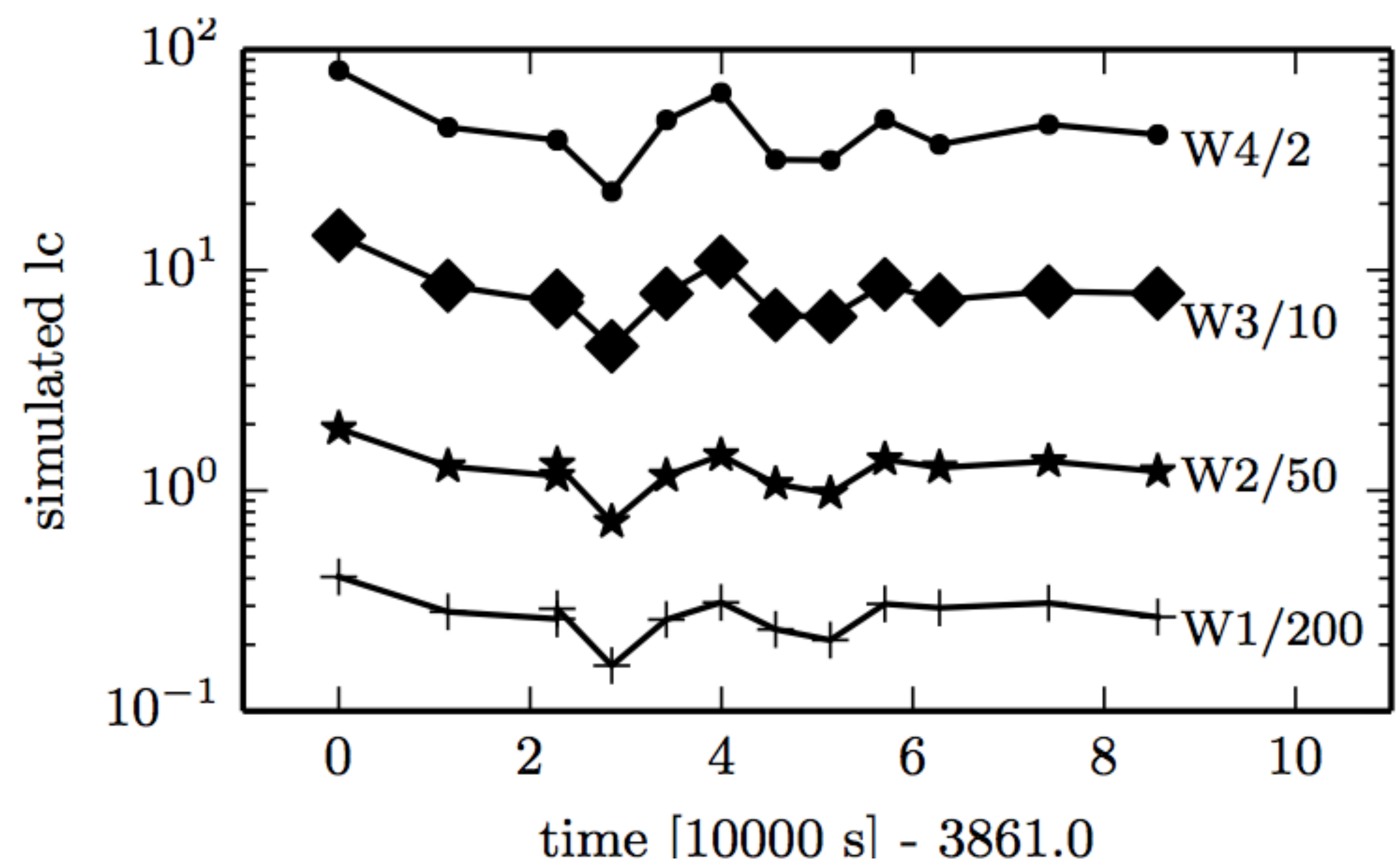
Observed NIR light curves

(Gandhi et al. 2011)



Simulation

Sample simulated light curves



Drappeau et al., MNRAS in press

Conclusions

- Internal shocks can account for the canonical SED of compact jets provided the power spectrum of injected fluctuations is close to $P(f) \propto f^{-1}$
- Internal shocks produce strong, frequency dependent, variability similar to that observed.
- Possible connection between X-ray POWER spectrum and Radio-IR PHOTON spectrum.

Future work

- Implementation of inverse Compton emission
  + effects of radiation losses on electron distribution

➡ Predictions for gamma-ray spectra and variability

➡ Application to AGN (and GRBs ?)

➡ Comparison with Fermi and HESS data, preparation of CTA

Thanks !