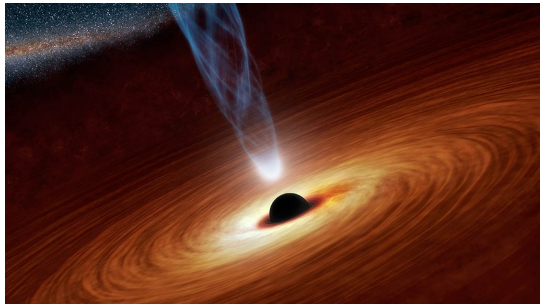
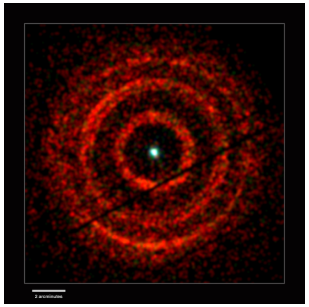
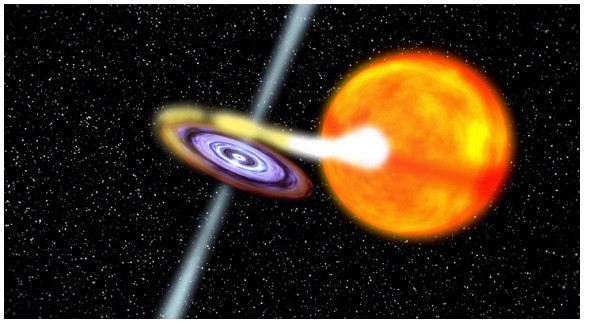






Multiwavelength Observations

John Tomsick

Space Sciences Laboratory/UC Berkeley

September 2018

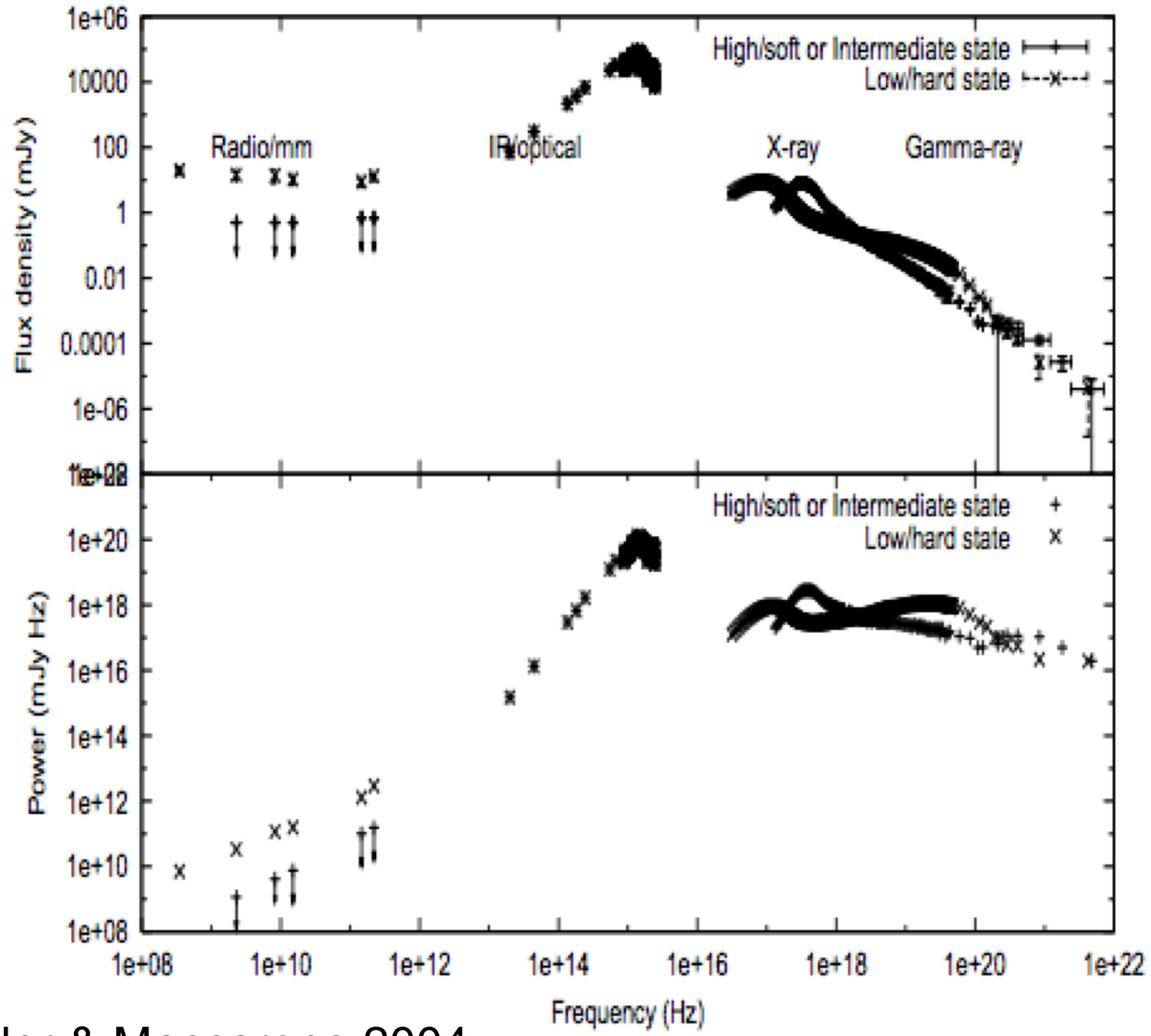
Outline

- Radio to X-ray energy spectra for
  - HMXB (Cyg X-1) in soft and hard states
  - LMXB in outburst (in the hard state)
  - LMXB in quiescence (very faint X-ray state)
    - Opportunity to measure the mass of the black hole
- Does the jet produce X-rays and gamma-rays?
  - Correlations between X-rays and radio
  - Evidence for multiple high-energy components

HMXB: soft and hard states

- Radio only detected in the hard state
- Optical/IR dominated by the companion star
- Typical X-ray changes
- Emission extends to at least a few MeV

Cygnus X-1

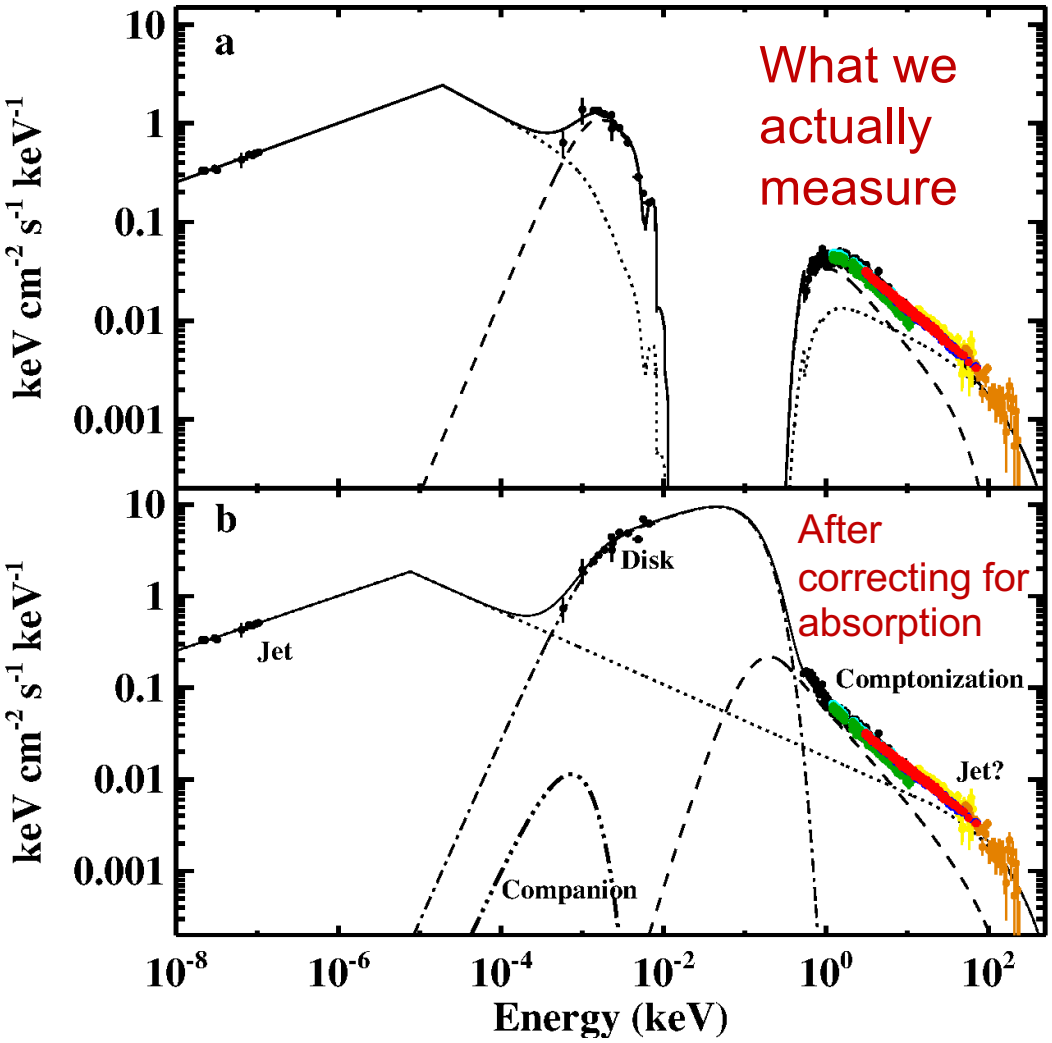


Fender & Maccarone 2004

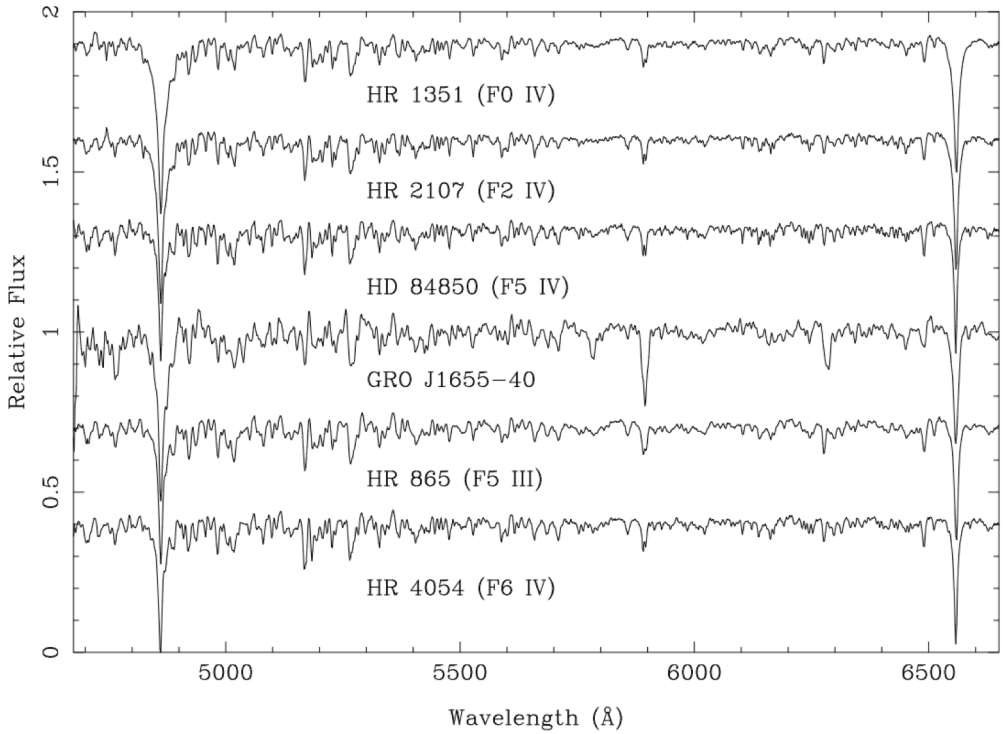
LMXB in outburst

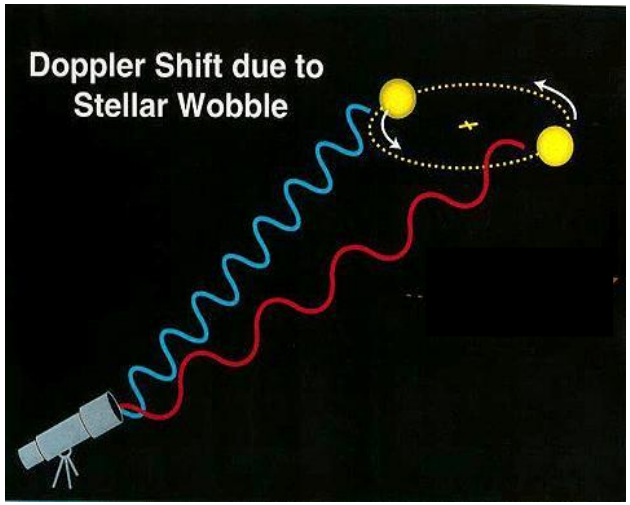
- This source has relatively low extinction, but is still difficult to observe in the UV
- Optical: disk emission dominates over companion star
- Jet may extend to high energies

Swift J1753.5-0127: hard state

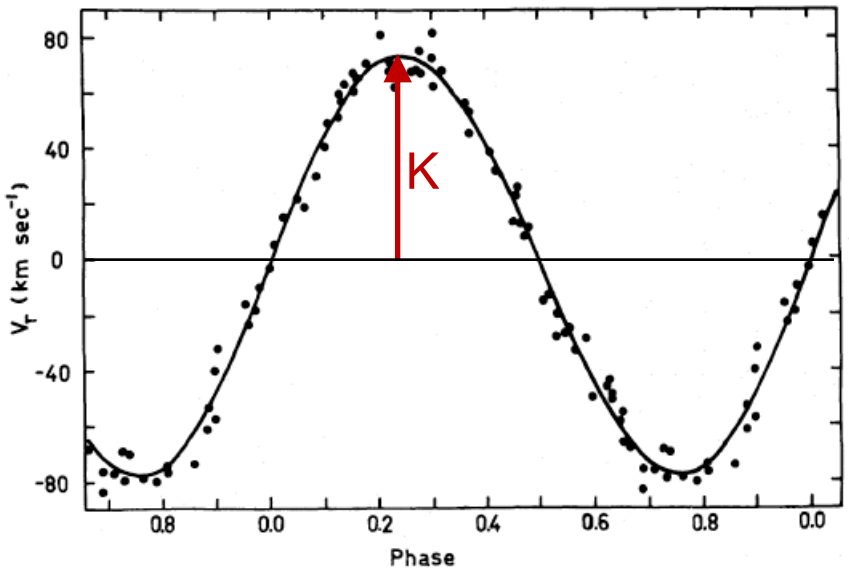


LMXB in quiescence

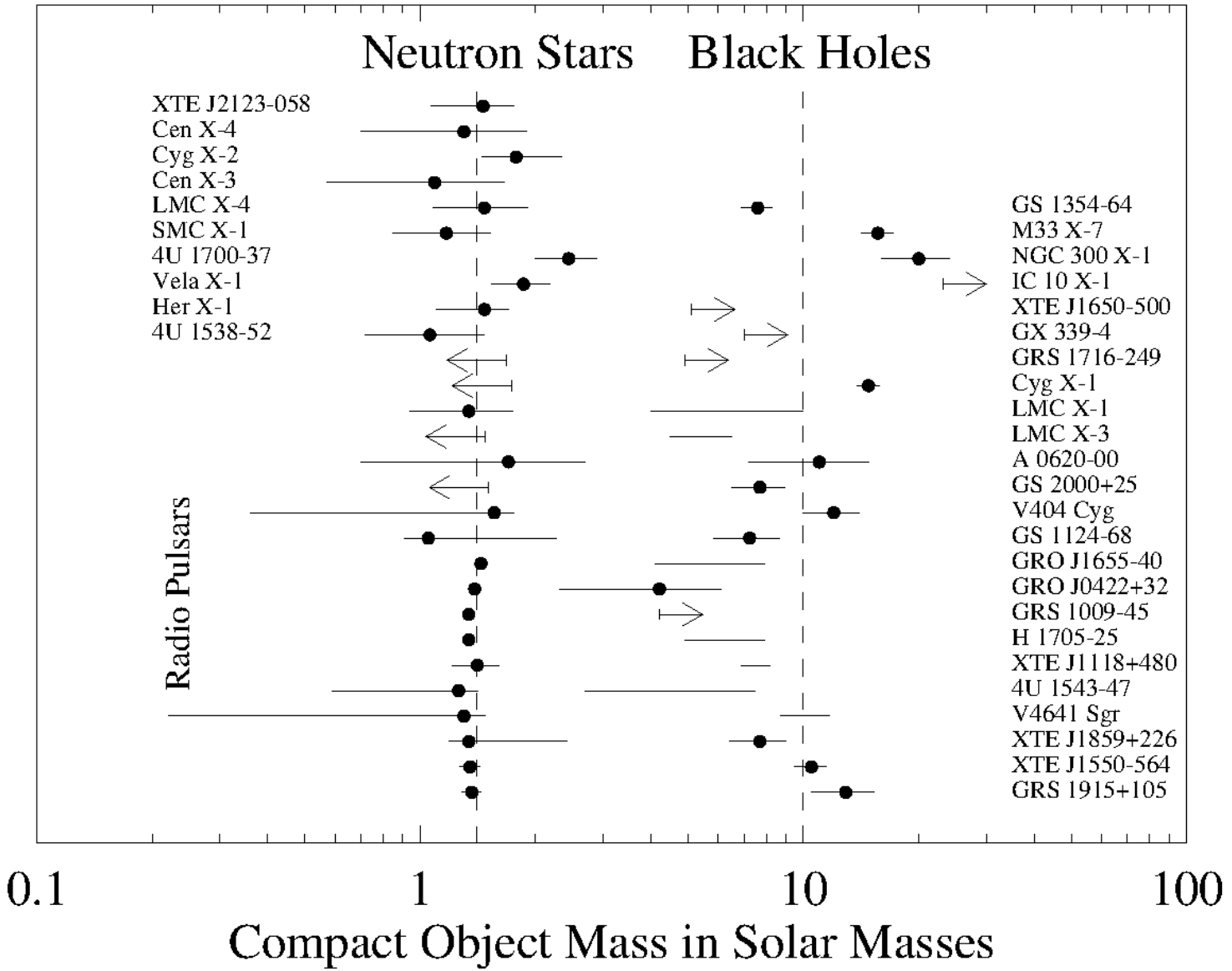




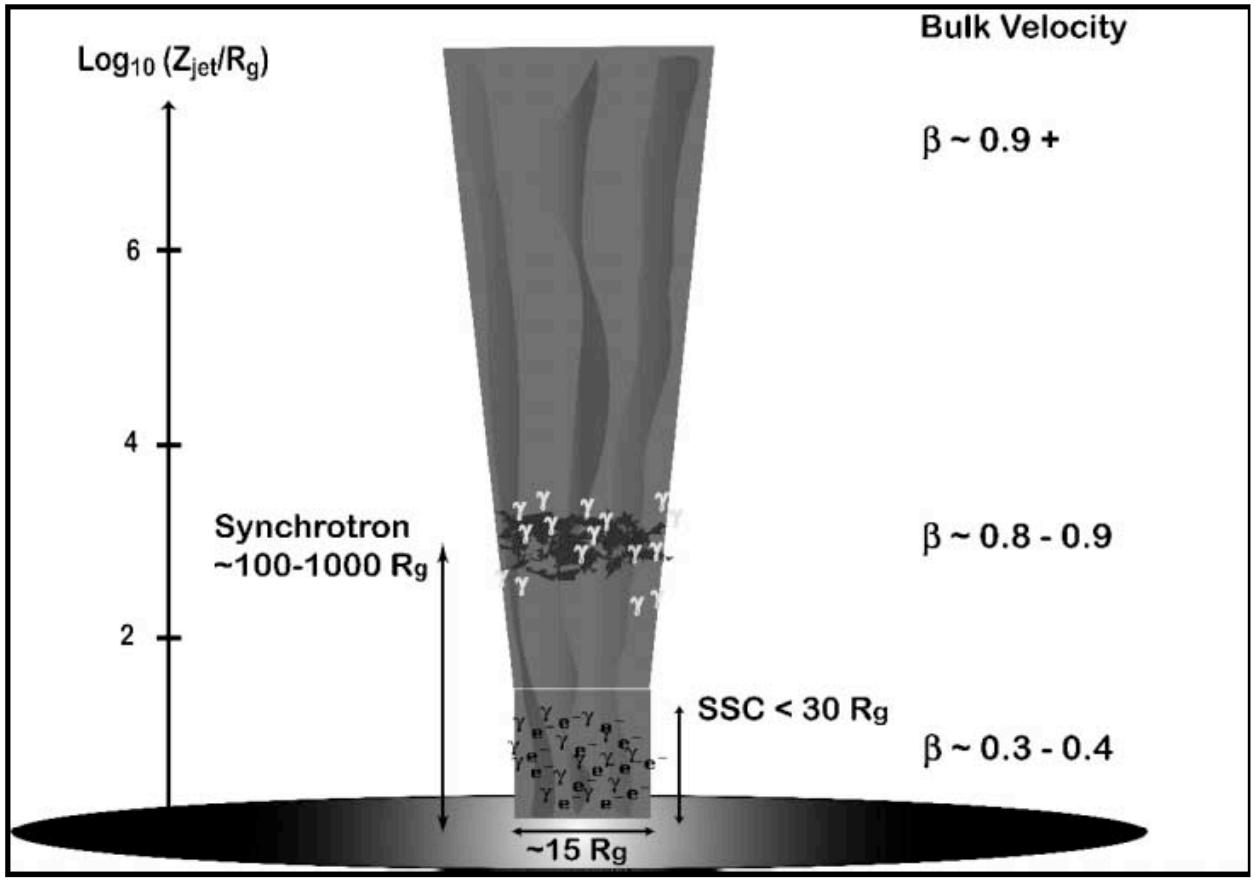
$$f = \frac{M_2^3 \sin^3 i}{(M_1 + M_2)^2} = \frac{P_{\rm orb}\ K^3}{2\pi G}$$



Masses of Neutron Stars and Black Holes



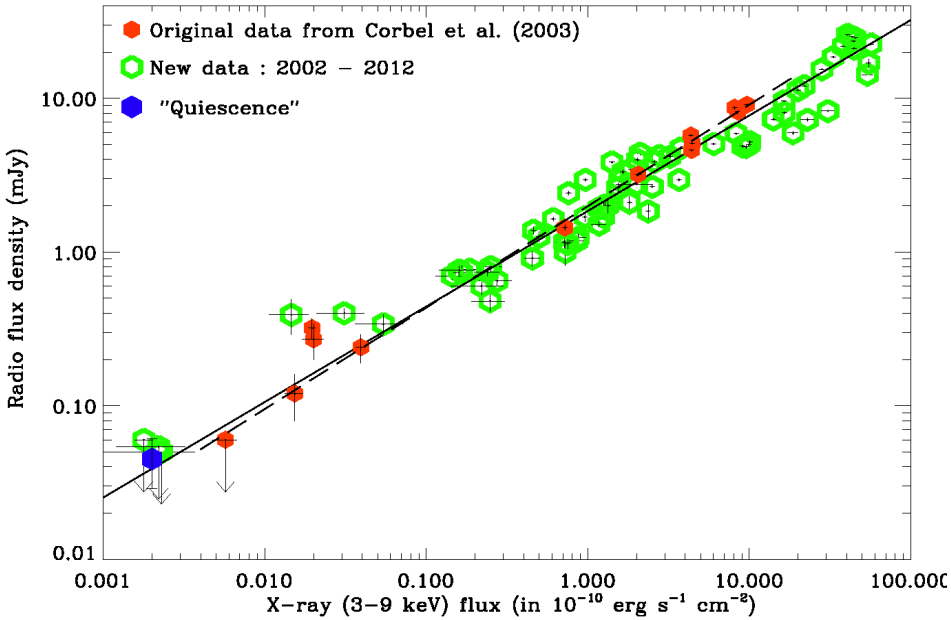
Does the jet produce X-rays and gamma-rays?



- Possible picture for jet emission by Markoff+05

X-ray/radio correlations

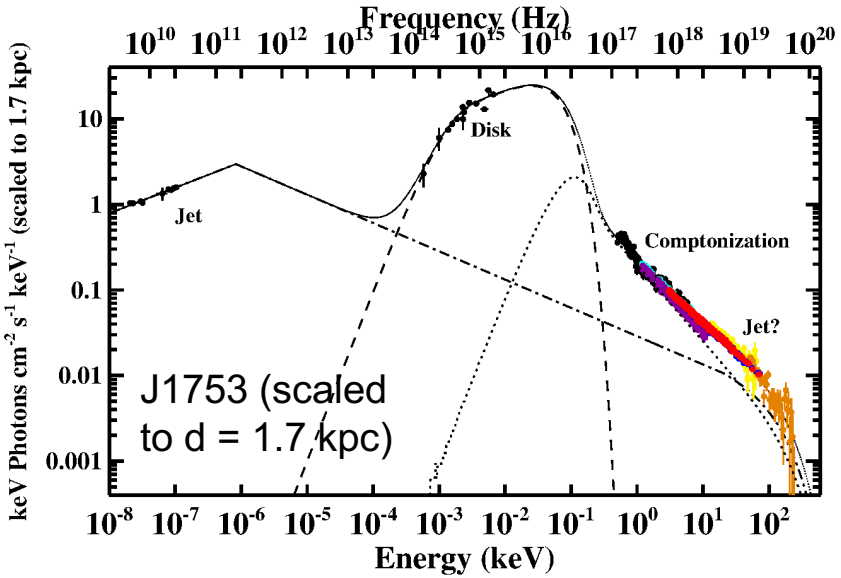
- Radio is from the compact jet, but what about X-rays?
- The X-ray and radio fluxes are strongly correlated

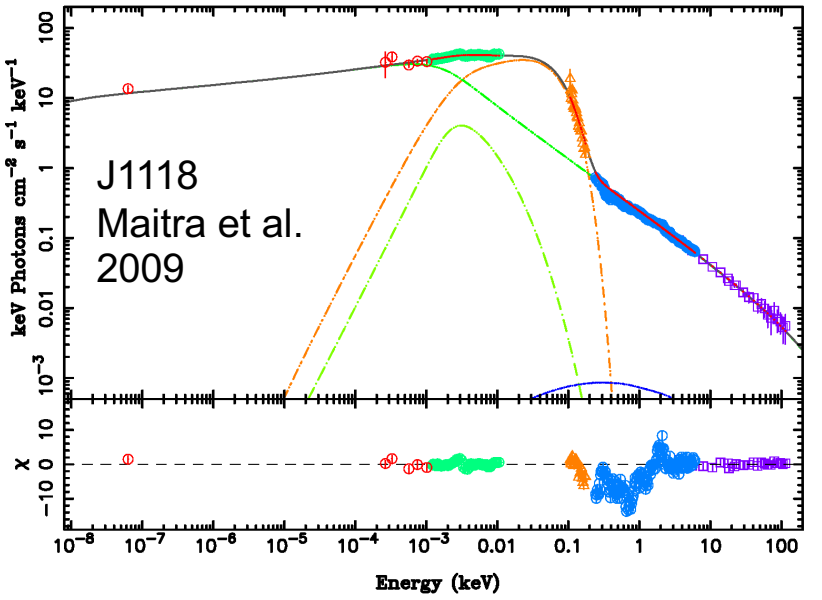


Observations of GX 339-4 made with *Swift*, *RXTE*, and ATCA (Corbel+13)

LMXB in outburst: J1753 vs. XTE J1118+480

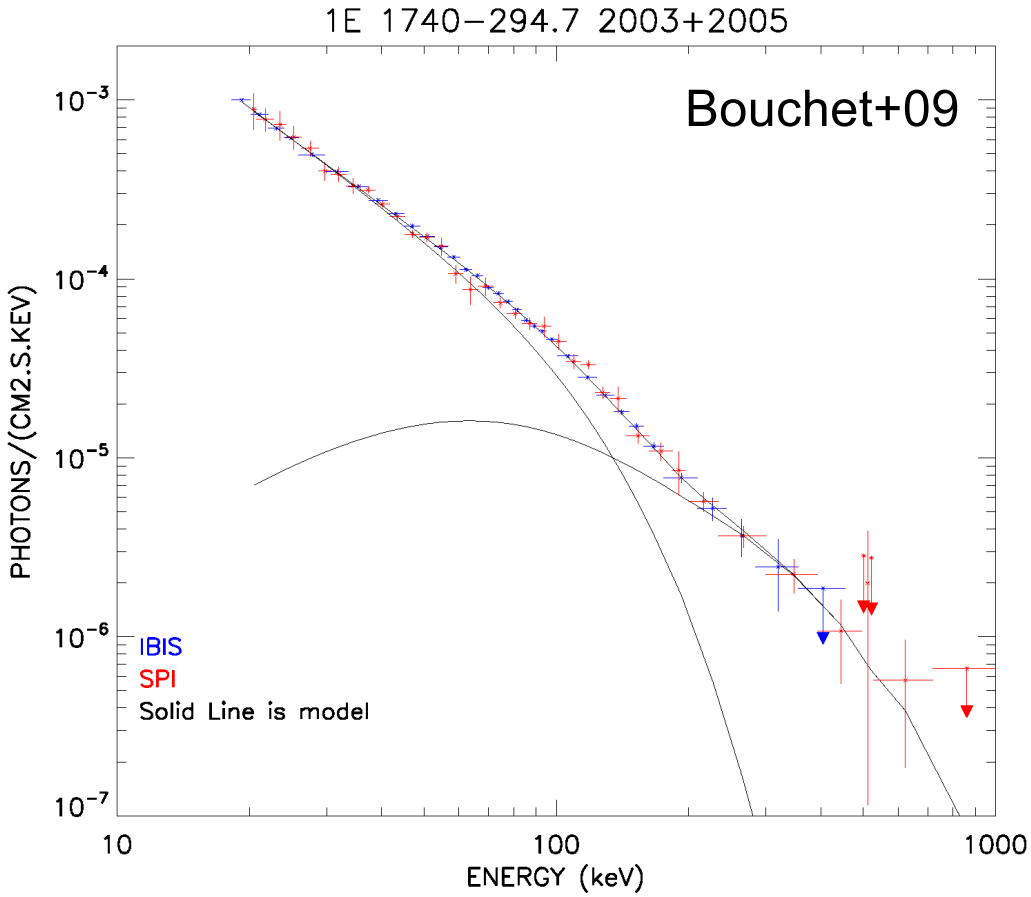
- How is XTE J1118+480 different?
  - Very low extinction allowing for UV detections
  - Stronger radio emission
  - Radio and X-ray could be part of the same component
- J1118 spectrum fit with a physical jet model





Many BH sources with evidence for multiple high-energy components

- Cyg X-1
- Swift J1753.5-0127
- GX 339-4
- GRS 1915+105
- 1E 1740.7-2942
- XTE J1550-564
- V404 Cyg



- Is there a high-energy contribution from the jet?
- Can polarimetry help us answer this question?