XRBs in Star-forming Galaxies

X-ray Luminosity Functions
Ultra-Luminous X-ray Sources

G. Fabbiano
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Santa Barbara

XRB Populations in Nearby Galaxies

- External galaxies provide `cleaner' samples
  - Distances uncertain for Galactic XRB
  - Extinction a major problem
  - Association of XRB with stellar populations
- We can find and study `extreme' sources
  - ULXs

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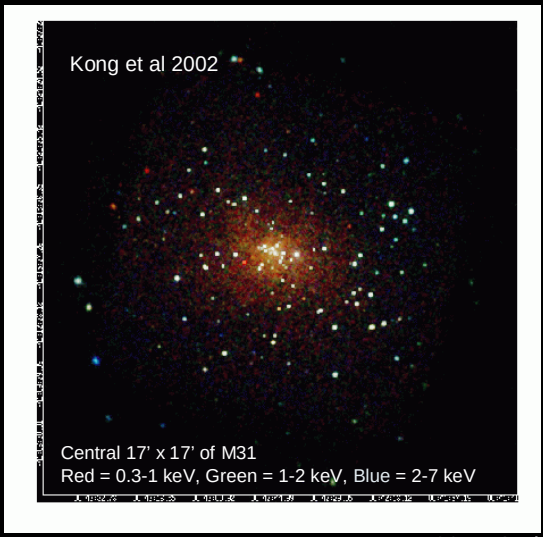
Chandra studies of X-ray Source Populations

Detection down to faint luminosities allows systematic populations studies



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M83 -- Soria & Wu 2003

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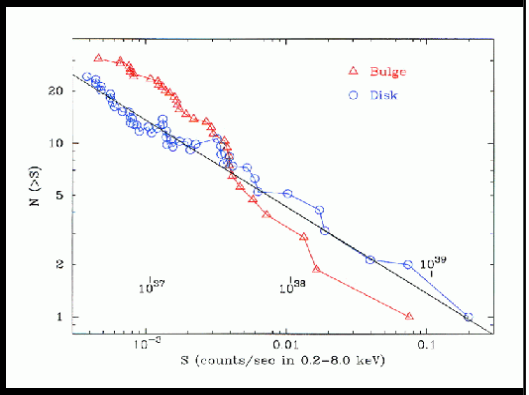
X-ray Luminosity Functions

- XLFs of Young XRB populations (disk) are flatter than those of the bulges
- XLFs of bulges have low luminosity breaks
  - E.g. M31
    - R1 < 2'
    - R2 < 8'
    - R3 >8'



M81 – Tennant et al 2001

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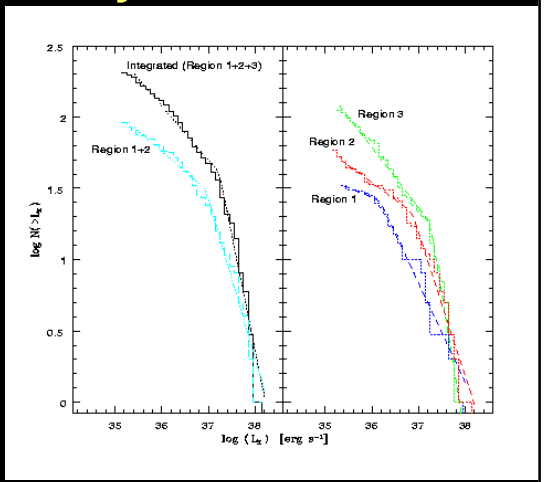

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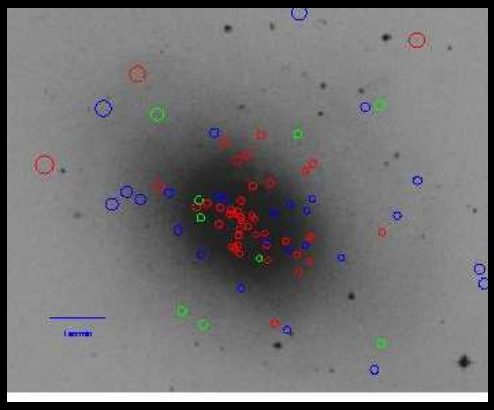
A word of caution on XLF breaks…

Kim & Fabbiano 2003, ApJ in press

- XLF of NGC1316, an early-type galaxy
  - Break in XLF disappears when proper corrections are applied
    - Background
    - Beam bias



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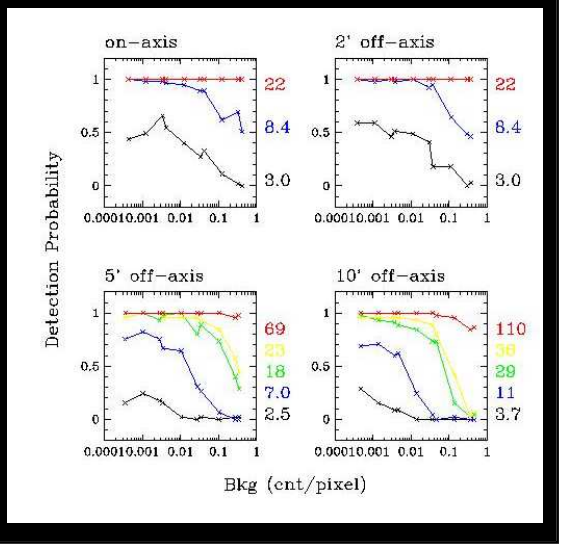

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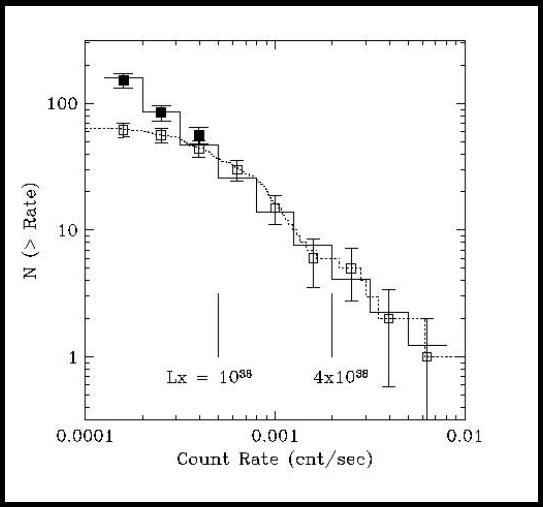

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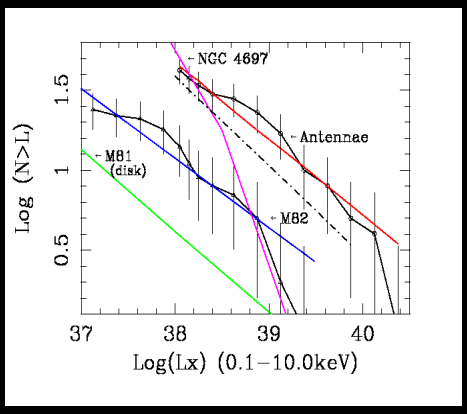
Drivers of the XLF

- More active star formation results in more and more luminous XRBs
- If star formation is not important, galaxy mass / stellar content is the driver.



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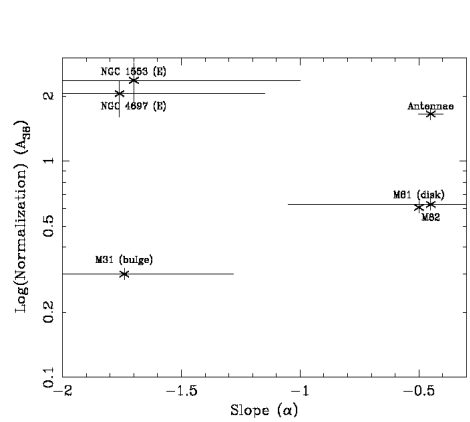

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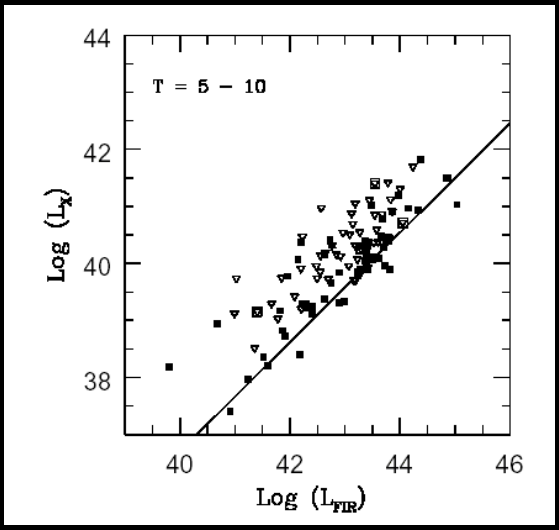
XLF and Star Formation

- Lx ~FIR correlations in Sc-Irr (e.g., Fabbiano et al 1988; Fabbiano & Shapley 2002)
- XLF ~ SFR in actively star forming galaxies (Grimm, Gilfanov & Suniaev 2003)



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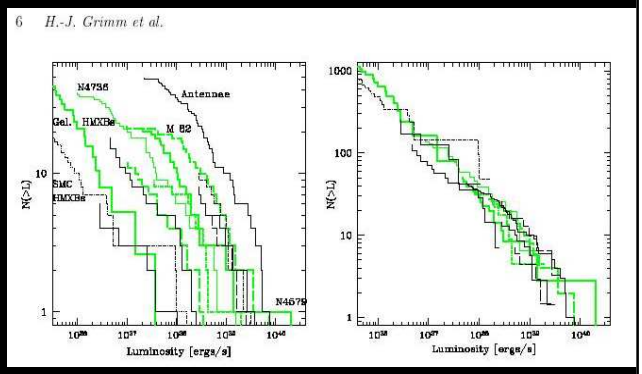

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Ultra Luminous X-ray Sources

- ULXs – $L_X > 10^{39}$ – a few 10^{40} ergs/s
  - $L_X > L_{Eddington}$ of stellar mass BH
- Are they XRBs?
  - Mostly: variability, spectral variability
- What type of XRB?
  - IMBH
  - Moderately beamed stellar BHB (King et al 2001; King 2002)
  - Relativistic beamed microquasars (Koerding et al 2002)

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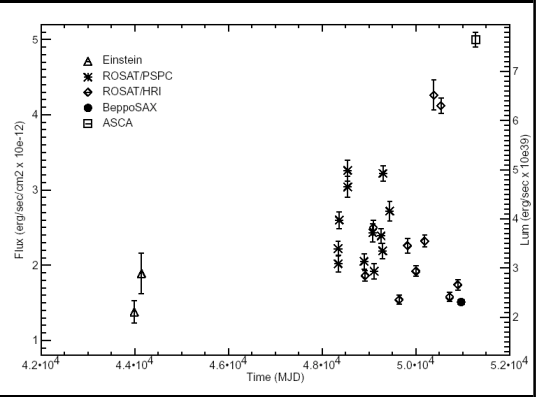
ULX Variability

- ULXs seen to vary on timescales of years down to hours
  - M81 X-9 (La Parola et al 2001)
  - ULXs in M82 (Chandra press release)
  - NGC5194 X-7 (Liu et al 2002)



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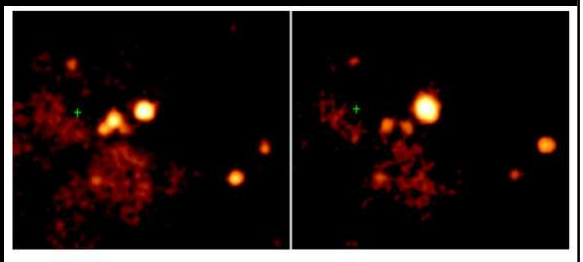

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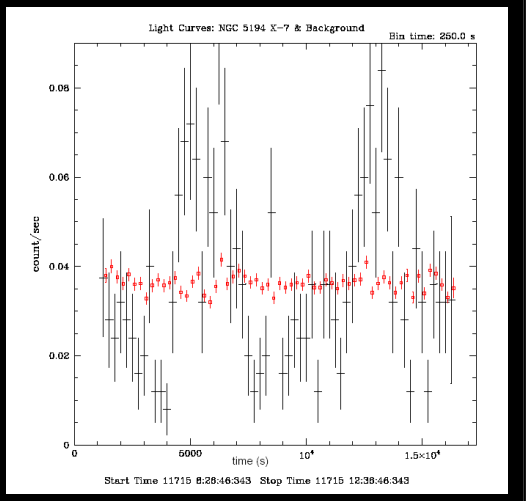

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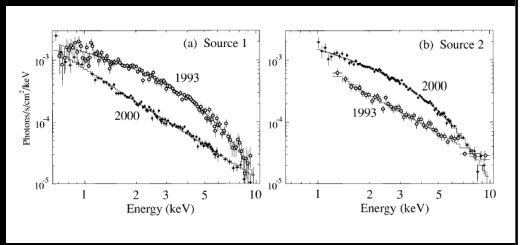
ULX – Spectral Variability

- High/soft – low/hard in IC342 ULXs (Kubota et al 2001)
- Disk and power-law variability in M33 X-8 (La Parola et al 2003)



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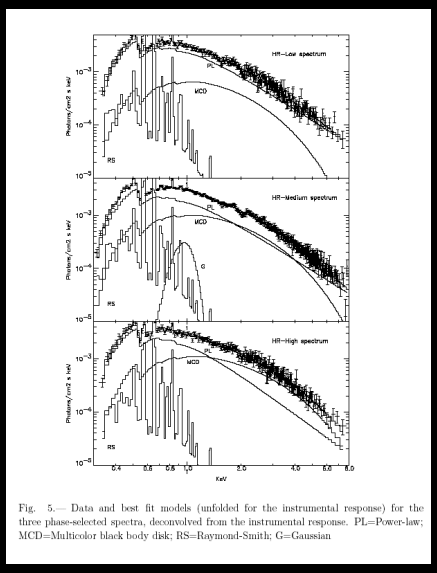

Fig. 5.— Data and best fit models (unfolded for the instrumental response) for the three phase-selected spectra, deconvolved from the instrumental response. PL=Power-law; MCD=Multicolor black body disk; RS=Raymond-Smith; G=Gaussian

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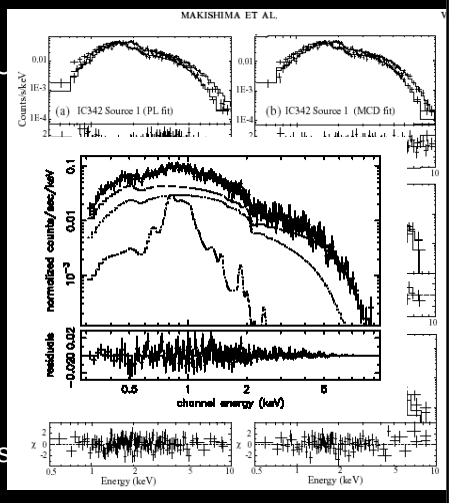
ULX – IMBH (as L_x may suggest)?

- The spectral conundrum
  - ASCA spectra too ` hot' (kT ~ 1.5 keV; Makishima et al 2000) >> Kerr BH?
  - XMM and Chandra are seeing softer components (kT ~100 eV; Miller et al 2003) >> IMBH ~1000Msol
  - But not always …
    - Coadded ULXs in The Antennae: ~1.2 keV components + Γ~1.4 power-law (as in microquasars; Zezas et al 2002)



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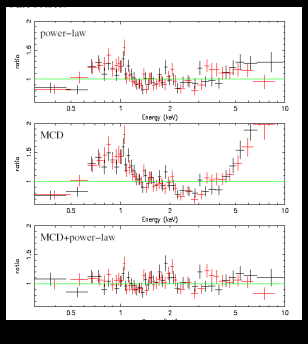

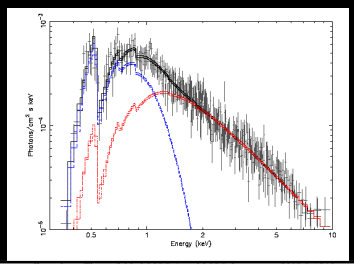

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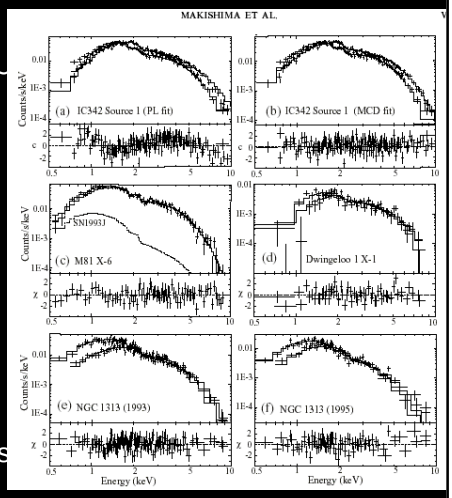

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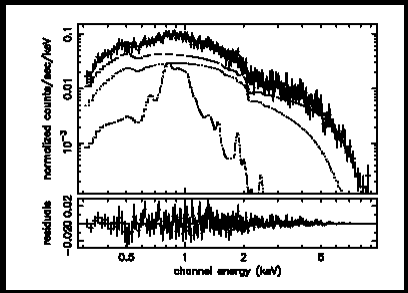

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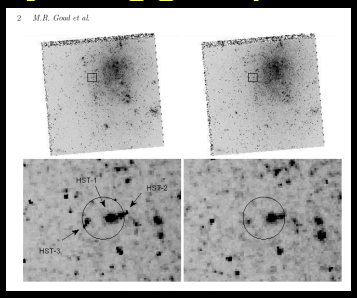

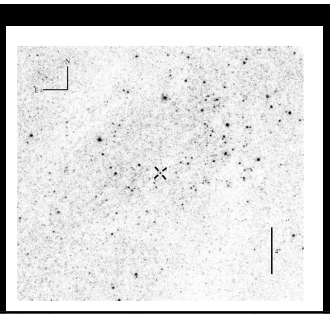

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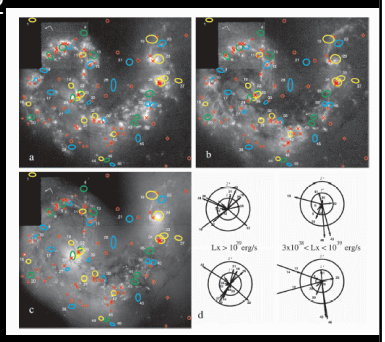

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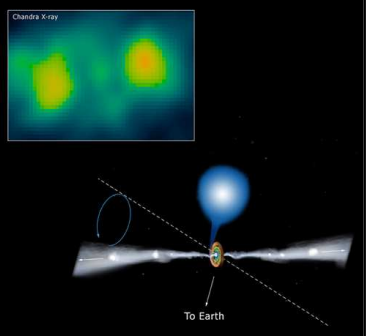

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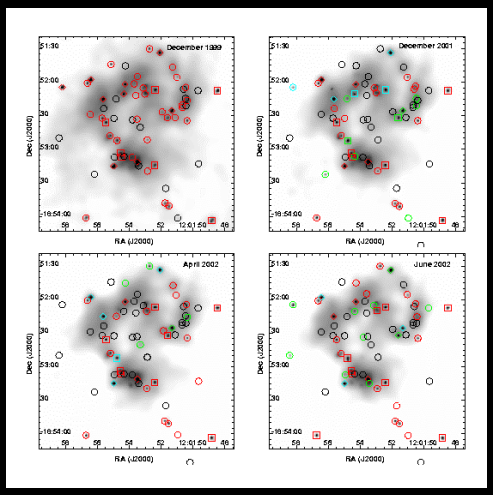
The Antennae XRBs and ULXs

- Chandra monitoring shows a lot of variability
- 7 of the 9 ULXs vary
- Discovery of variable SSULX



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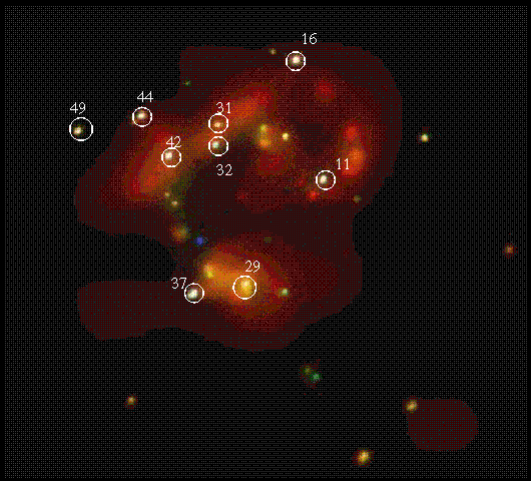
The Antennae: ULX –Variability

- 7/9 ULXs vary
- Light curves show bumps, dips, long-term trends
- 1 source (37): high/soft-low/hard
- 4 sources: high/hard-low/soft



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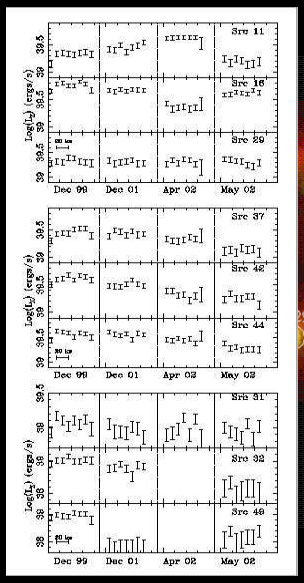

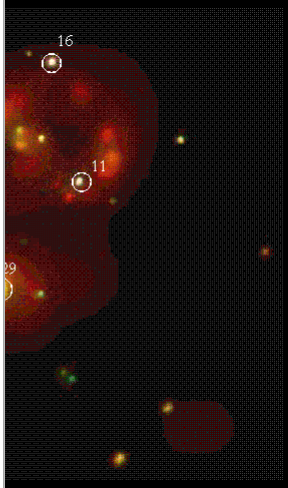

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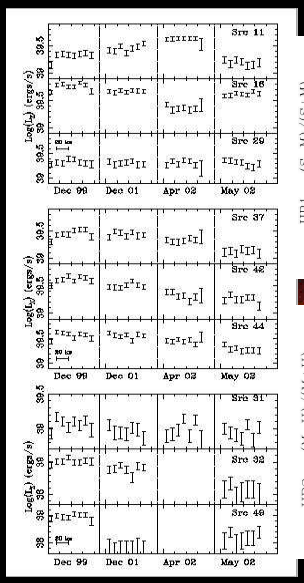

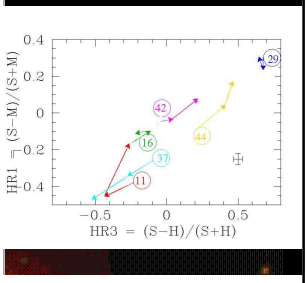

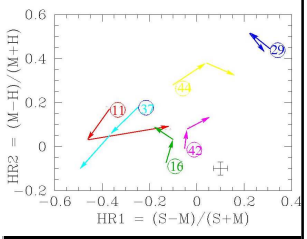

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What are they?

•Compact accreting objects – **XRBs** , probably beamed (King et al 2001, Zezas & Fabbiano 2002)

•High/soft –low/hard

- •Cyg X-1 like (disk/corona) source?
- •Anomalous high state Comptonized disk (Kubota et al 2002)?

•High/hard –low/soft

- •BHB with very high accretion rates

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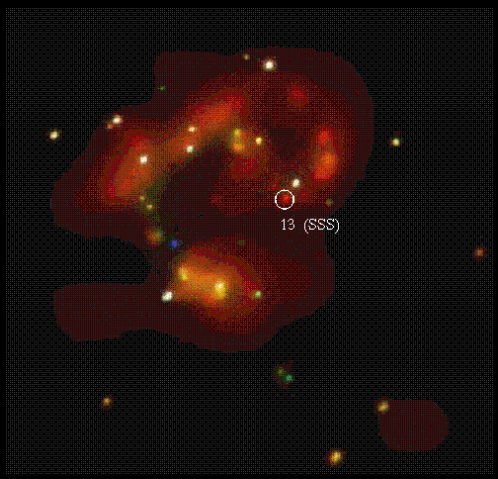
The Antennae: Super-Soft ULX

- Source 13
  - SS and with sub-ULX Lx in 1999 Dec.(Zezas et al 2002)
  - Reaches absorption corrected Lx ~ 10^{40} ergs/s in 2002 Jun
  - Spectrum BB kT~100 eV, N_H~3 10^{21} cm^{-2}



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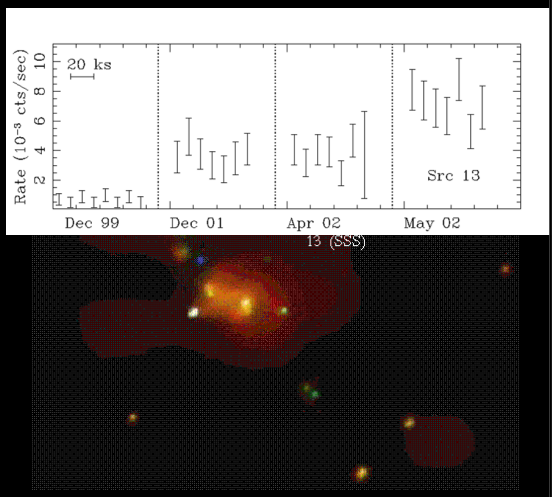

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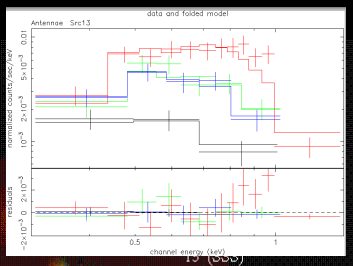

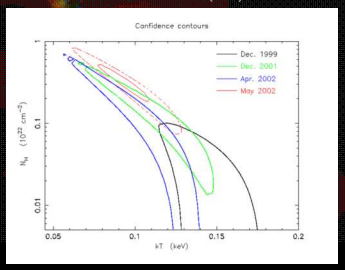

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What is it?

•**IMBH?** >200 Msol, but R_{BB} varies by a factor of 10

•R_{BB} ~ 10^9 cm beamed emission from a nuclear burning **WD**?

•Photospheric emission of wind from **~15 Msol BH** (as in M101 P098, Mukai et al 2003)?

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What's next?

- Vicky's talk: comparing XLFs with XRB population synthesis models
- Systematic identification or characterization of XRB with HST and ground based telescopes (e.g. radio)
- We need deep monitoring observations of key galaxies (the approach used for The Antennae)
  - Deep XLF >> with completeness corrections!
  - Spectra / Colors , variability

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