

ChASeM33: A Chandra Legacy Program

A 1.4Ms Chandra ACIS Survey of M33

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Motivation and Overview

In order to understand galaxies in general, one needs to investigate nearby galaxies on small scales with high spatial resolution.

Use Chandra to probe the global structure of the ISM, the stellar populations that shape it, and investigate the sources which show time variability.

M33 is an ideal target as it is nearby ($D=817\text{kpc}$), moderately face-on (56°), and has low foreground and internal absorption ($N_{\text{H}} \leq 2 \times 10^{21} \text{ cm}^{-2}$).

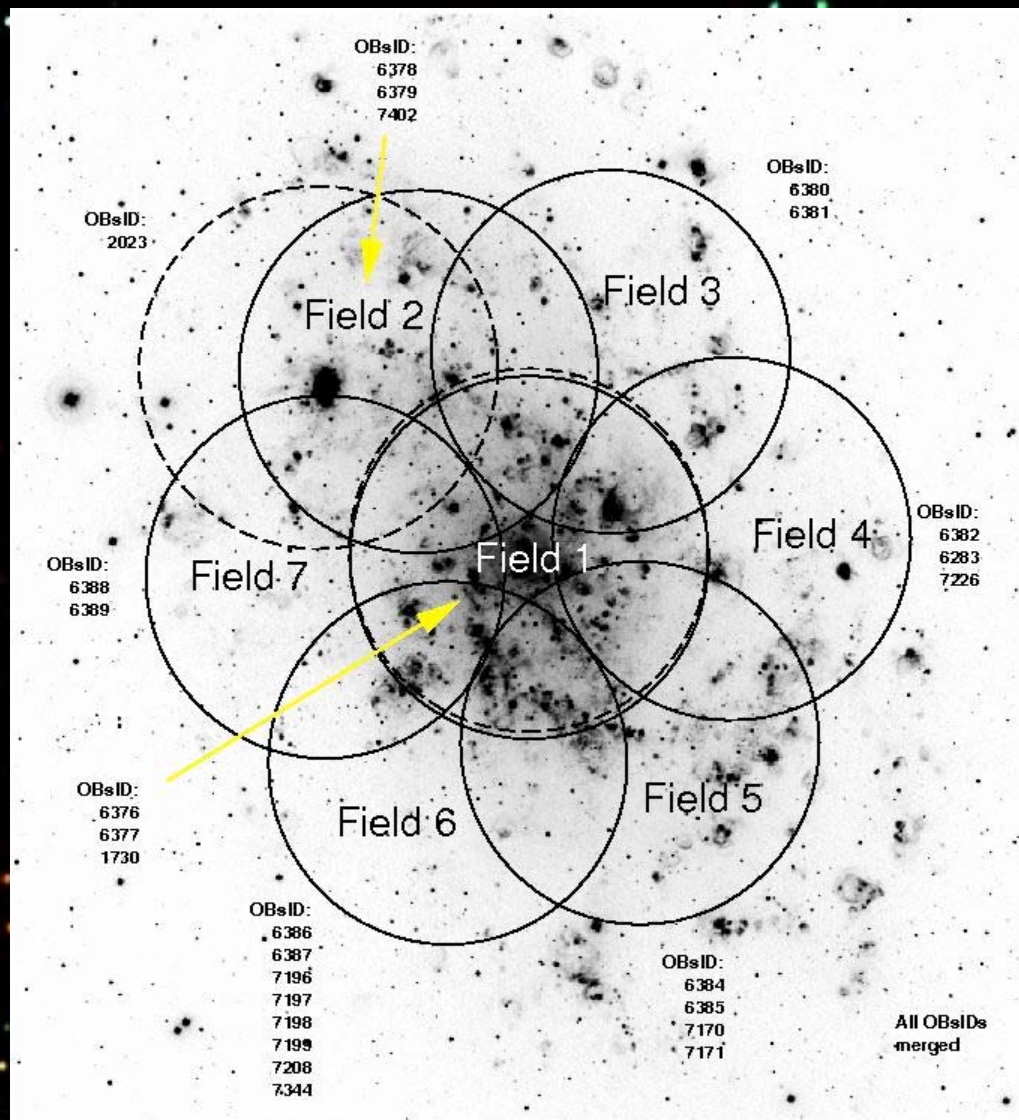
Target is compact enough to be surveyed by a reasonably small number of Chandra pointings.

Unlike the MW, all sources are at a common distance.

Survey Strategy

- Cover the inner part of M33 ($r \approx 18' \approx 4 \text{ kpc}$), where high resolution is most important
- 7 fields + 2 archival observations covering 70% of D25
- 200ks per field (1.4Ms total)
- Sensitive to long-term and short-term variability \rightarrow 2 visits per field (2 x 100ks)

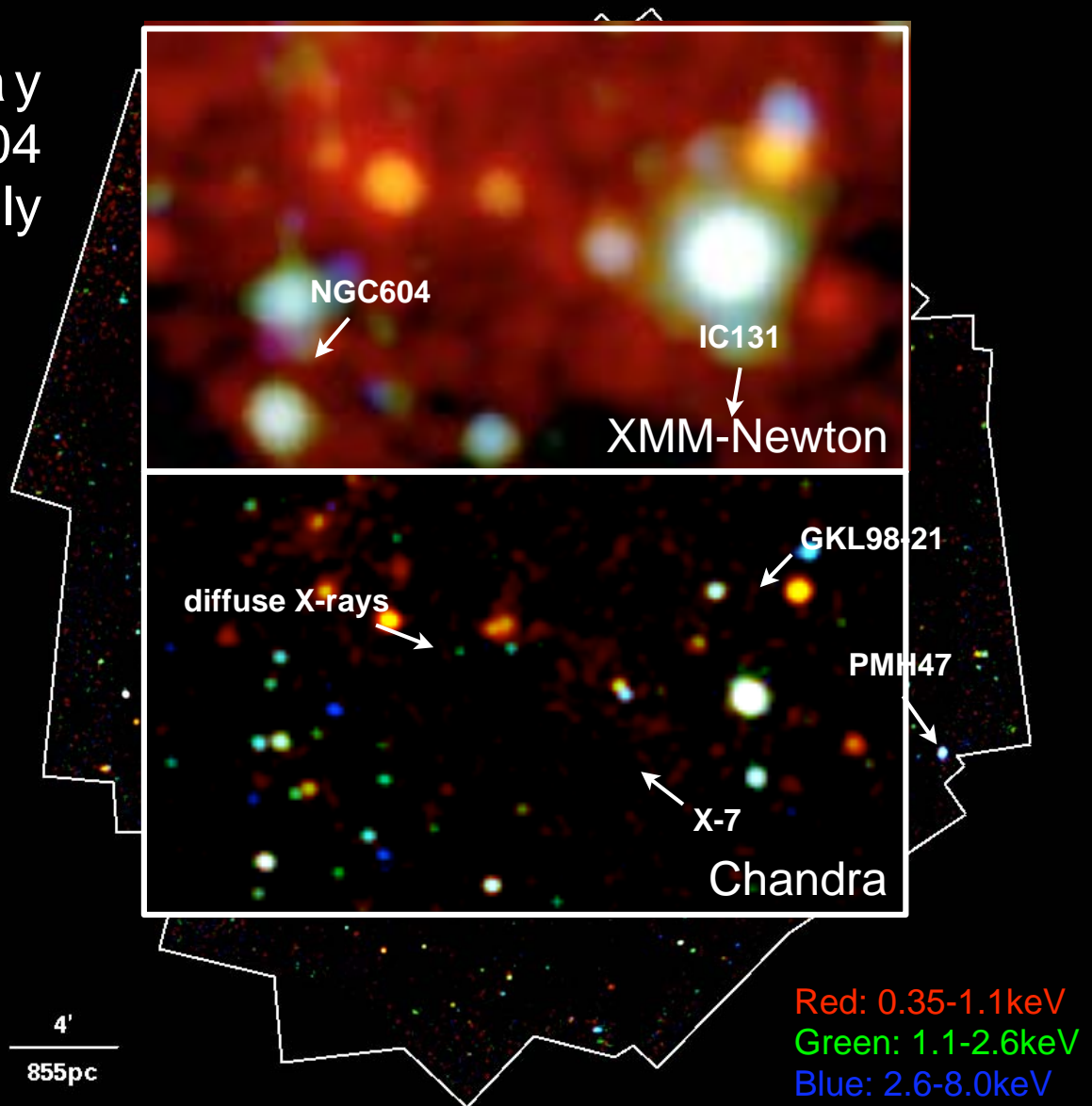
See also Plucinsky et al. (2008) and poster.



Circles have 8' radii (PSF is $\leq 6''$).

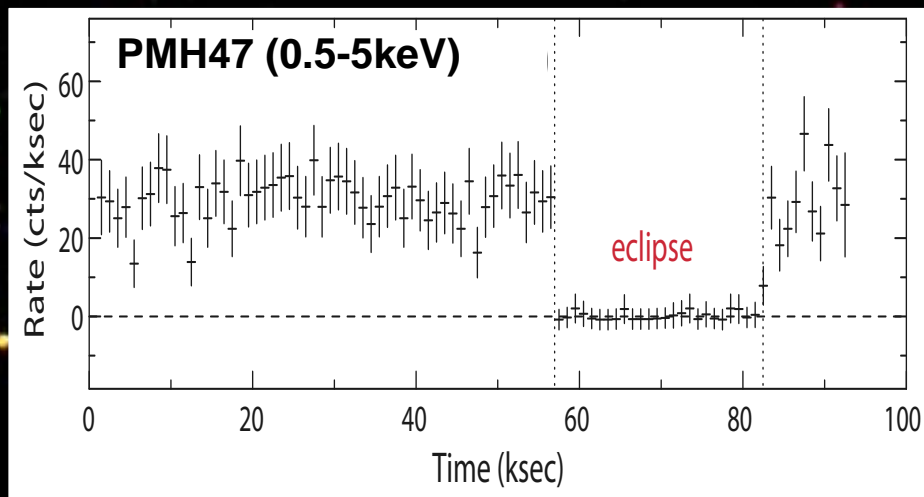
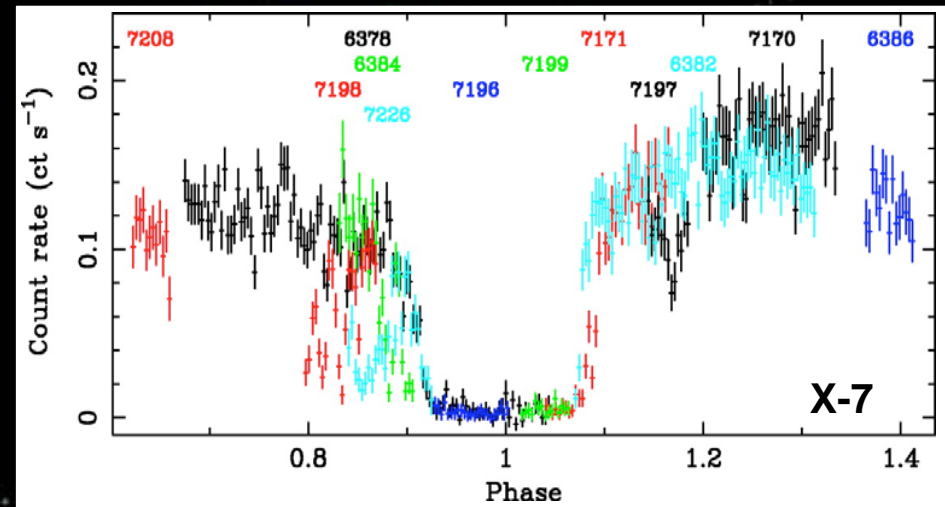
The ChASeM33 source catalog

- Detected ~670 X-ray sources (Pietsch et al. 2004 cover D25, but detected only 408 sources with XMM)
- Limiting sensitivity of $L_x \approx 2 \times 10^{34} \text{ erg/s}$ (0.35-8keV)
- Most sensitive and spatially best resolved X-ray survey of any galaxy
- Spectroscopic follow-up observations: 125 optical counterparts have been identified so far



Eclipsing X-ray Binaries

- Two eclipsing XRBs found so far
- X-7 is the first detected eclipsing BH XRB!
- X-7 is one of the two most massive stellar BH XRBs known! ($16M_{\text{sun}}$ with a $70M_{\text{sun}}$ companion, Orosz et al. 2007)
- Challenges our understanding of BH formation in binary systems (e.g. Valsecchi et al. 2009)



- Such discoveries require long and deep observations to cover the ingress and egress of the eclipse

X-7

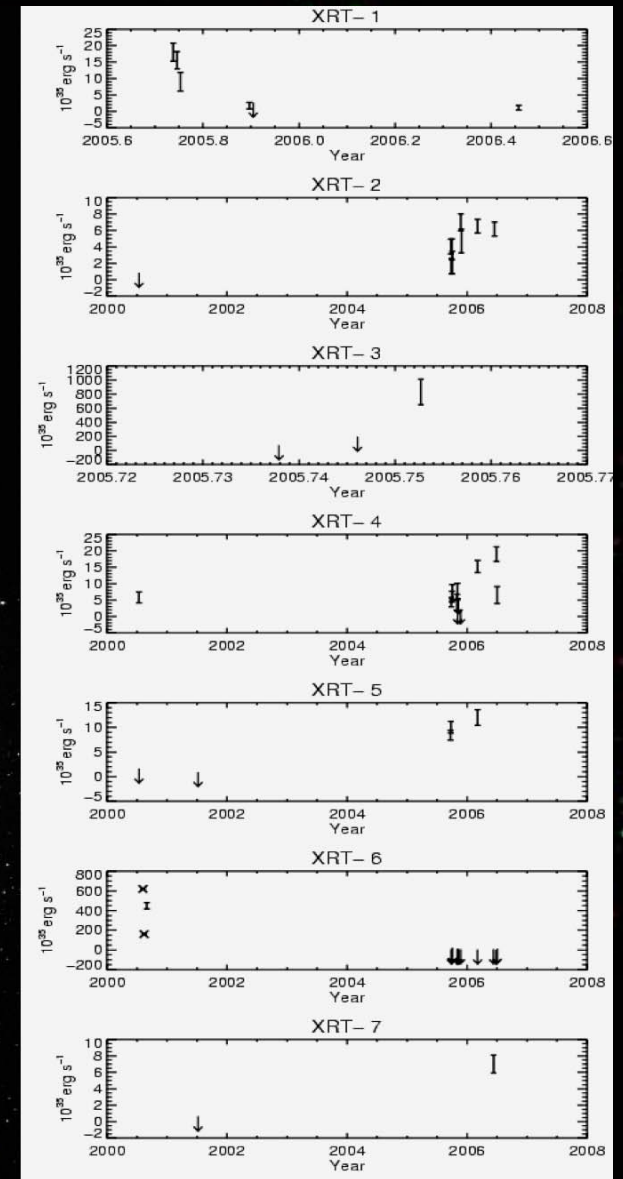
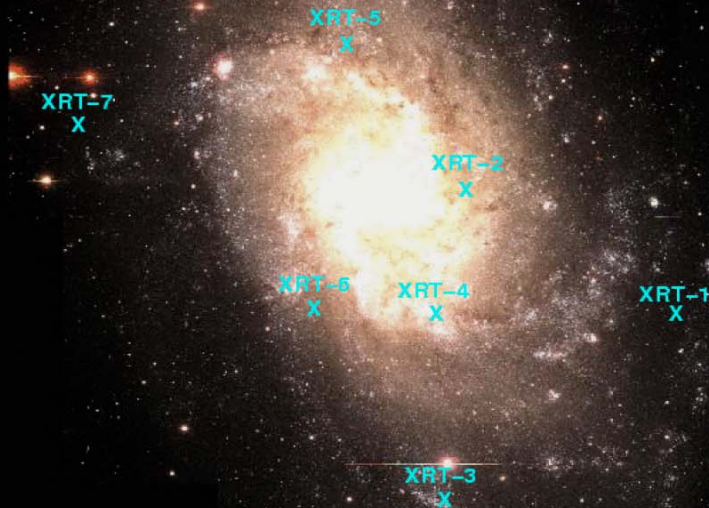
PMH47

See Pietsch et al. (2006, 2009)

Transient X-ray Sources

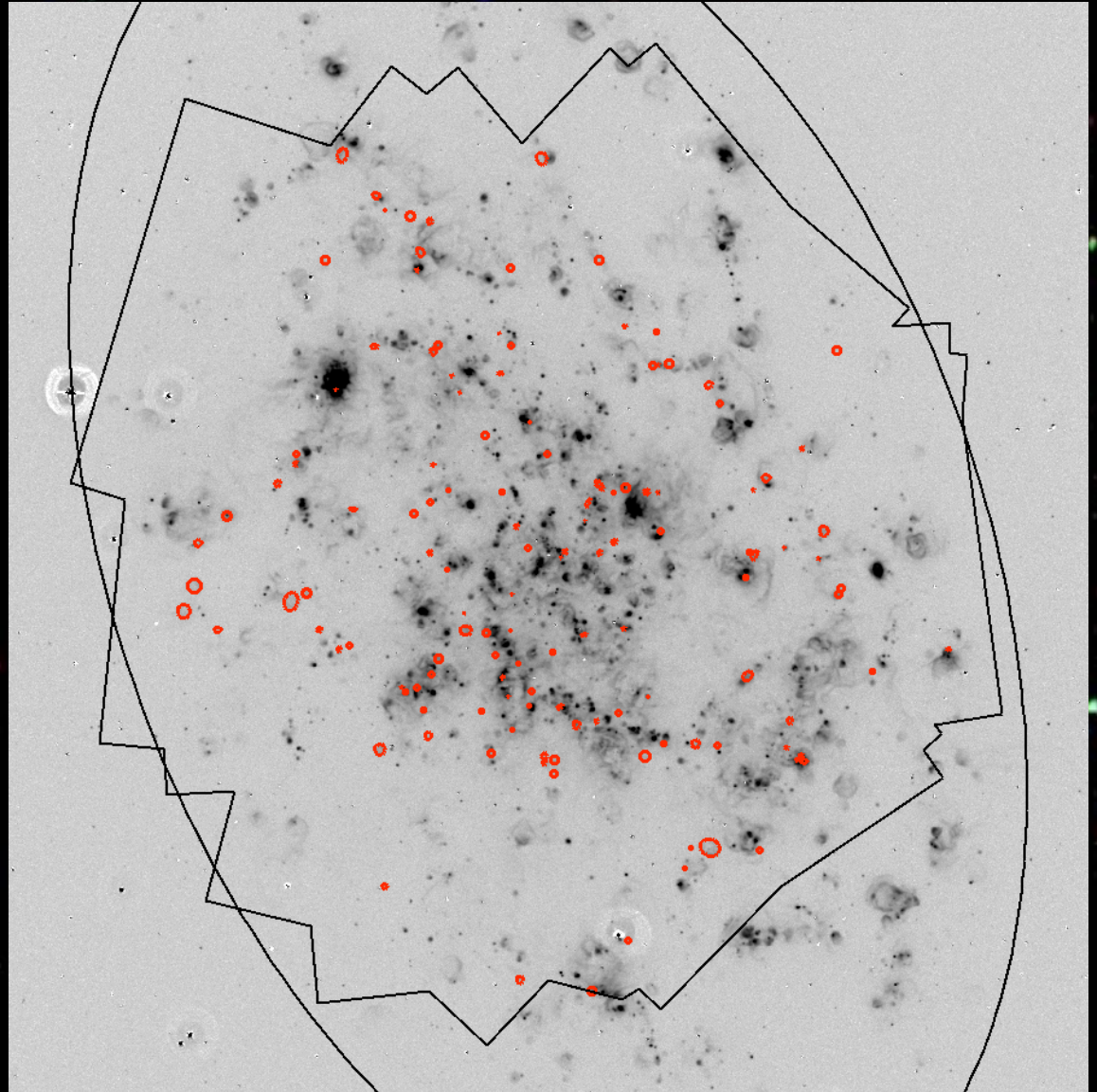
- 9 transient sources were confidently detected
- Most of them are relatively **faint HMXRBs** with $L_x \leq 3 \times 10^{36} \text{ erg/s}$
- This is different from M31, where most transients are **bright LMXRBs**
- Differences are most likely due to the younger XRB population in M33, as this galaxy has no bulge and therefore no old stellar population

See Williams et al. (2008) for details.



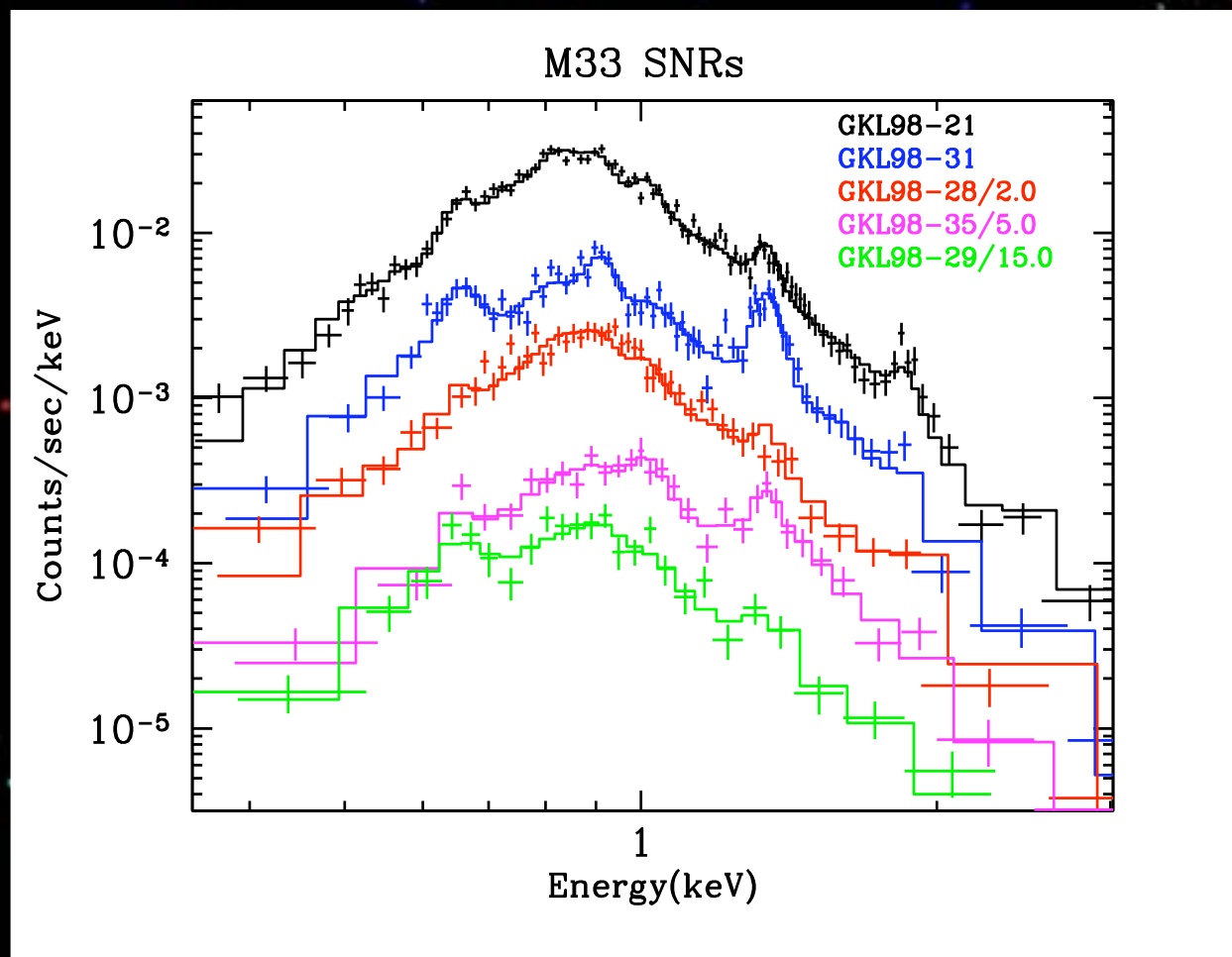
The SNR population in M33

- M33 has 137 known or suggested SNRs
- We detected 74 SNRs in X-rays (35 were known before)
- We found 1 PWN candidate
- There are no analogs to Cas A, Tycho, or the Crab SNR in M33
- The largest homogeneous sample for any galaxy so far



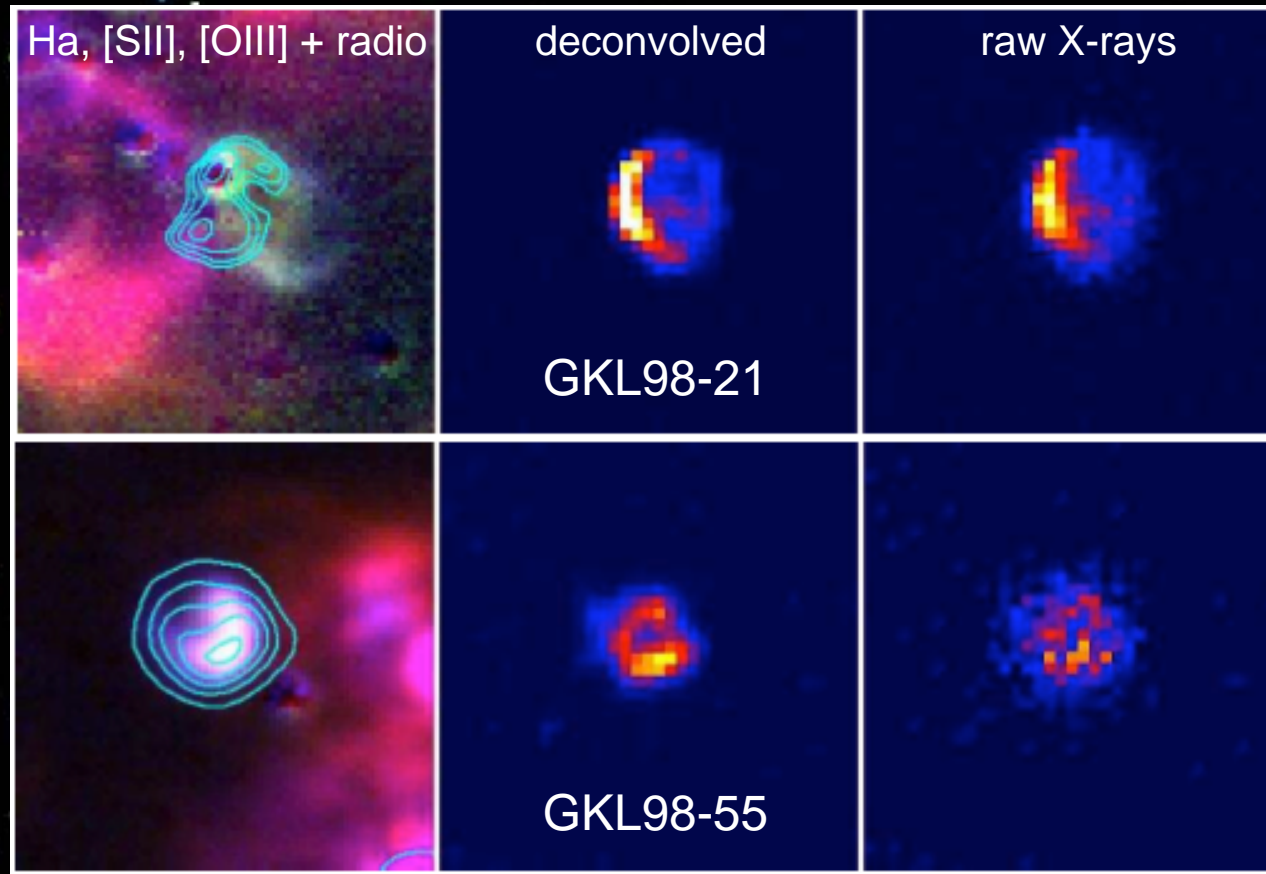
The SNR population in M33

- 7 SNRs with enough counts for a detailed spectral analysis
- GKL98-21, the brightest SNR ($L_x=1.7 \times 10^{37}$ erg/s), seems to interact with the ambient ISM (Gaetz et al. 2007)
- At least 3 SNRs have X-ray spectra which show enhanced abundances due to ejecta from type II SNe
- Sample is complete for SNRs brighter $L_x \geq 4 \times 10^{35}$ erg/s



See paper by Long et. al (2009, submitted) and poster for details.

The SNR population in M33



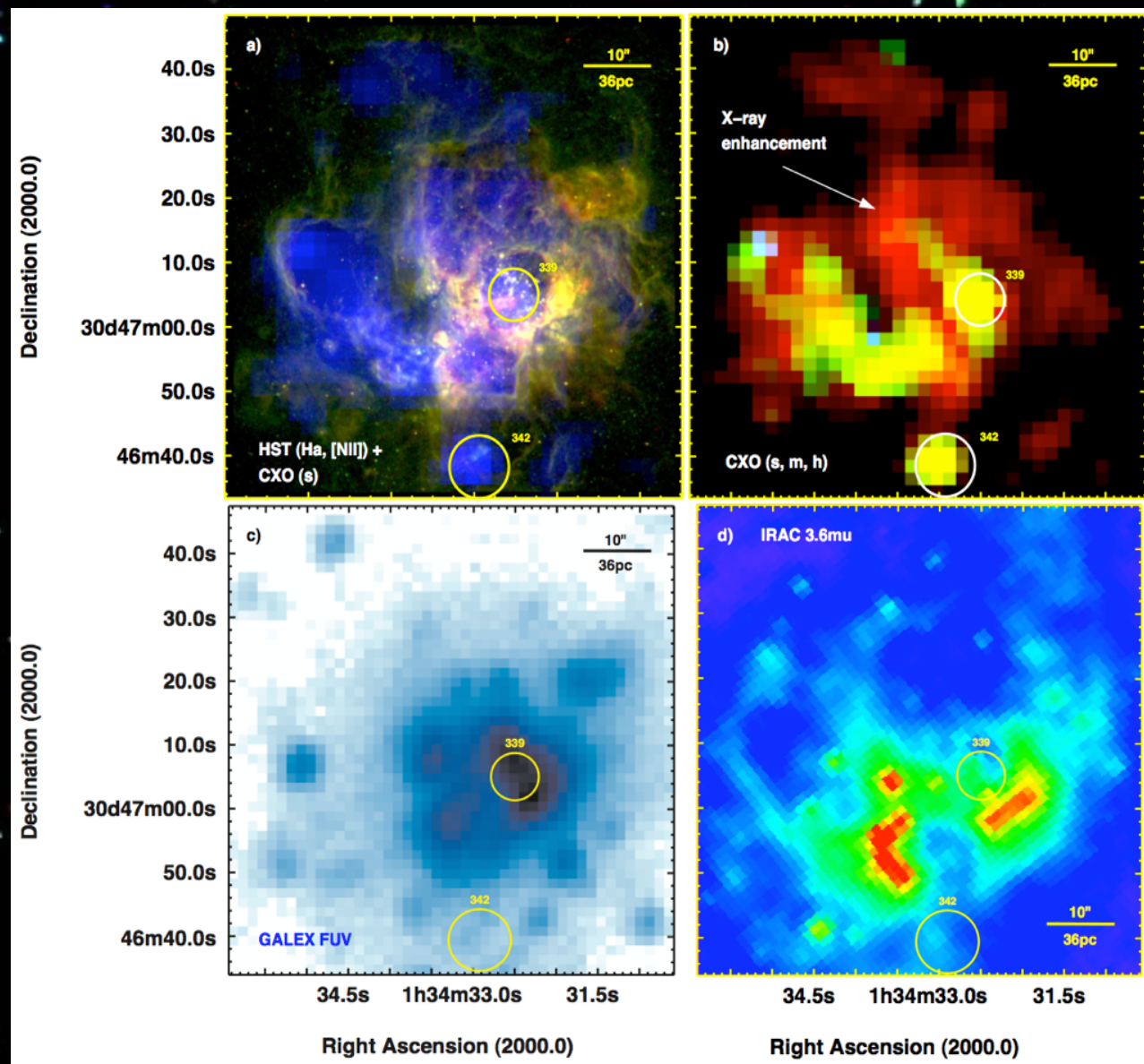
These appear to be the most distant SNRs ($D=817\text{kpc}$) for which Chandra still resolves substructure!

See paper by Long et. al (2009, submitted) and poster for details.

The Giant HII region: NGC604

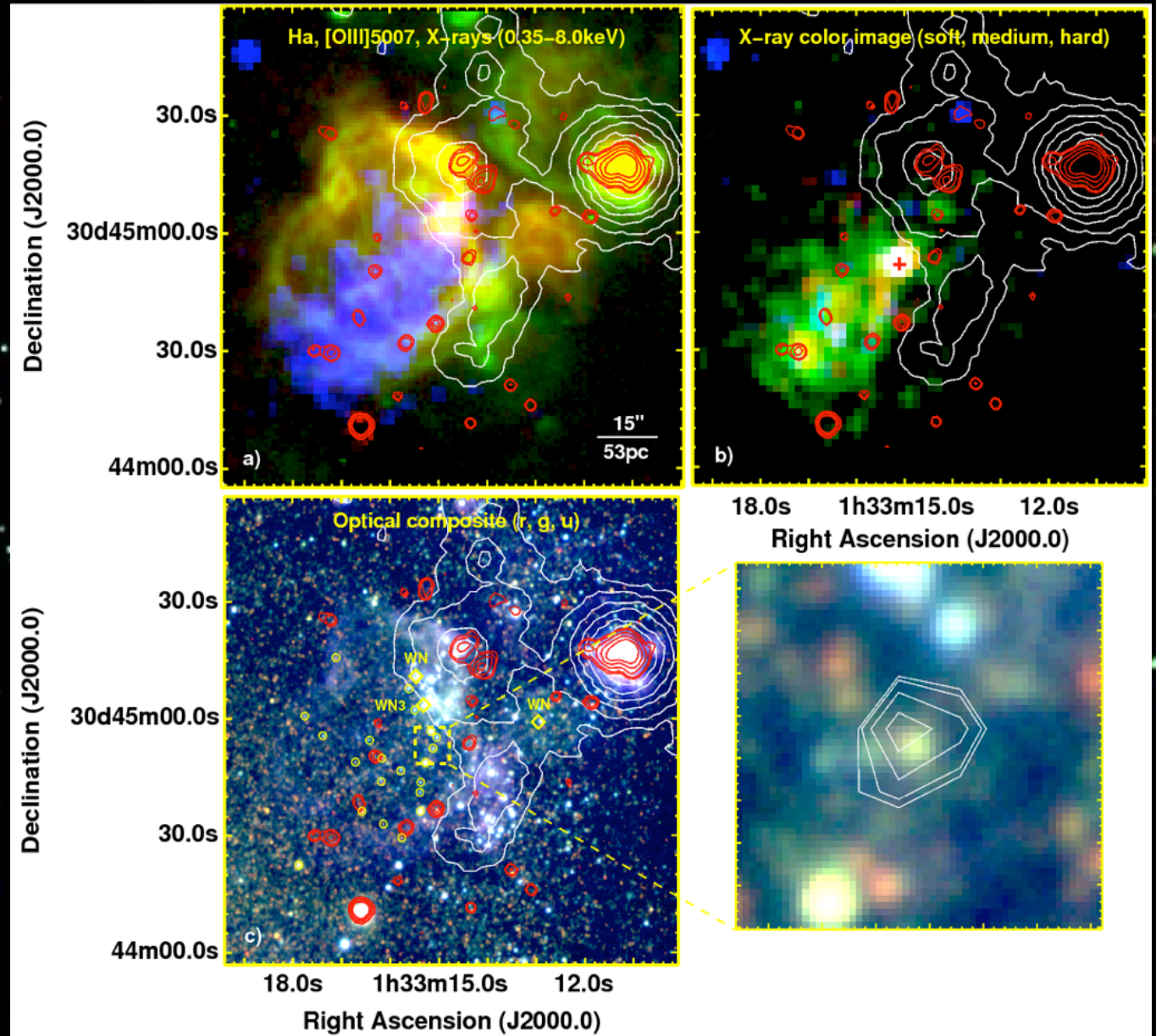
- NGC604 is the largest and most X-ray luminous GHR in M33
- Diffuse X-ray emission is thermal ($kT \approx 0.5 \text{ keV}$)
- $L_x \approx 1.4 \times 10^{36} \text{ erg/s}$, only 5% above 2keV
- X-rays in the western part (young) are caused by colliding stellar winds (consistent with standard bubble model)
- X-rays in the east (old) are likely due to SNRs and SNe (inconsistent w/ standard bubble model)

See Tüllmann et al. (2008) and poster.



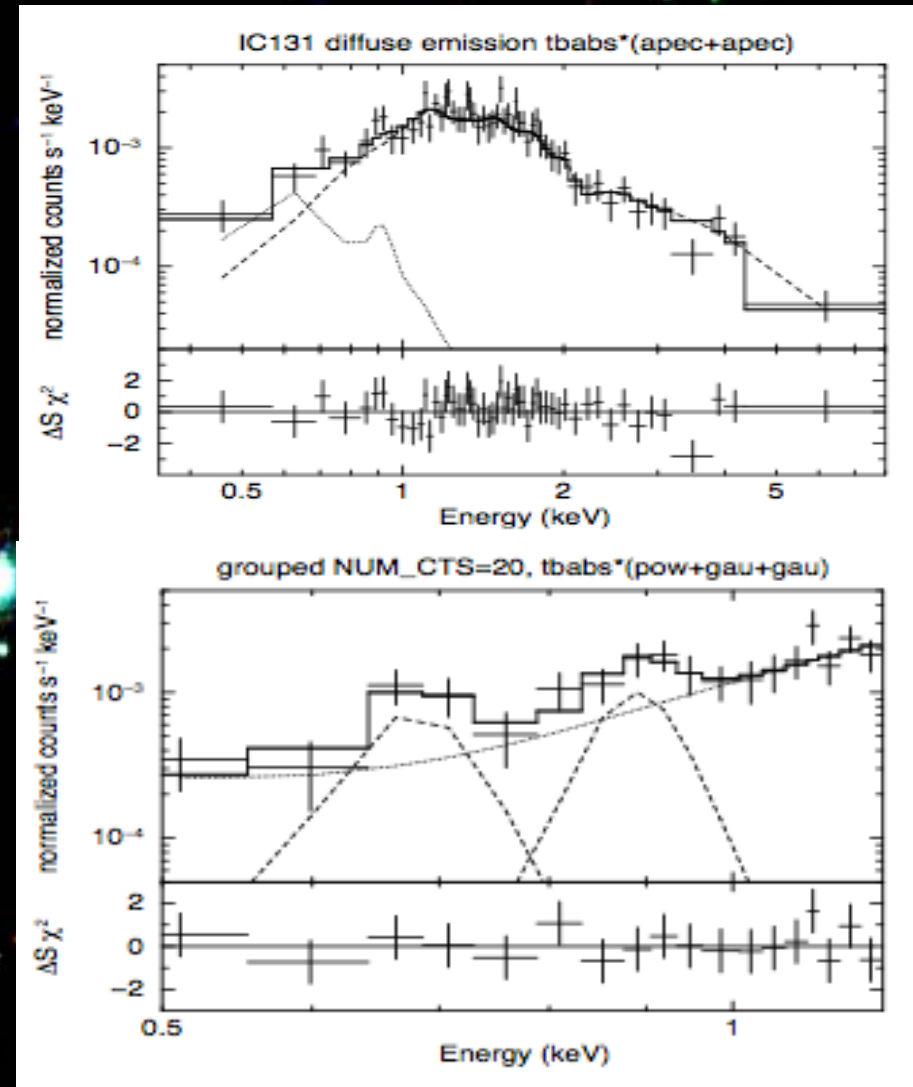
The Giant HII regions: IC131

- IC131 is the 2nd most X-ray luminous GHR in M33
- Extent of the X-ray emission ~ 200 pc
- No O-type stars inside the bubble
- Age of the stellar population: $\sim 8 - 77$ Myr
- Only one point source detected. Could be a variable HMXRB
- Nature of the extended X-ray emission unclear



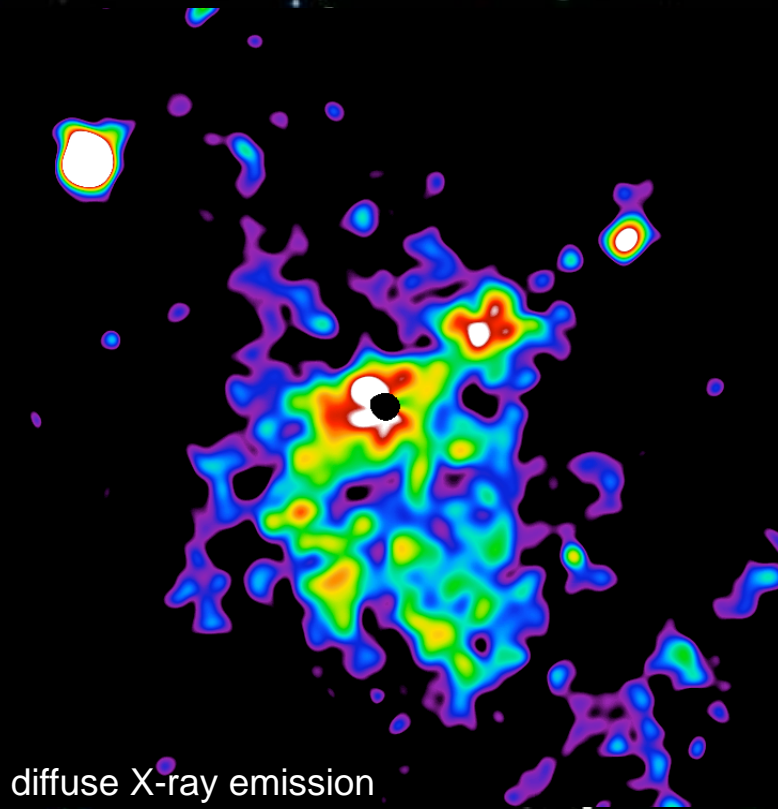
The Giant HII regions: IC131

- Simple thermal ($kT_e=4.3\text{keV}$) and non-thermal ($\Gamma=2.1$) models fit equally well.
- $L_x \approx 8 \times 10^{35}$ erg/s, $\sim 40\%-53\%$ of L_x are emitted above 2keV.
- IC131 is extreme regarding the combination of hardness and extent of the X-ray emission.
- No close analogs. **Why not observed elsewhere?**
- Diffuse X-ray emission remains puzzling. Serious **challenge to existing models.**

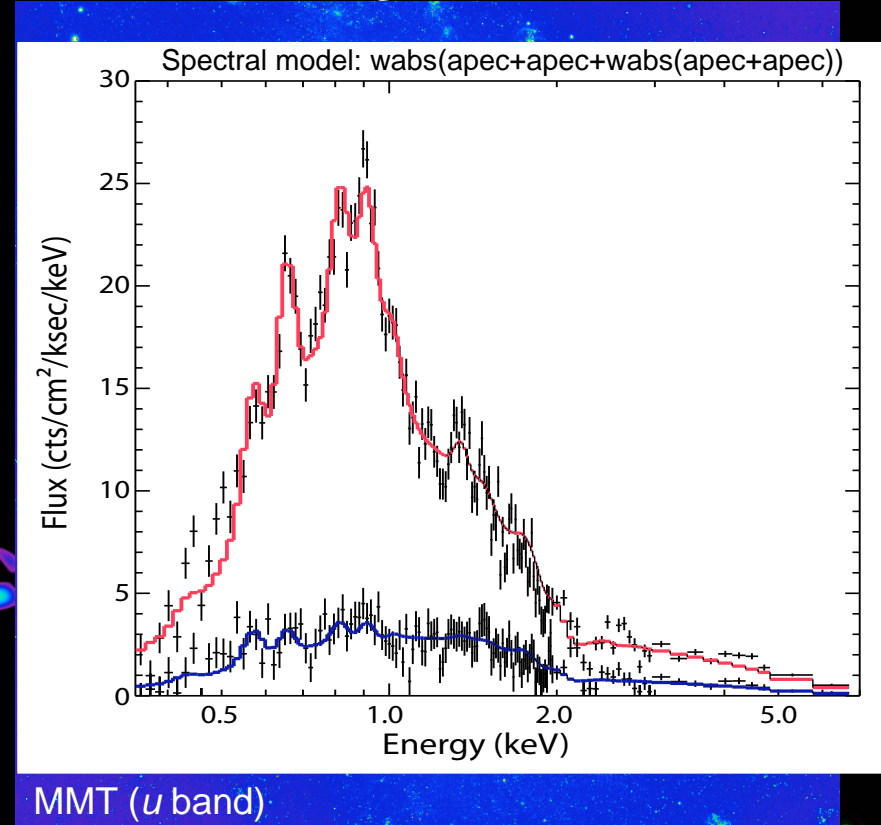


See paper by Tüllmann et al. (2009, submitted) and poster.

Outlook (large-scale X-ray emission)



diffuse X-ray emission



- Diffuse X-ray emission appears to be thermal.
- Best-fit requires 2 components ($kT_s=0.26$, $kT_h=0.76\text{keV}$; $\sim 25\%$ are emitted by the hard component)
- Temperatures are typical for late-type spirals

Kuntz et al. (2010, in prep.)

ChASeM33 Data Products

First Look catalog (Plucinsky et al. 2008, ApJS 174, 366): is public!

Download from: http://hea-www.harvard.edu/vlp_m33_public/home8.html

Included are: source catalog (epoch 1 only), source net counts, fluxes, and hardness ratios.

The final source catalog (Tüllmann et al. 2010, in prep.): will be public!

Check http://hea-www.harvard.edu/vlp_m33_public/ in the near future.

The data release includes: source catalog, eventlists for each source, their spectra (incl. ARFs and RMFs), and merged eventlists, images + exposure maps (bin=1, in different energy bands).

Publications

- **1st eclipsing XRB**: Pietsch et al. (2006), ApJ 646, 420
- **SNRs**: Gaetz et al. (2007), ApJ 663, 2342.
- **First Look paper**: Plucinsky et al. (2008), ApJS 174, 366
- **Transient Sources**: Williams et al. (2008), ApJ 680, 1120
- **GHRs**: Tüllmann et al. (2008), ApJ 685, 919
- **2nd eclipsing XRB**: Pietsch et al. (2009), ApJ 694, 449
- **SNRs**: Long et al. (2009), submitted
- **GHRs**: Tüllmann et al. (2009), submitted
- **Source catalog**: Tüllmann et al. (2010), in prep.
- **Diffuse X-ray emission**: Kuntz et al. (2010), in prep.