Suzaku Detection of Nonthermal X-ray Emission in the LMC Superbubble N11

Larry Maddox (U of Illinois)
Rosa Williams (Columbus State U)
You-Hua Chu (U of Illinois)

The Suzaku X-ray Universe
December 11, 2007
Superbubbles

• Form around OB associations or clusters
  – Stellar winds and supernovae
• Can reach diameters of >100 pc
• May combine to form larger shell structures
• Can eject hot gas into galactic halos through blowouts
Weaver et al. 1977 - the most popular model
Interstellar Bubble Model

Weaver et al. 1977
Dunne et al. (2001)
Superbubbles

• Exhibit relatively slow expansion velocities
  - 20 – 50 km/s

• Thermal X-ray emission from hot interior
  - Brehmsstrahlung and line emission
  - characteristic temperatures of ~0.2 keV for most

• Few have been observed to have significant nonthermal X-ray emission
Nonthermal X-rays

- Previously, only two SBs have shown nonthermal X-ray emission
  - 30 Dor C (Bamba et al. 2004)
    - limb-brightened SB, photon index $=2.1 - 2.9$
    - consistent with synchrotron
  - N51D (Cooper et al. 2004)
    - flatter index ($\sim1.3$), no limb-brightening
    - suggested interaction of stellar winds with SN shocks
N11

- Second largest H II region in LMC
- Contains four OB associations
  - LH9 surrounded by filamentary shell
  - other three shrouded in gas
N11

- Studied in X-rays by ROSAT and XMM-Newton
  - thermal plasma with $kT \sim 0.19$ keV
  - high energy never explored
N11

- High energy sensitivity of *Suzaku* allows for probing of spectrum above 2 keV
- Observed on 7-8 Nov, 2006
  - 22 ks GTI
  - No, we did not destroy XIS2!
Nonthermal X-rays

- X-ray peak coincident with central shell and LH9
- Extracted spectra from region covering entire shell
Spectral Analysis

- Attempted several thermal models
  - only acceptable fit included powelaw
  - $kT \sim 0.18$ keV
  - photon index $\sim 1.9$
N 11 Properties

- Derived physical parameters
  - \( n_e = (0.14 - 0.35) f^{-1/2} \text{ cm}^{-3} \)
  - \( E = (4 - 10.5) f^{1/2} E_{51} \)
  - \( M = (3960 - 9900) f^{1.2} M_\odot \)
Energy Budget

• Compared our energy calculations to theoretical model of stellar evolution Starburst99
  
  − predicted total stellar energy input
    • \( E_{\text{mech}} = 17.5 \pm 2 \ E_{51} \)
  
  − total energy observed (kinetic + thermal)
    • \( E_{\text{total}} = (10 - 16) \ E_{51} \) for \( f = 1 \)

• Total Energy deficit
What is the Mechanism?

• Nonthermal emission is consistent with synchrotron emission source
  - photon index = 1.9
  - nonthermal radio emission in region

• Other possible mechanisms need to be tested
  - Inverse Compton
  - Nonthermal Bremsstrahlung
Possible Clues?

- Emission appears to be harder on western side of the shell of N11
  - seen also in XMM-Newton observations
  - could be interaction between internal SN shock with the shell.
Conclusion

• N11 is the third LMC SB to have detected nonthermal X-ray emission

• Energy budget analysis shows a deficit in thermal energy output compared with input from stellar evolution

• Though emission is consistent with a synchrotron mechanism, we are testing other possible physical explanations
Future work

- *Suzaku* is an excellent tool to probe for nonthermal X-ray emission in SBs
- Starting a program to observe more X-ray bright SBs in LMC to search for more nonthermal emission (N44, N206, N154)
  - will test for multiple nonthermal mechanisms