



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

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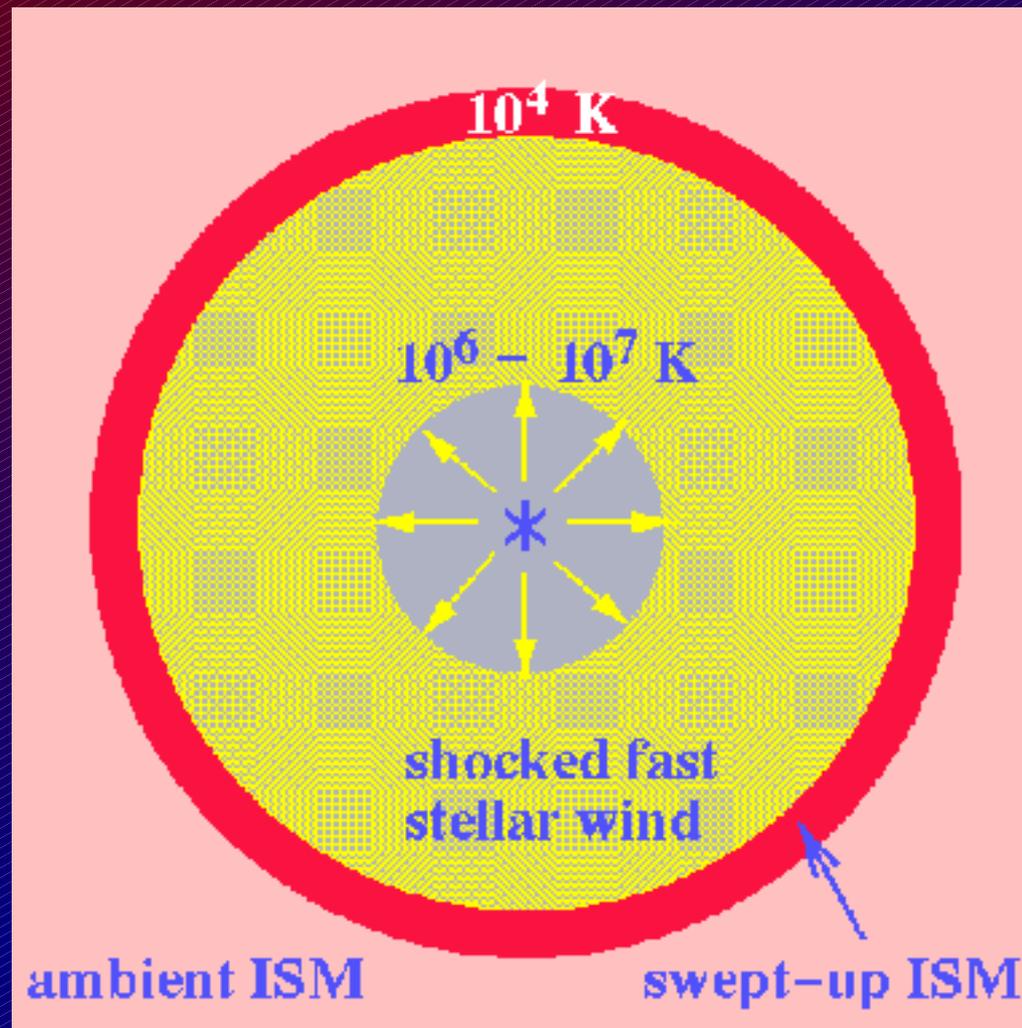
The *Suzaku* X-ray Universe

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**

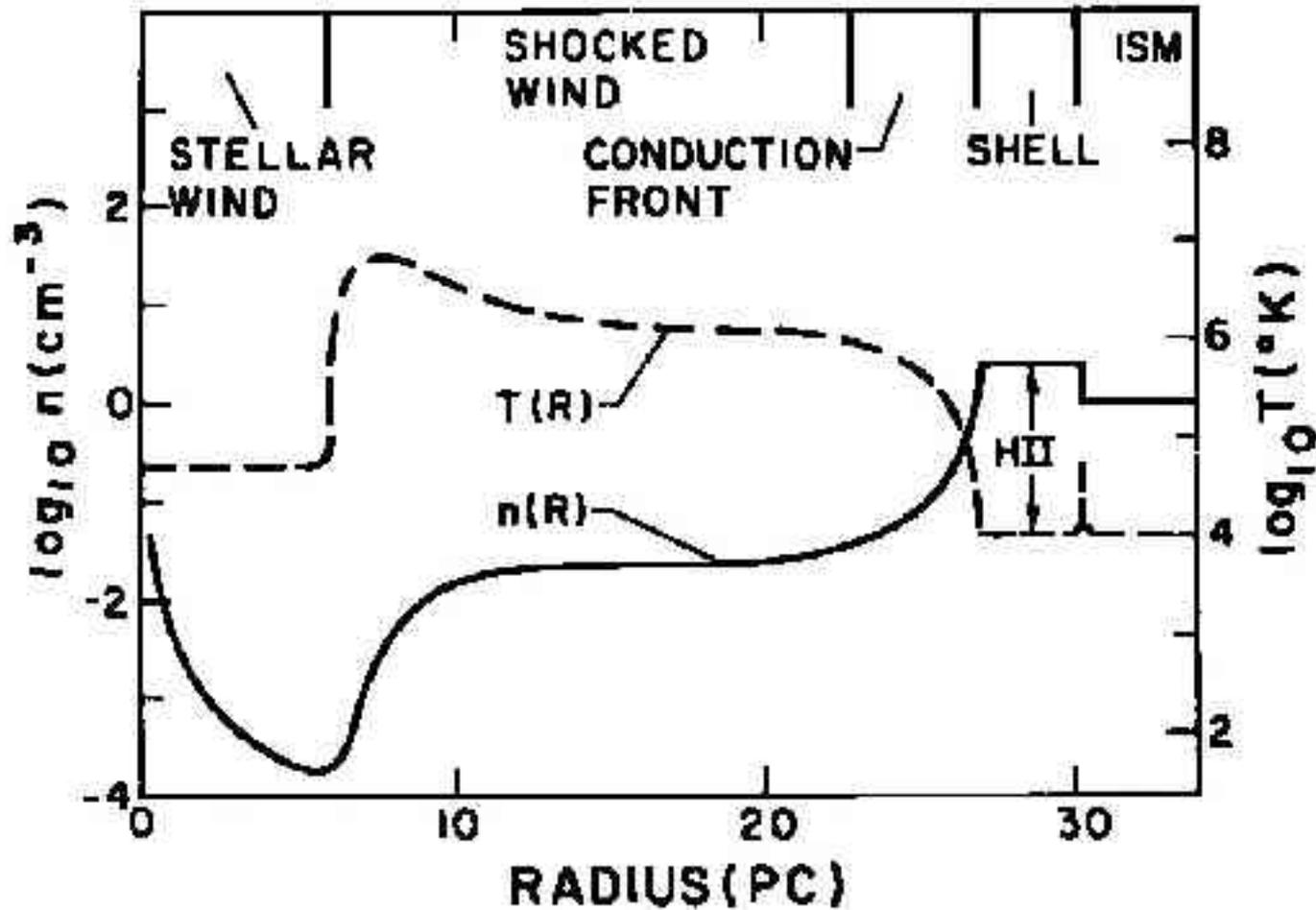
Interstellar Bubble



Weaver et al. 1977 - the most popular model

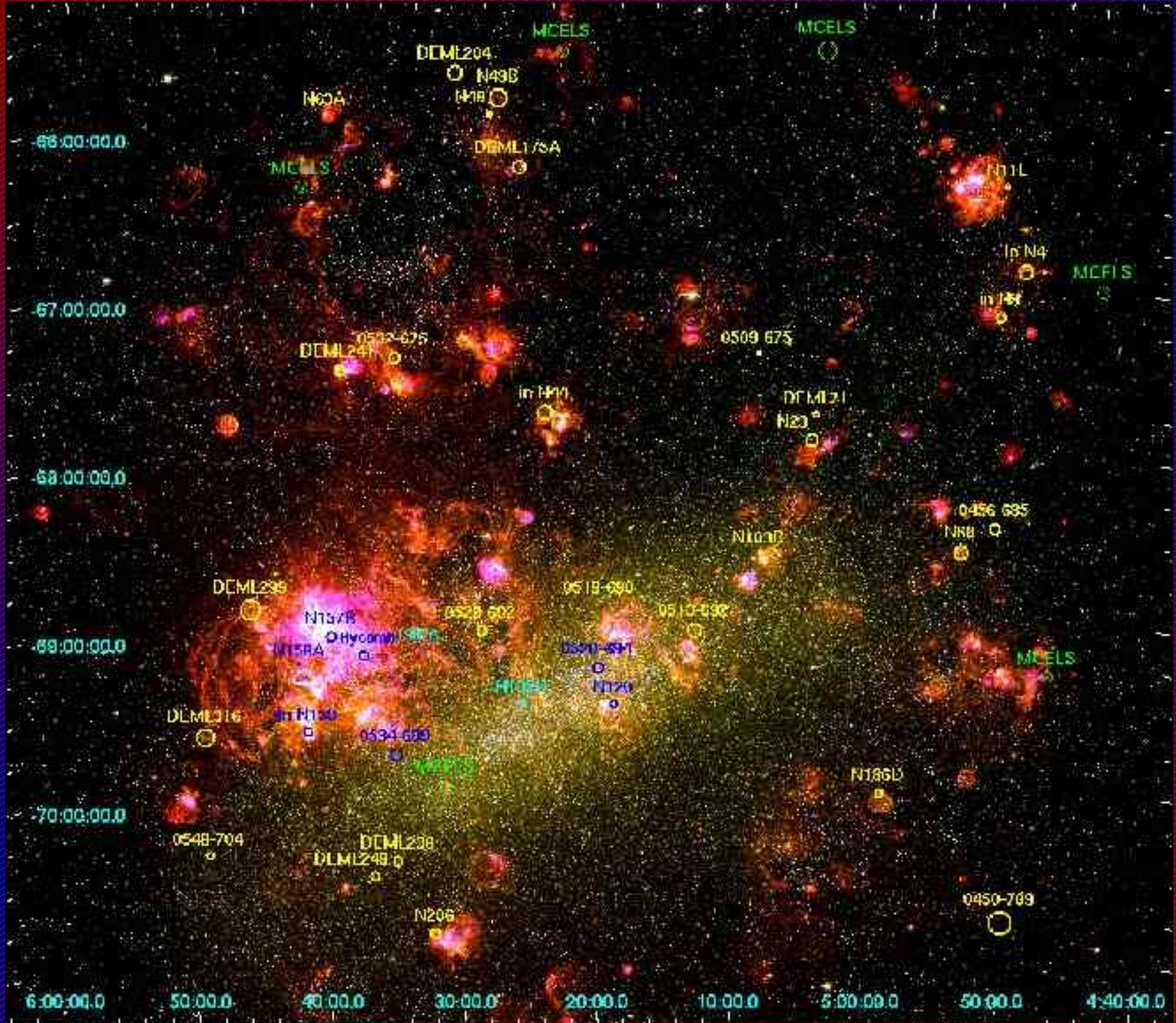
Interstellar Bubble Model

Weaver et al. 1977



Superbubbles

- **Exhibit relatively slow expansion velocities**
 - 20 – 50 km/s
- **Thermal X-ray emission from hot interior**
 - Bremsstrahlung 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 (~1.3), 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

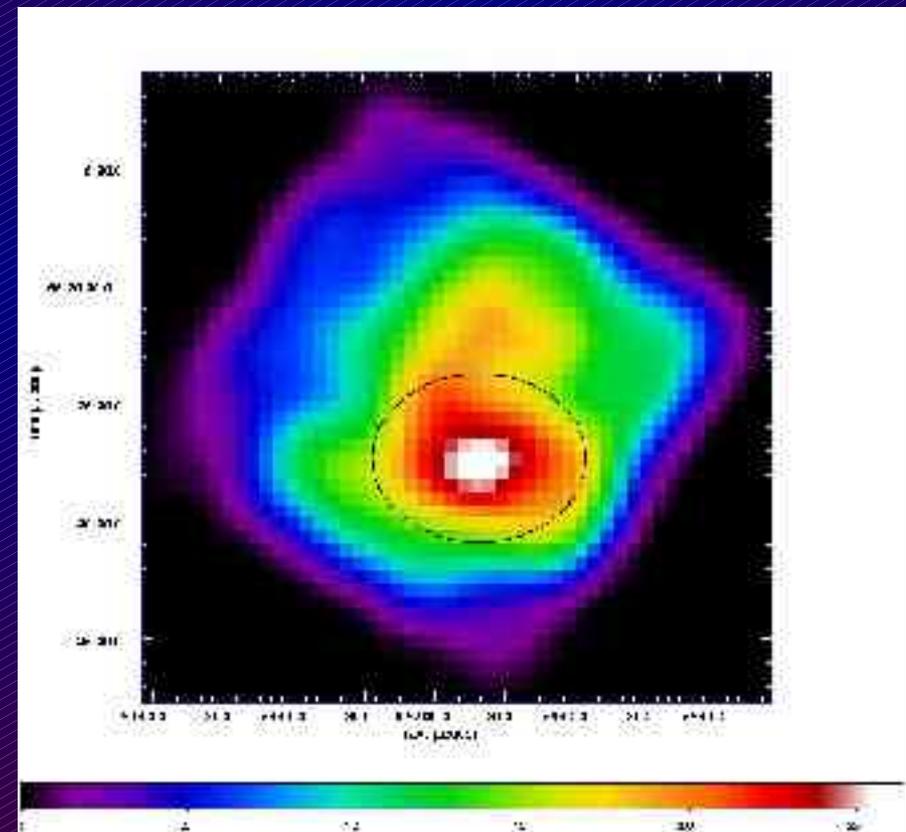
N11



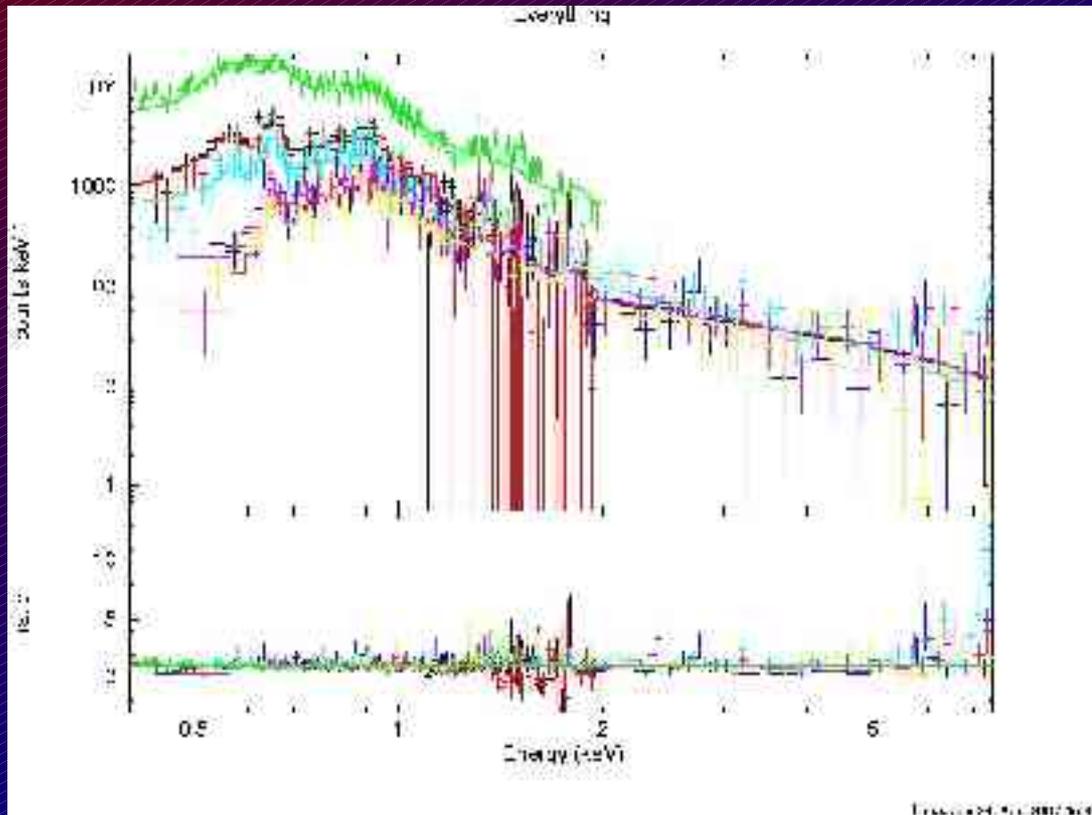
- High energy sensitivity of *Suzaku* allows for probing of spectrum above 2 keV
- Observed on 7-8 Nov, 2006
 - 22 ks GTI
 - No, we did not destroy XIS2!

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 powerlaw
 - $kT \sim 0.18$ keV
 - photon index ~ 1.9

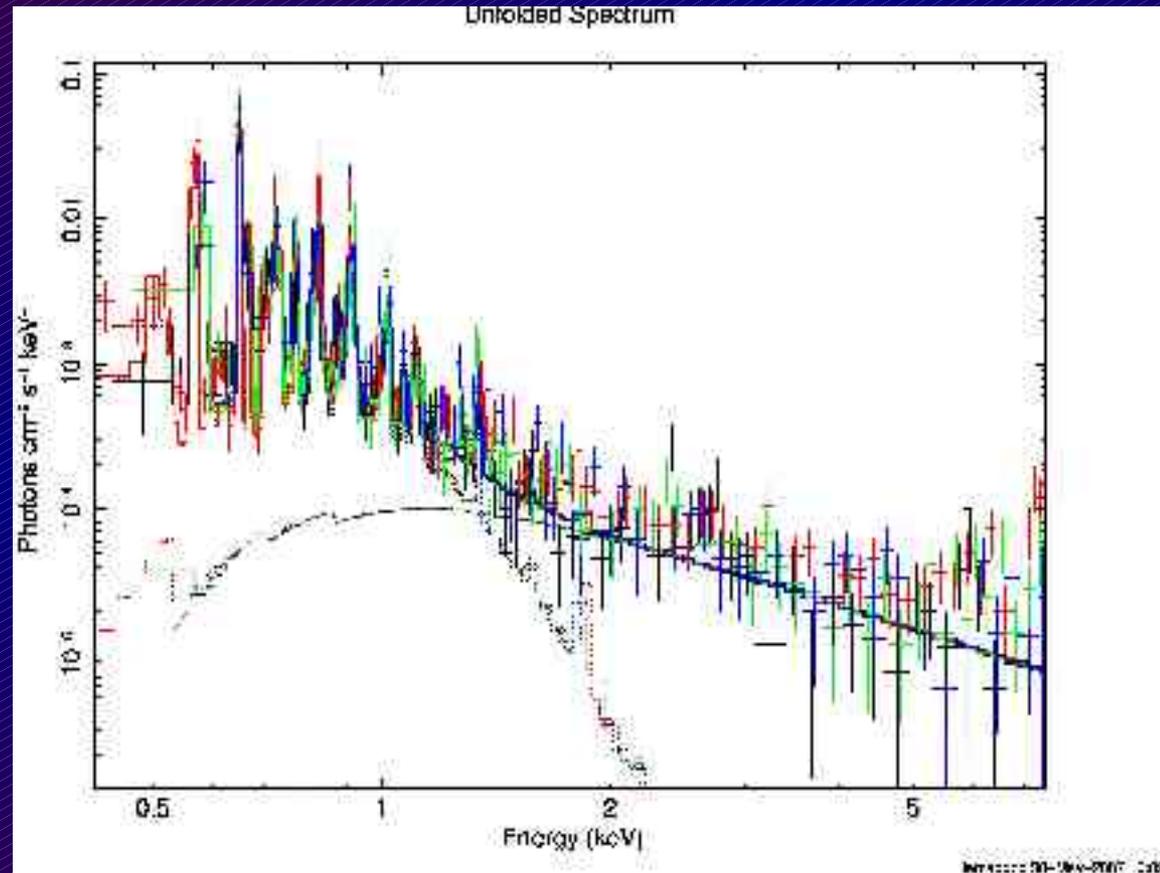
N 11 Properties

- 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 nothermal mechanisms

