Thermal SNRs as Standard Candles
Why Use SNRs with Thermal Spectra as Standard Candles?

- flux is constant in time (mostly true), need to exclude SNRs with central source
- typically have strong lines at energies of interest
- extended sources so pileup effects are reduced

**Candidate Thermal SNRs Considered at IACHEC**

1) Cas-A
2) N132D
3) E0102
Cas A: Chandra Three-color image

Red: 0.5-1.5 keV
Green: 1.5-2.5 keV
Blue: 4.0-6.0 keV

6 X 6 arcmin

Significant spectral variations throughout the remnant

Emission in small regions is time-variable

Weak central source

Very bright, pileup in the brightest filaments with Chandra
Cas A: OBSID 114, Representative Spectrum from one region

Spectrum from one region

Strong Si & S lines

Spectra are useful for gain calibrations
N132D: Chandra Three-color image

Red: 0.3-0.5 keV
Green: 0.5-0.75 keV
Blue: 0.75-7.0 keV

2.0 X 2.5 arcmin

Complicated morphology

Significant spectral variations as a function of position

Significant Fe emission which complicates spectrum below 1.2 keV
Chandra X-Ray Observatory

N132D

Significant
Fe emission
Complicates
Spectrum
below
1.2 keV
Gratuitous Pretty Pictures of E0102, DePasquale (SAO)

1.2 X 1.2 arcmin

Least complicated morphology

**S3 Summed Data ~100 ks**

**Three Color Image**

Red: 0.2-75 keV, Green: 0.8-1.1 keV, Blue: 1.1-2.0 keV
RGS Spectrum of E0102, Pollock (ESAC):

Simplest spectrum of the three objects given the little or no Fe emission
Advantages of E0102 compared to Cas-A and N132D

**E0102:**
- small size - minimizes PSF and off-axis angles effects, degrades resolving power of the gratings the least
- simple spectrum - well-characterized by gratings
- O, Ne, Mg emission - provides line complexes at energies not covered by on-board sources
- morphology - most uniform of the three

**Cas-A:**
- larger size - PSF and off-axis angles effects more important, resolving power of the gratings significantly degraded by source extent

**N132D:**
- complex spectrum - lots of Fe which complicates spectrum
- O, Ne, Mg lines - provides line complexes at energies not covered by on-board sources

Disadvantages of E0102

- Chandra - brighter regions have some pileup
- Suzaku - nearby XRB can contaminate spectrum
Given the previous arguments we have focussed our efforts exclusively on E0102 since the last IACHEC meeting.
Thermal SNR Working Group Process

8 telecons since July 2007, twiki page (DePasquale) set up to disseminate information:

cxc.harvard.edu/twiki/bin/view.cgi/SnrE0102/WebHome
Construction of the Definitive E0102 Model

Absorption: • adopt Wilms et al. 2000 model as tbabs in XSPEC
  • adopt a two-component absorption, Galactic and SMC, Galactic component fixed at $5.36 \times 10^{20}$ cm$^{-2}$ with Wilms abundances, SMC component is free to vary with abundances set to Russell & Dopita 1992 SMC abundances

Continuum: • adopt APEC no-line continuum model
  • adopt a two-component continuum, a relatively low-temperature component and a higher temperature component

Line Emission: • use Gaussians for the lines, 30-40 lines, currently under discussion
  • freeze energies to known values and set widths to zero
  • constrain normalizations of lines of same ionization state to values determined by the RGS and HETG

This is NOT an astrophysical model, it is an empirical model !!!!
How to Constrain the Model Components

1) RGS and HETG constrain SMC $N_H$ and normalization and temperature of low-temperature APEC no-line continuum

2) MOS, pn, & XIS determine normalization and temperature of high-temperature APEC no-line continuum

3) RGS and HETG determine line fluxes from 0.3-2.0 keV

4) MOS and pn determine line fluxes for lines above 2.0 keV

5) ALL instruments fit with the resulting model

6) Iterate to agree on the definitive model

My goal for this meeting would be to complete steps 1-4 and start iterating on step 5.
How Can the Gratings Constrain the Line Parameters?

Raw images from the MEG and HEG, Dewey (MIT)

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How Can the Gratings Constrain the Line Parameters?

Raw spectra from the MEG and HEG, Dewey (MIT)
How Can the Gratings Constrain the Line Parameters?

RGS spectra 22-38 Å from Pollock (ESAC)
How Can the Gratings Constrain the Line Parameters?

RGS spectra 13-25 Å from Pollock (ESAC)
How Can the Gratings Constrain the Line Parameters?

RGS spectra 6-14 Å from Pollock (ESAC)
Compare RGS model to pn data, Haberl (MPE)
Compare RGS model to pn data, Haberl (MPE)
There are significant spectral variations within E0102, DePasquale (SAO)
Astrophysics Will become More Important as We Refine the Model

E0102 IS changing with time!!!!, DePasquale (SAO)
Conclusions

• we are close to a “definitive” spectral model for E0102

• we plan to quote agreement amongst the various instruments at OVII (560-574 eV), OVIII (654 eV), Ne IX (905-922 eV) and Ne X (1022 eV)

• we expect to write an SPIE paper immediately preceding this meeting for the June SPIE conference