Class Problem – Astronomical Observation and Instrumentation

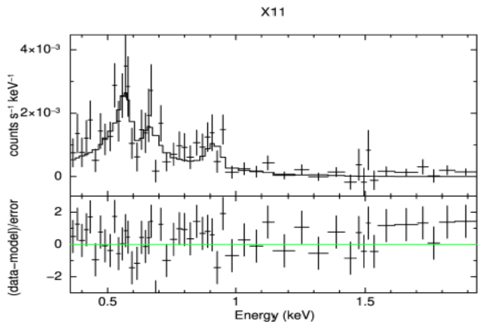
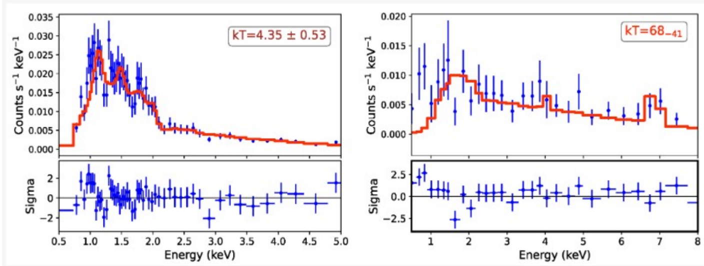


Fig. 5. Combined EPIC MOS spectra and best-fit models for sources X11, X15 and X42. The spectra of X11 and X42 are fitted with one temperature thermal plasma model. The spectrum of X15 is fitted with two temperature thermal plasma components shown with red dashed and blue dotted lines. The fit residuals for all sources are displayed in the bottom panels of each plot, with error bars representing 1σ uncertainties.

Figure 6. (**Left**) Chandra spectrum (blue) and fit (red) of SN 1986J, ObsID 794. Lines of Mg and Si are visible in the fit. (**Right**) The XMM PN spectrum (blue) and fit (red) of SN 2005kd, XMM ID 0410581101. In this case, the Fe K line at around 6.7 keV, and a Ca line at ≈4 keV, are both apparent. The fit is consistent with that in [13]. In both of these Type IIns, the spectra are clearly thermal.



Sources: https://arxiv.org/pdf/2506.09120 and https://www.mdpi.com/2218-1997/11/5/161

a. What portion of the EM spectrum is being studied in Figures 5 and 6 above? (might block out captions for this)

X-ray or 0.35-8.0 keV are acceptable

b. Using the table, identify the elements seen in the three objects.

element	Energy (Kev)	element	Energy (Kev)	element	Energy (Kev)
O	0.18	Mg	1.33	Ar	3.32
Mg	0.25	Mg	1.45	Ar	3.69
Mg	0.27	Fe	1.66	Ca	3.86
O	0.64	Si	1.87	Ca	3.89
O	0.66	Si	1.98	Ca	4.11
Fe	0.80	Si	2.14	Ca	4.95
Fe	0.81	S	2.42	Fe	6.47
Ne	0.92	S	2.44	Fe	6.54
Ne	0.93	S	2.63	Fe	6.97
Ne	1.02	Ar	3.10	Fe	7.80

X11: 0.55-0.6 keV (O), 0.63-0.67 keV (O), 0.88-0.92 (Ne)
SN 1986J: ~1.2 keV (Mg), ~1.5 keV (Mg), 1.8-2.0 (Si)
SN 2005kd: ~1.7-1.8 keV (Fe or Si okay), 4.0 keV (Ca), ~6.7-6.9 keV (Fe)

c. Based on these elements, what type of supernova did each of these remnants come from? Justify your answer.

X11: type Ib or II
SN 1986J: Type Ib or II
SN 2005kd: type Ia

d. If the spectra of X11 is assumed to be completely thermal, what temperature would its source be?

Peak λ ~0.6 keV,

$$T=\frac{0.003\,m\cdot K}{\lambda_{peak}}=\frac{0.003\,m\cdot K}{hc/E}=\frac{0.003\,m\cdot K}{\left(\frac{1240\,eV\cdot nm}{600\,eV}\right)\cdot\frac{m}{10^9\,nm}}=1.45\cdot 10^6\,K$$

Peak λ ~0.55 keV,

$$T=\frac{0.003\,m\cdot K}{\lambda_{peak}}=\frac{0.003\,m\cdot K}{hc/E}=\frac{0.003\,m\cdot K}{\left(\frac{1240\,eV\cdot nm}{550\,eV}\right)\cdot\frac{m}{10^9\,nm}}=1.33\cdot 10^6\,K$$

Answer should be within this range

e. If this same temperature is instead caused by shocks within the Sne remnant, what would be the material's initial velocity if the material is stationary after the shock? (Assume a pure Hydrogen material, m_H = 1.67 x 10^{-27} kg and 1eV = 1.602 x 10^{-19} J)

0.6 keV, $E_i=\Delta E\rightarrow\frac{1}{2}m_H v_i^2=\left(600\,\frac{eV*1.602\cdot 10^{-19}\,J}{1\,eV}\right)$

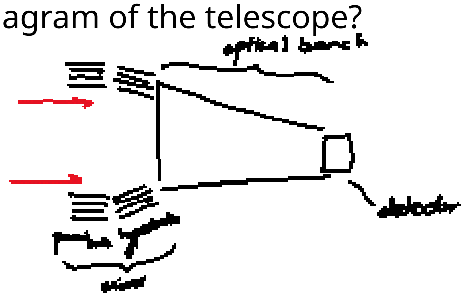
$$\rightarrow v_i=\sqrt{\frac{\left(600*1.602\cdot 10^{-19}\right)}{\frac{1}{2}m_H}}=3.39\cdot 10^5\,m/s$$

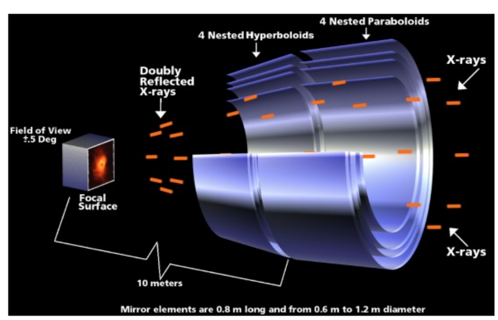
0.55 keV, $E_i=\Delta E\rightarrow\frac{1}{2}m_H v_i^2=\left(550\,\frac{eV*1.602\cdot 10^{-19}\,J}{1\,eV}\right)$

$$\rightarrow v_i=\sqrt{\frac{\left(550*1.602\cdot 10^{-19}\right)}{\frac{1}{2}m_H}}=3.25\cdot 10^5\,m/s$$

Answer should be within this range

f. Both sets of data were taken with Chandra, can you draw a rudimentary diagram of the telescope?





g. Finally, if the detector collects a field of view +/- 0.5 deg but is the physical size of 16.9' x 16.9', what total deflection does Chandra's most external mirrors (aperture of 1.2 m) need to apply to incoming light if the optical bench is 10 m?

60' → 16.9'