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S. S. HOLT
E. A. BOLDT
P. J. SERLEMITSOS

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Iron Line Emission From X-Ray Sources

by

S. S. Holt, E. A. Boldt and P. J. Serlemitsos
NASA, Goddard Space Flight Center, Greenbelt, Maryland

ABSTRACT

X-ray sources for which thermal models have been proposed should exhibit line structure for energies below 10 keV. The $(1s)^2$ - 1s 2p transition in Fe XXV at 6.64 keV is that emission line which is characteristically the most easily observable, and its presence (or absence) in experimentally observed spectra is shown to severely constrain proposed models.

INTRODUCTION

Tucker and Gould (1966) have developed a framework in which the radiation from an optically thin plasma at temperatures in excess of 10^6 °K may be studied. Using this approach, Tucker (1967) has constructed temperature- and elemental-abundance dependent models for thermal X-ray sources, and has pointed out that the differential structure of the X-ray emission spectrum below 10 keV can yield specific limitations on the physical nature of the source. Sartori and Morrison (1967) have postulated that presumed non-thermal radio sources (such as the Crab Nebula may have X-ray emission spectra which are, in fact, thermal in origin. It is the purpose of this letter to point out that such thermal models may not be chosen to empirically fit the observed continuum with thermal continua without considering the effect of line emission

In the construction of Figure I we have used the line strengths for the three composition models as a function of temperature given by Tucker (1967). The bremsstrahlung component of the continuum was computed using the standard free-free emission prescription (cf. Allen, 1955), where we took a Gaunt factor of

$$\frac{\sqrt{3}}{\pi} K_0\left(\frac{\hbar\omega}{2kT}\right) \exp\left(\frac{\hbar\omega}{2kT}\right)$$

for hydrogen, and unity for the other elements in the abundances given by Tucker for his three models. The recombination radiation contribution to the continuum was evaluated using the functional form given by Tucker and Gould (1966) normalized to the models of Tucker.

An X-ray experiment with energy resolution of ~ 25% at 6.9 keV, and a statistical uncertainty of ~ 10% in the flux in a 1 keV energy bin at that energy, would be capable of detecting the iron line emission at the 1σ level for the universal abundance model (model I) over the most interesting part of the temperature range, and could easily detect the iron line emission from models which are iron-rich.

Conclusions

Our laboratory has used a detector which possesses an energy resolution of ~ 25% (FWHM) at 6.9 keV in a rocket borne x-ray observation of the Crab Nebula and the Taurus region of the sky (Boldt, Desai, and Holt 1968). The data from this exposure to the Crab Nebula were lumped into 1 keV bins as suggested above for three separate proportional counters, and no positive indication of iron in any of the detector records was obtained, with a statistical error of ~ 15% in each energy bin. If we combine the three independent records, the statistical error in the composite 1 keV channel at 6.9 keV is 9%.

The low temperature region chosen for the Crab by Sartori and Morrison is 2 keV (2.32×10^7 °K). According to Figure 1, universal abundances in the Crab at this temperature would give us an increase at the 1σ level. Model II (M_o supernova shell) would give almost 2σ, and model III ($\sim 30\ M_o$ supernova shell) would give us about 8σ. The statistics in our results for models I and II are hardly compelling, but are certainly not indicative of a thermal source.

The two temperatures chosen by Sartori and Morrison are not unique. The presently available data, in fact, would necessitate more than two temperature regions in order to achieve consistency with the entire spectrum from 1 keV to 200 keV. We wish to point out, however, that any temperature region chosen between 20 and 100 million degrees will give observable iron line emission for most of the possible elemental abundance models. The continuum from lower and higher temperature regions will be insignificant in the neighborhood of 7 keV compared to the contribution from the 20-100 million degree region, if the 20-100 million degree region is a necessary constituent of the model.

The x-ray source which has been most consistently reconciled with a thermal model is Sco X-1, at a temperature of 50-60 million degrees. We would expect the iron emission from this source to be observable. The most recent Sco X-1 data which we have seen (one exposure by Hill et al (1968), and two exposures by Gorenstein et al (1968) all seem to exhibit an excess in photon intensity in precisely the energy region where we would predict the iron emission. We suggest that all experimenters reexamine their data with this criterion in mind.

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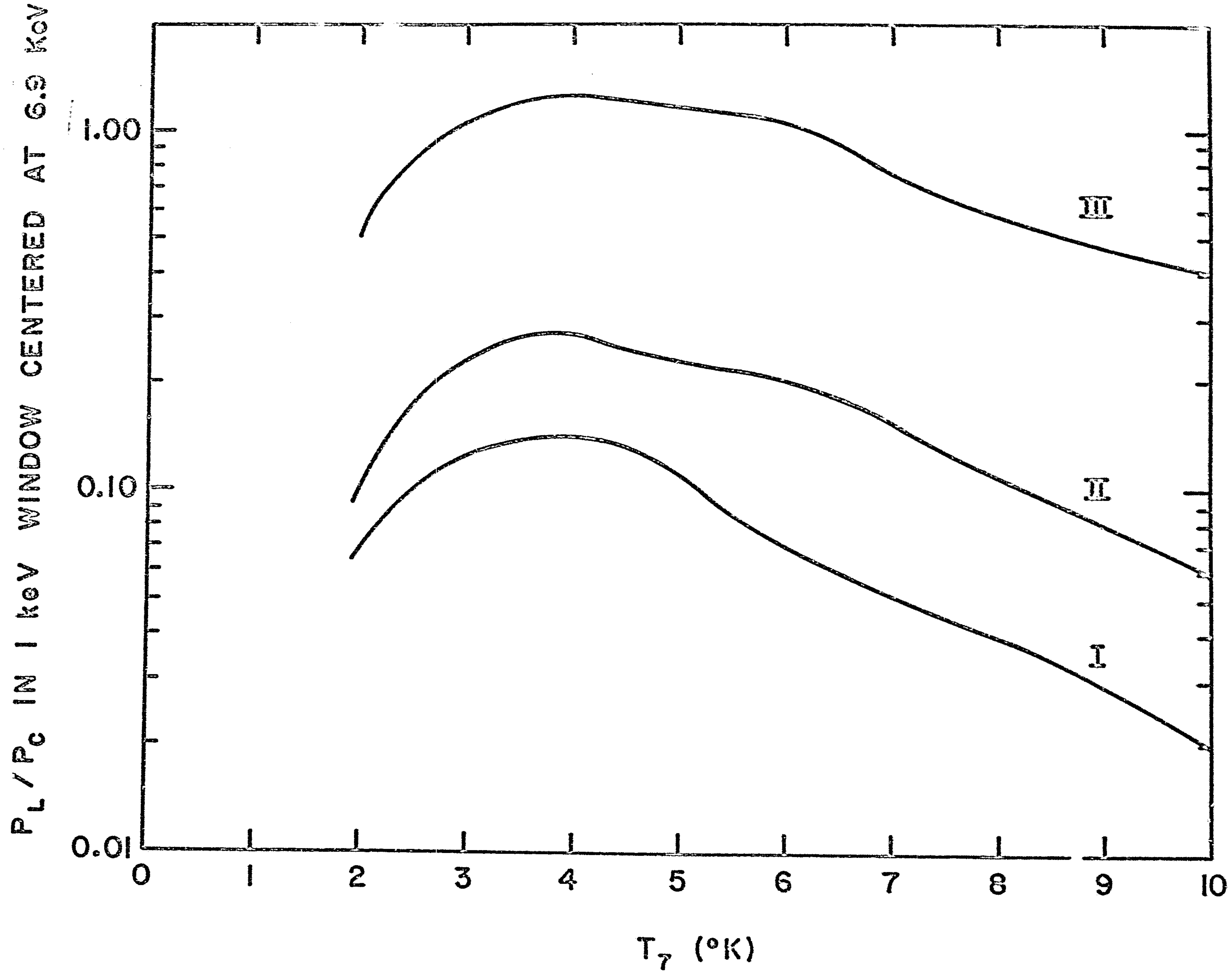
Figure Caption

1. Ratio of power emitted in Fe line emission to power emitted in continuum (bremsstrahlung plus recombination radiation) emission in a 1 keV window centered at 6.9 keV, as a function of temperature. The three traces I, II and III refer to the three models of Tucker (1967).


P_L / P_c IN 1 keV WINDOW CENTERED AT 6.9 KeV
1.00
0.10
0.01
0
1
2
3
4
5
6
7
8
9
10
T_7 (°K)
III
II
I