CHANDRA X-RAY OBSERVATIONS AND THE SPALLOGENIC ORIGIN OF SHORTLIVED RADIONUCLIDES.

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Introduction: Material derived from the interstellar medium, or injected from a supernova remnant or AGB star, or made via spallation by relativistic baryons in the solar nebula, can all contribute isotopically anomalous material to the solar nebula. The local spallation of material by an energetic young Sun [1] is an attractive source of short-lived radionuclides (^{7,10}Be, ^{41}Ca, ^{26}Al) inferred to have been present in various CAIs, gas-rich grains and chondrules [2]. *In situ* spallation requires MeV particle fluences ~10^5 times above levels of contemporary cosmic ray and solar energetic particle (SEP) fluences [3,4,5]; but X-ray observations of pre-main sequence (PMS) stars' flaring levels can give direct empirical constraints on the viability of the spallation model.

Data: The high sensitivity and resolution of the *Chandra X-ray Observatory* launched in 1999 permits detailed characterization of the magnetic flaring of 1 M_o PMS analogs of the early Sun, especially in the Orion Nebula Cluster (ONC) where ~1000 stars with ages ~0.5-2 Myr are concentrated in a single field. Results from other PMS populations are very similar. Two 12-hour exposures made in 1999 and 2000 show that the mean X-ray luminosity of a complete sample of 43 $0.7<M<1.4$ M_o ONC stars is $<\log L_x>=30.3$ erg/s in the 0.5-8 keV band, ~10^3 above the average active Sun level today. Twenty-eight of these stars exhibited intraday variability. While it is difficult to distinguish individual flares from quiescent levels from these short exposures, we estimate that 1 flare with $29.0<L_{x,peak}<31.5$ erg/s with X-ray energies 10^{32} to $>10^{36}$ ergs occurs every 1-2 days in PMS solar analogs. This is $10^{1.5}$ times stronger and $10^{2.5}$ times more frequent than seen in the contemporary Sun. The estimated enhancement in MeV proton fluences is 10 times above the X-ray fluence, or a total of 10^5 times above SEP levels. We also hope to present preliminary results from the *Chandra Orion Ultradeep Project* (COUP) based on a 10-day nearly-continuous exposure of the ONC made in January 2003, to derive impulsive flare precursors to the long-duration events and the frequency distribution of flare intensities and durations, improving particle fluence estimates.

Discussion: All young solar analogs exhibit huge elevations in magnetic flare levels, with estimated baryon fluences consistent with the requirements of a nebular spallogenic origin for several short-lived meteoritic isotopic anomalies. These are supported by radio continuum studies of enhanced gyrosynchrotron emission in PMS stars [6]. However, the location and geometry of the flaring magnetic fields is uncertain and additional model assumptions must be made to assure that the flare particles efficiently impact nebular solids to produce the observed distribution of isotopic anomalies [5].

References: [1] Feigelson E. D. and Consolmagno G. J. 1982. 13th Lunar & Planetary Science Conference, pp. 213-214; Feigelson E. D. 1982. *Icarus* 51:155-163; Feigelson E. D. et al. 2002. *Astrophysical Journal* 572:335-349; Feigelson E. D. and Montmerle T. 1999. *Annual Reviews of Astronomy and Astrophysics* 37:363-408. [2] Goswami J. N and Vanhala H. A. 2000. *Protostars and Planets IV,* 963. [3] Gounelle M. et al. 2001. *Astrophysical Journal* 548:1051-1070. [4] Goswami J. N. et al. 2001. *Astrophysical Journal* 549:1151-1159. [5] Lee T. et al. 1998. *Astrophysical Journal* 506:898-912. [7] Guedel M. 2003. *Annual Reviews of Astronomy and Astrophysics* 40:217-261.