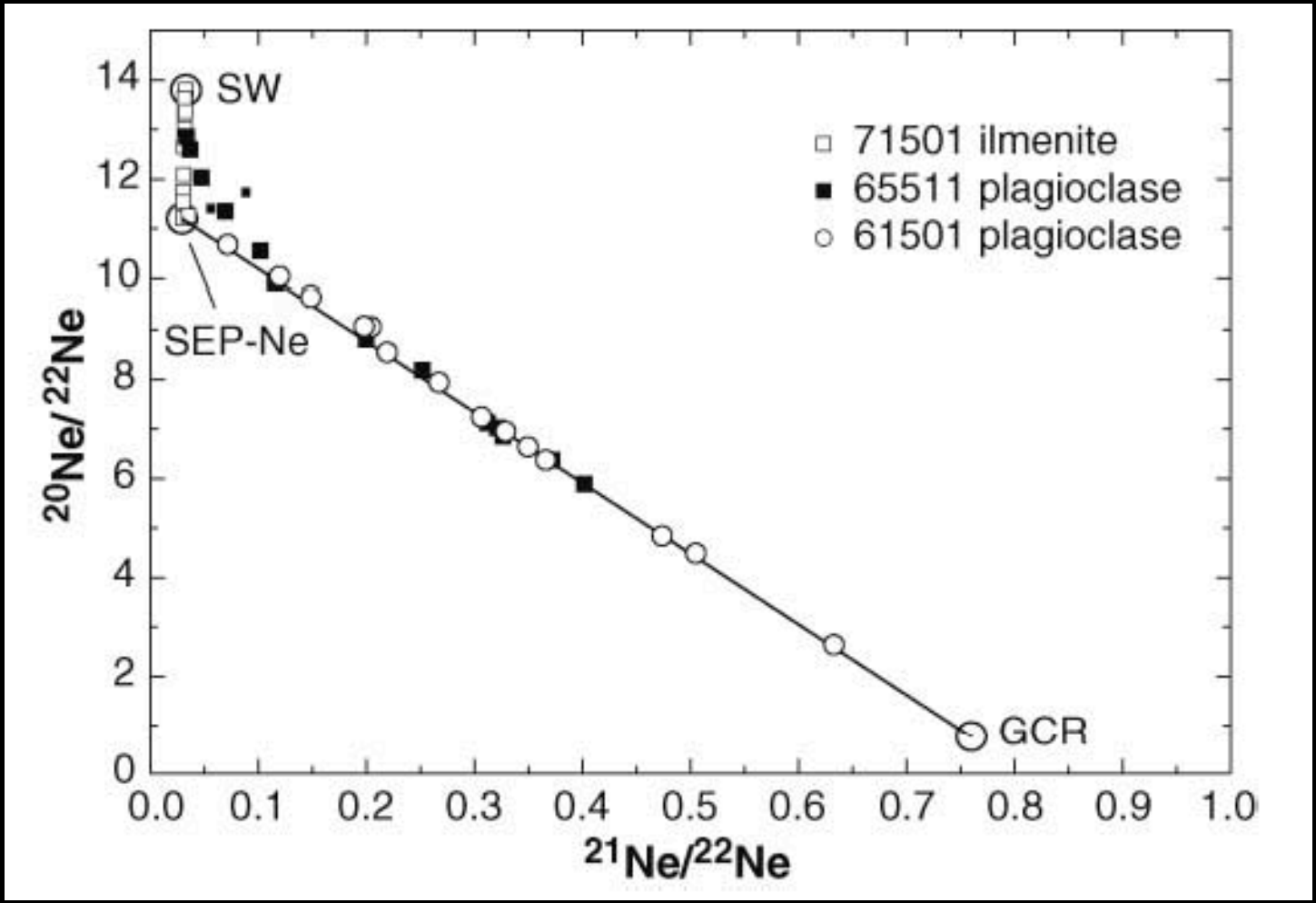
History of Solar and Galactic Cosmic Radiation

Kurt Marti

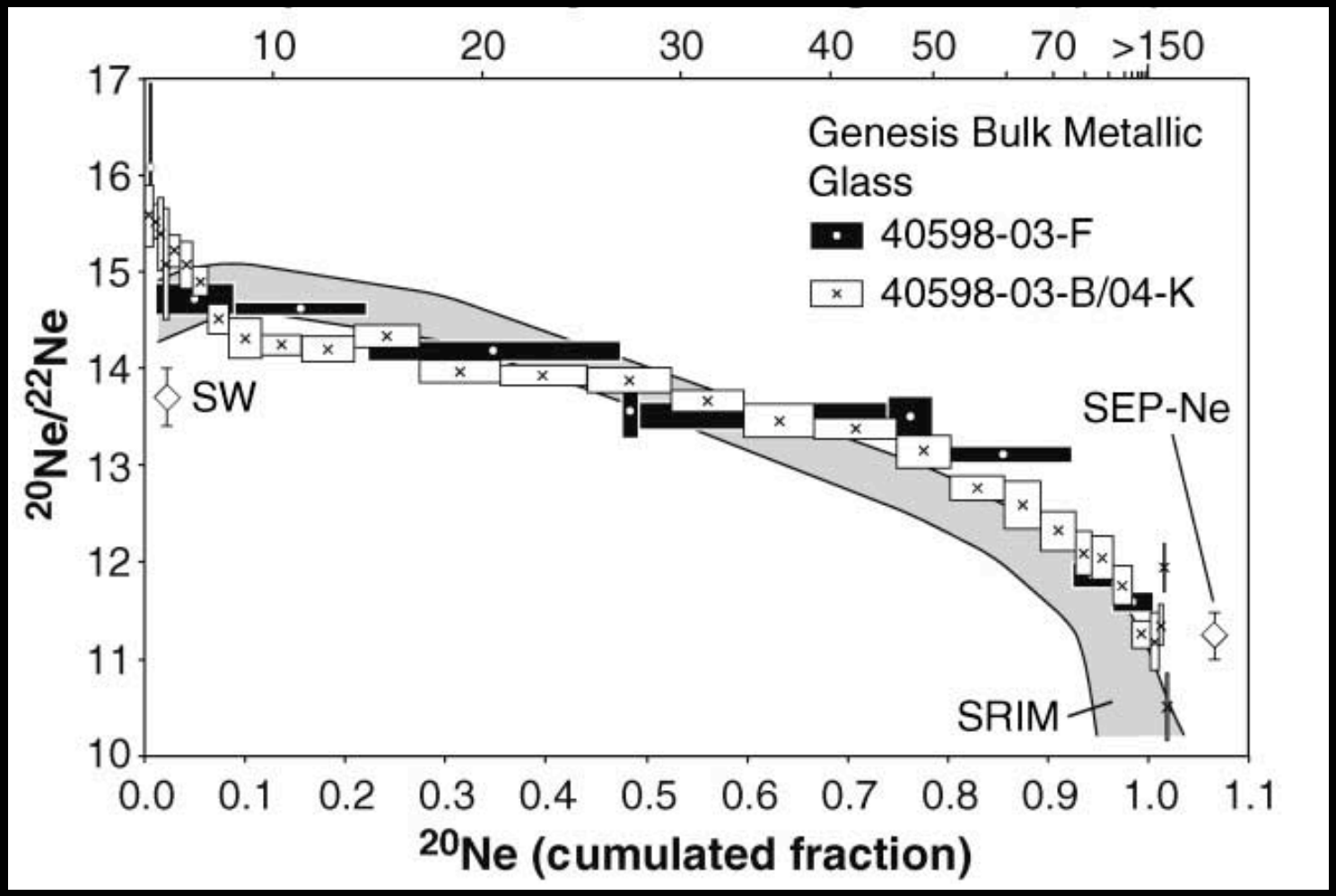
Department of Chemistry, University of California San Diego, La Jolla, USA

Solar particles



Grimberg et al. (2006) *Science* 314 1133

Implantation depth according to SRIM (nm)



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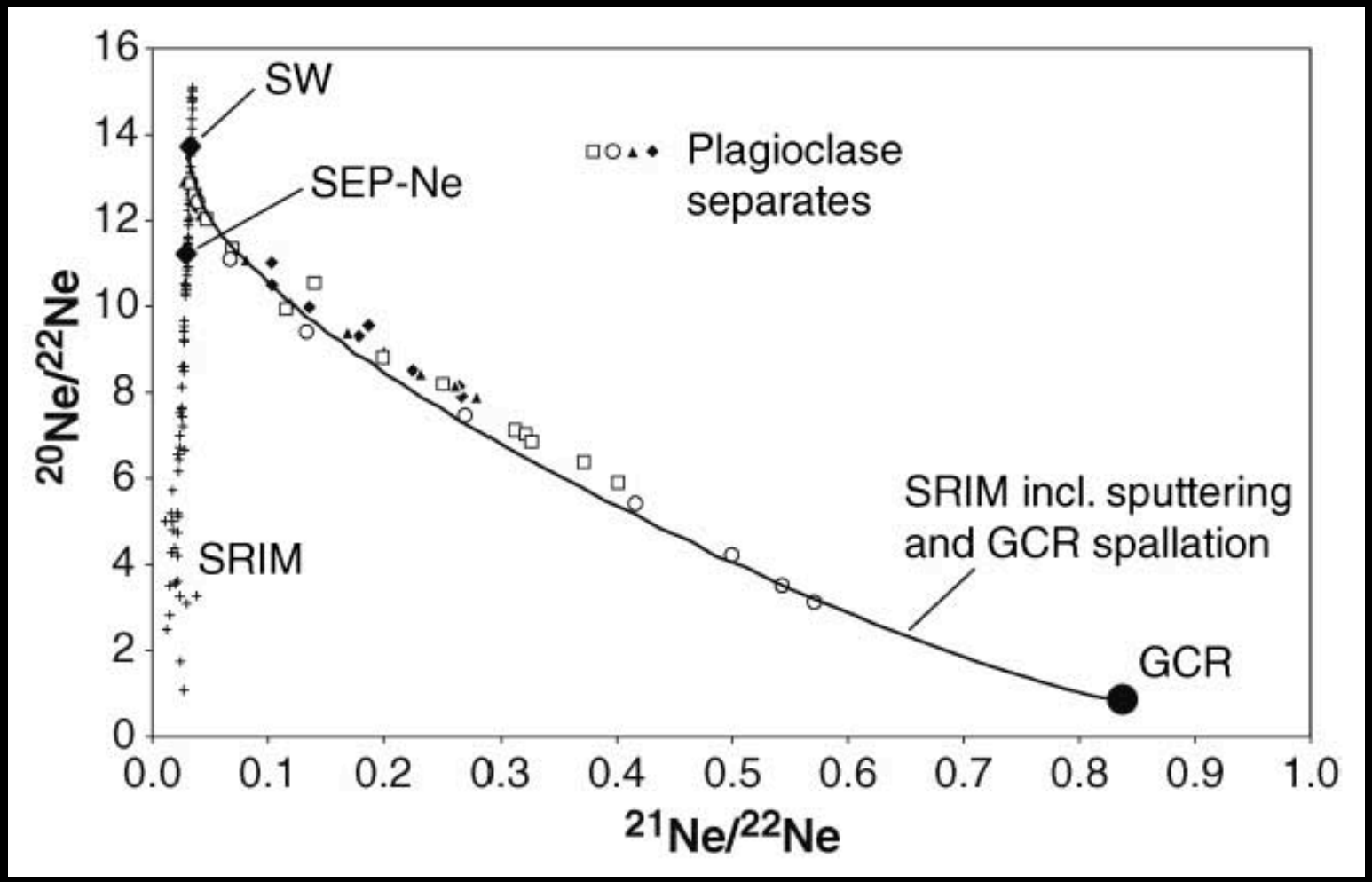
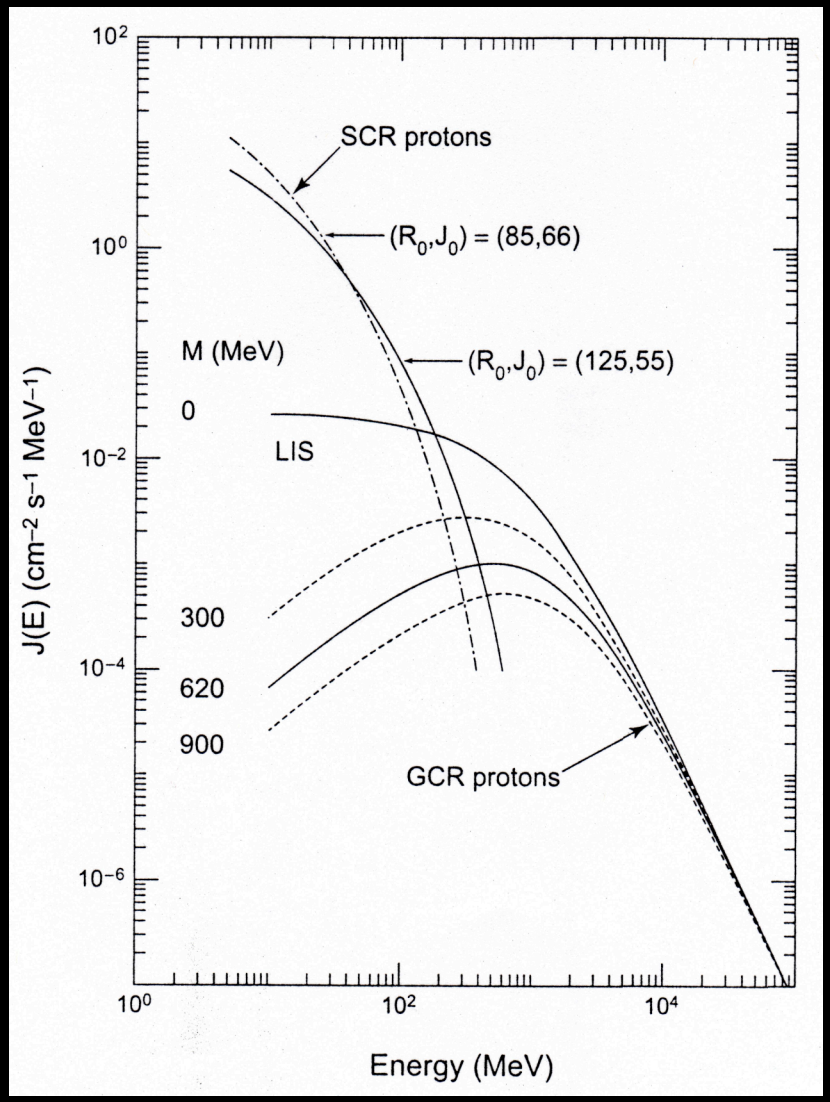
Ne implantation comparison



Grimberg et al. (2006) *Science* 314 1133

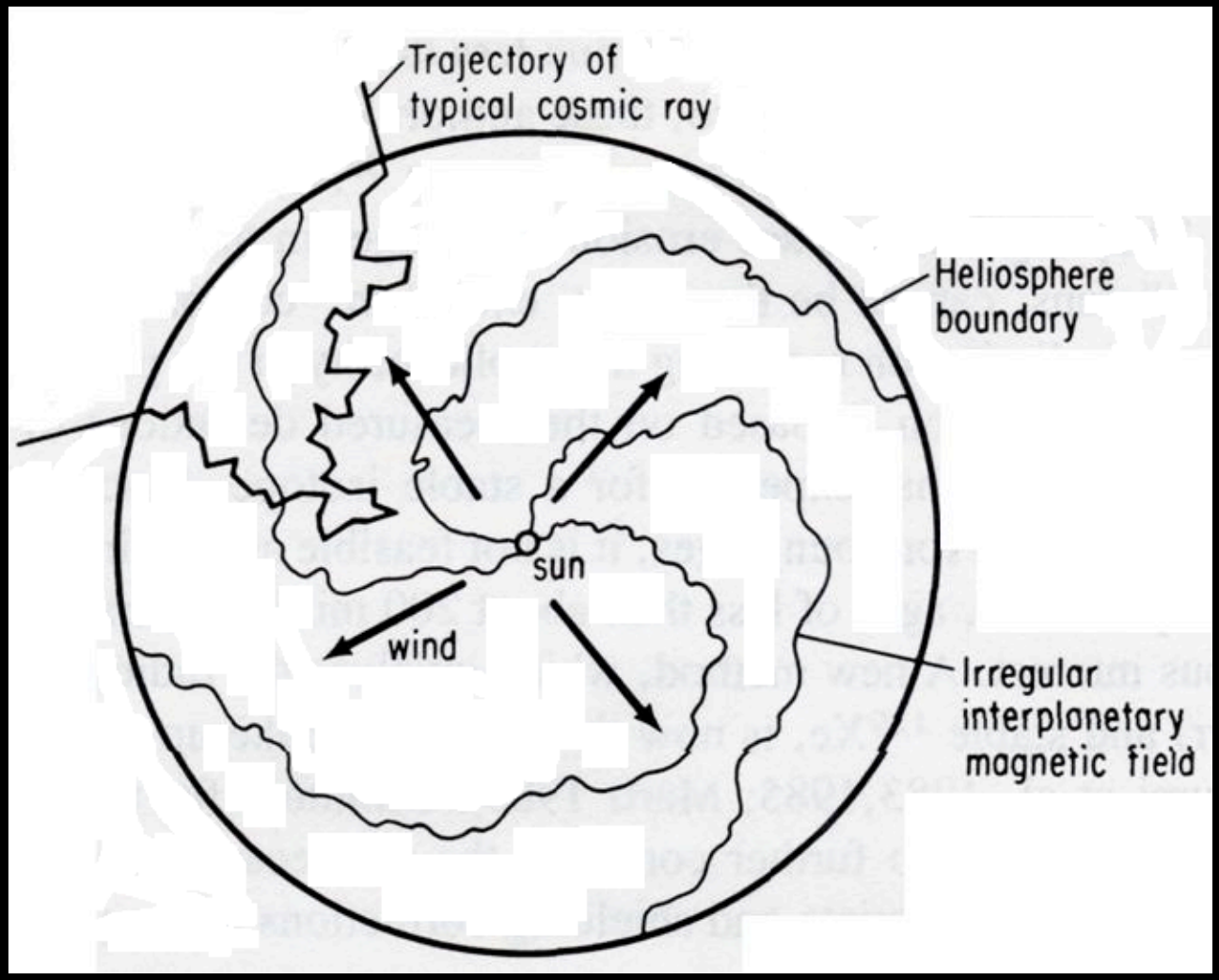
Solar (SCR) and galactic (GCR) cosmic-rays



Michel et al. (1996) Nucl. Instrum. Methods Phys. Res. 113, 434.

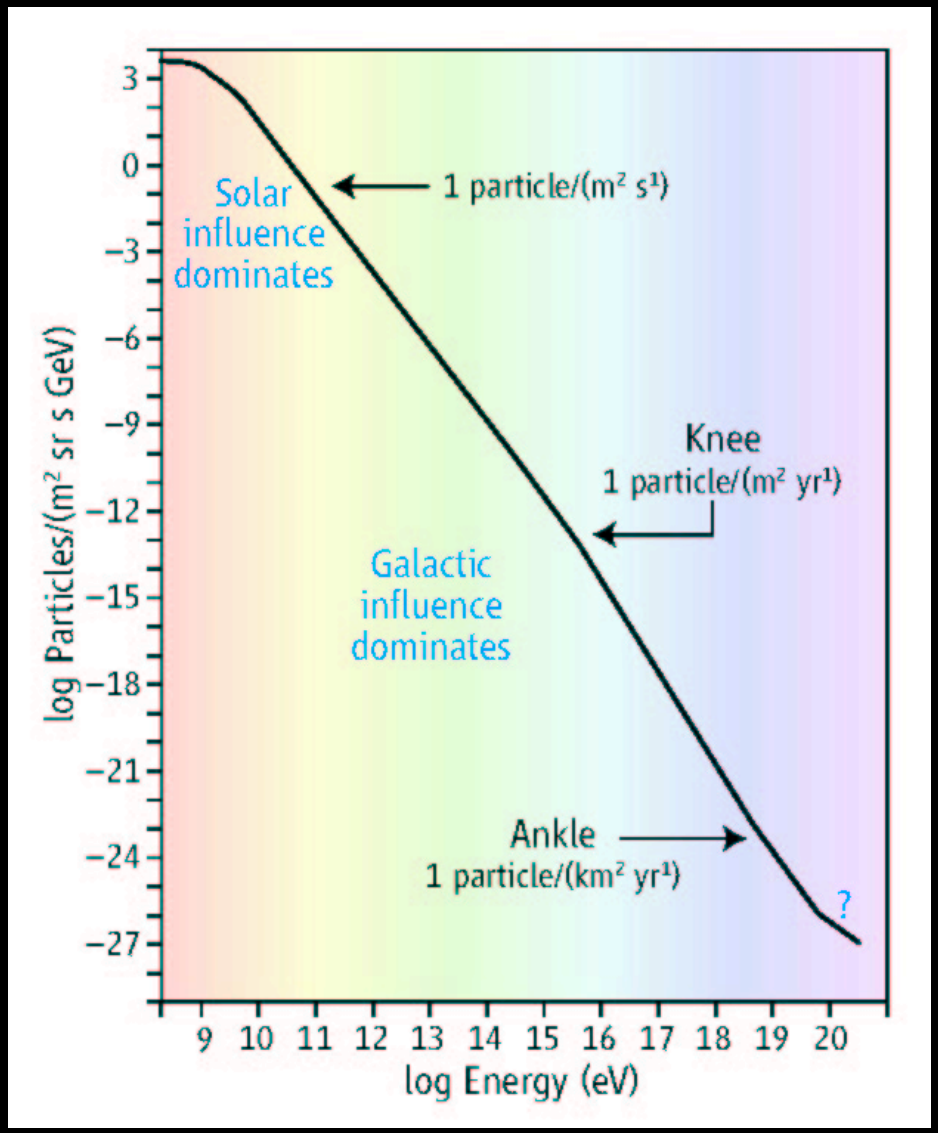
Kurt Marti
2007. 2. 28.
Kmarti@ucsd.edu

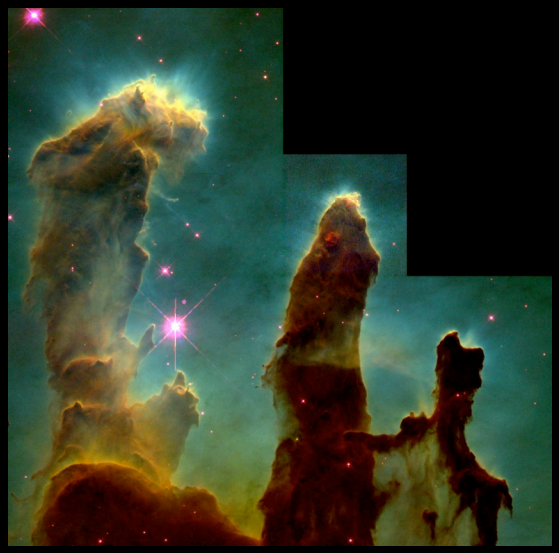
Trajectory of a cosmic ray



Kurt Marti
2007. 2. 28.
Kmarti@ucsd.edu

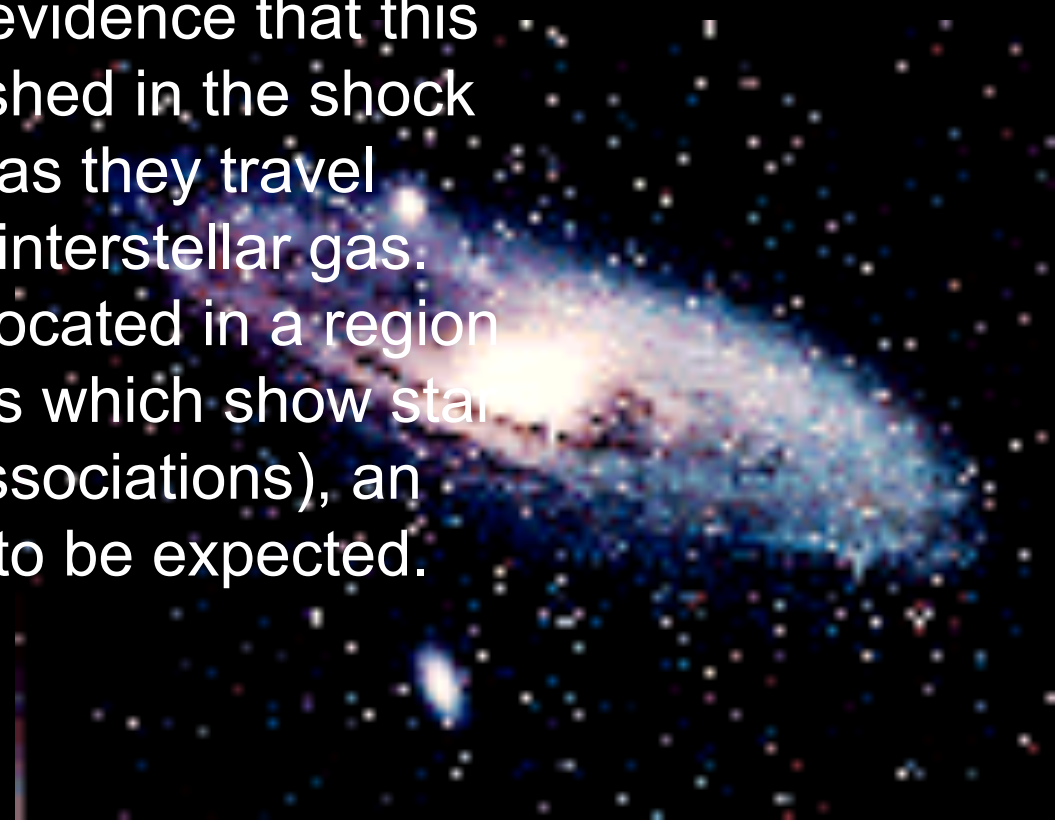
Cosmic rays and rotation of the galaxy



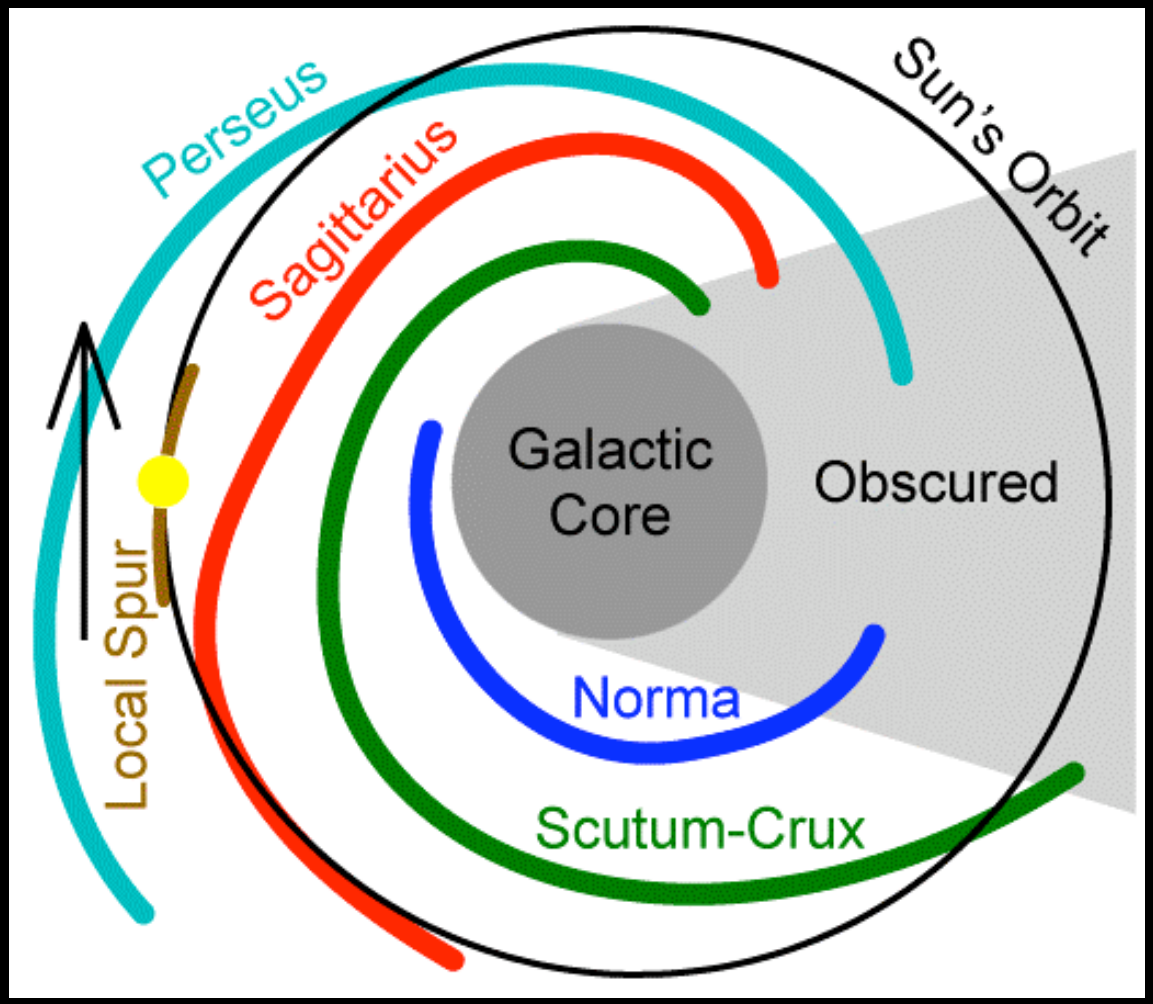


Origin and flux changes

Energies carried by GCR (typically 100 MeV to 10 GeV) are thought to derive from supernovae (SN) explosions. There is a considerable amount of evidence that this acceleration is accomplished in the shock waves of SN explosions as they travel through the surrounding interstellar gas. Whenever the Sun was located in a region of the galactic spiral arms which show star formation regions (OB associations), an increased GCR flux has to be expected.



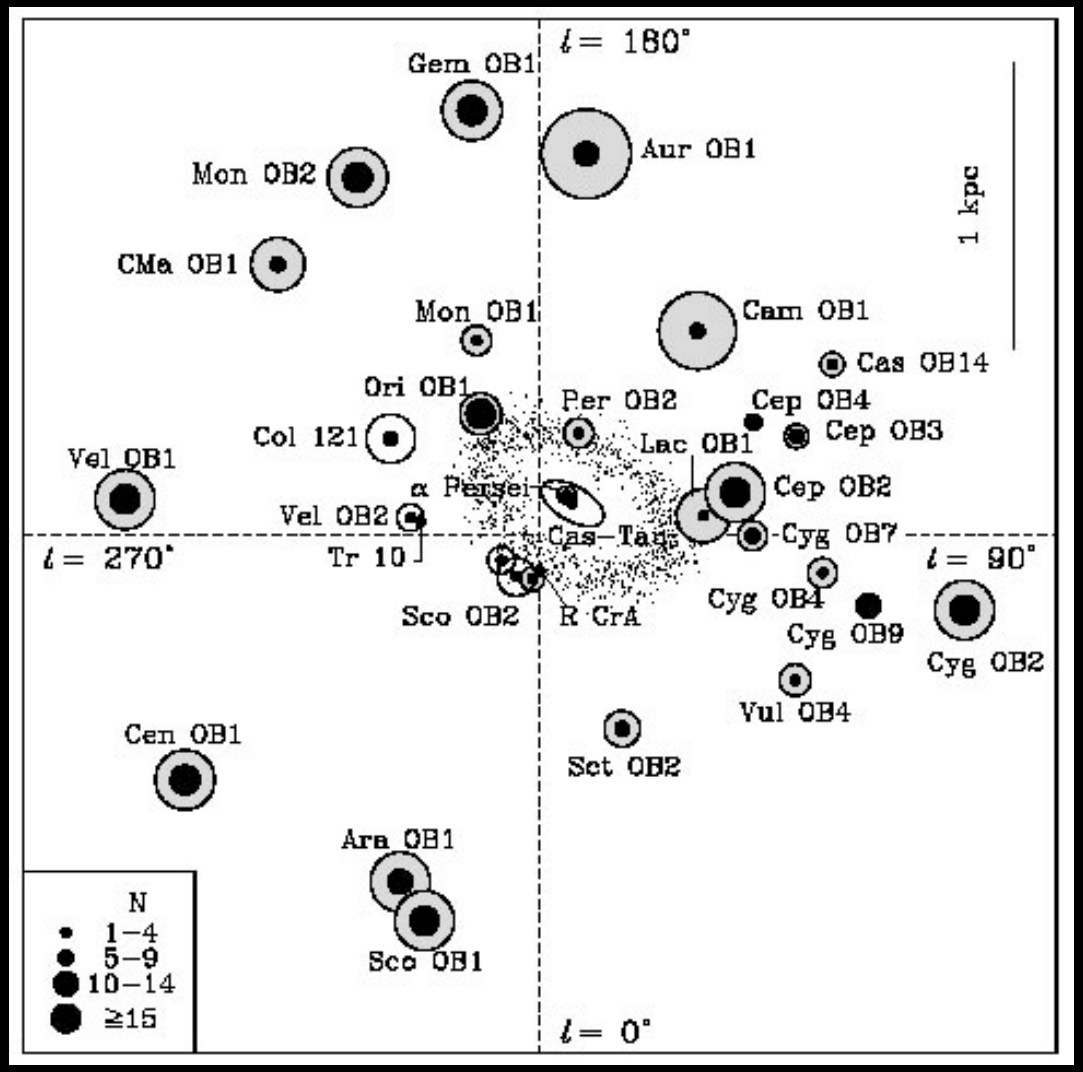
Sun's orbit



Kurt Marti
2007. 2. 28.
Kmarti@ucsd.edu

Local structures

OB associations

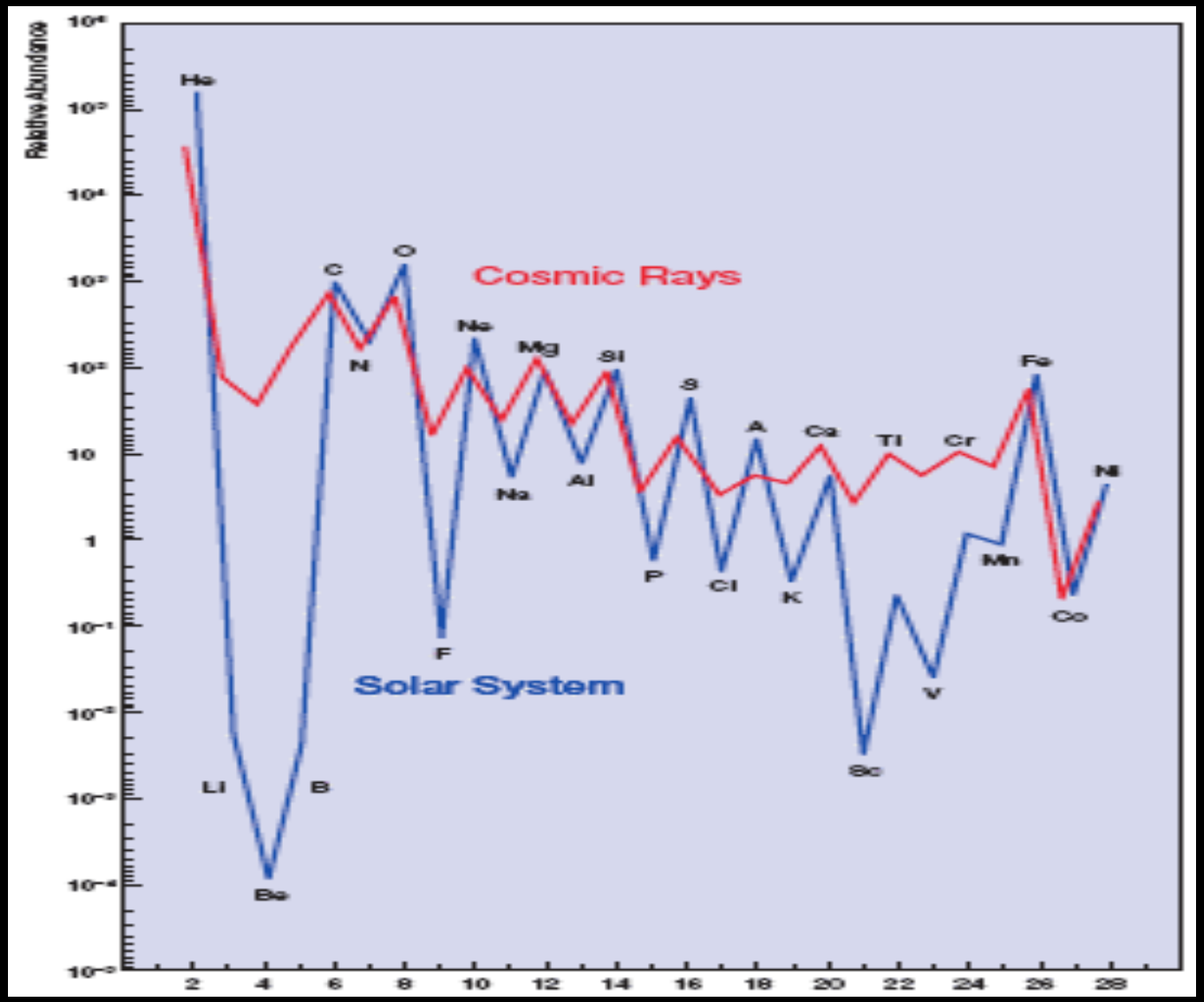


Zeeuw et al. (1999)The Astronomical J.117, 354.

Kurt Marti
2007. 2. 28.
Kmarti@ucsd.edu

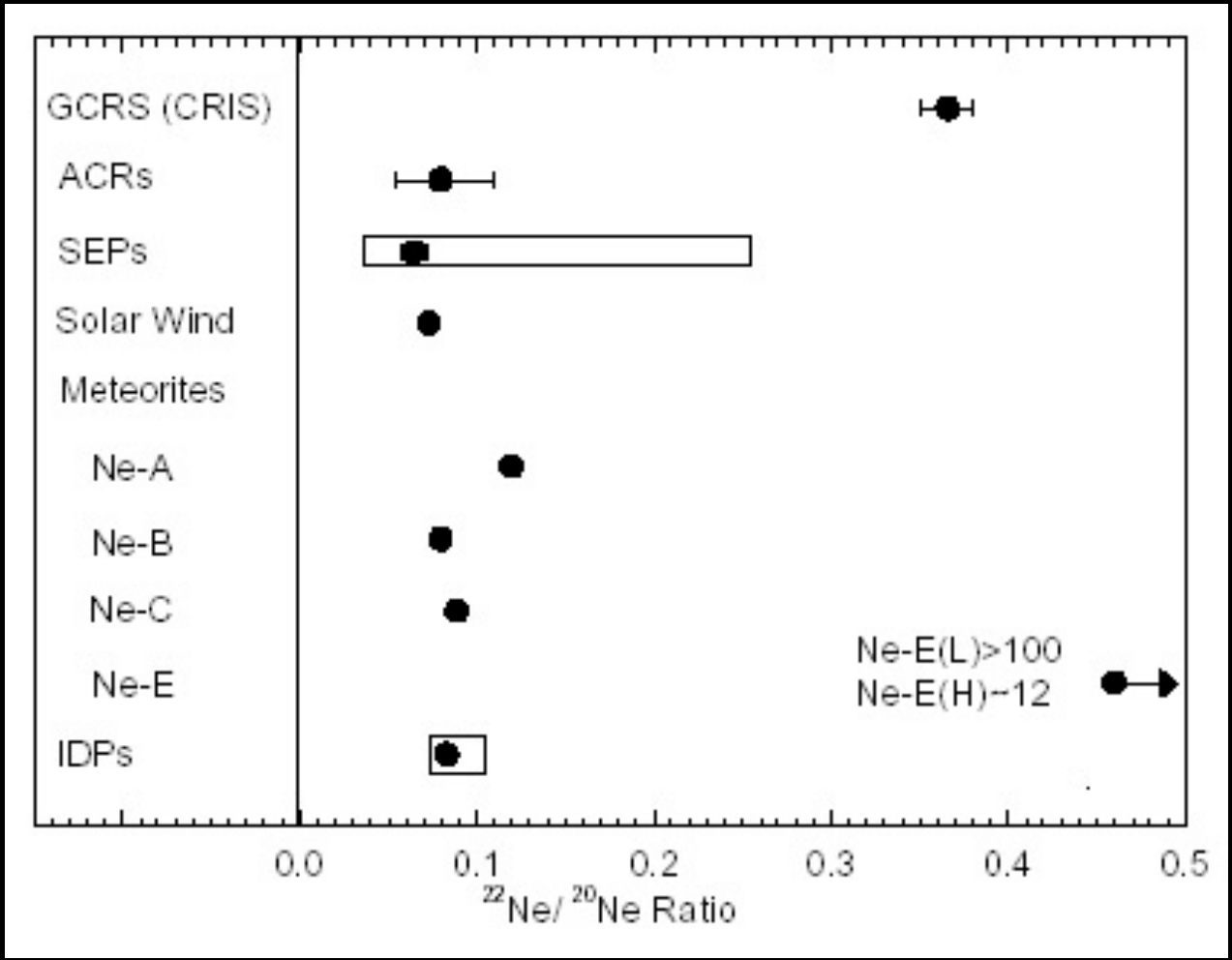
The Southern Cross

Cosmic ray abundances



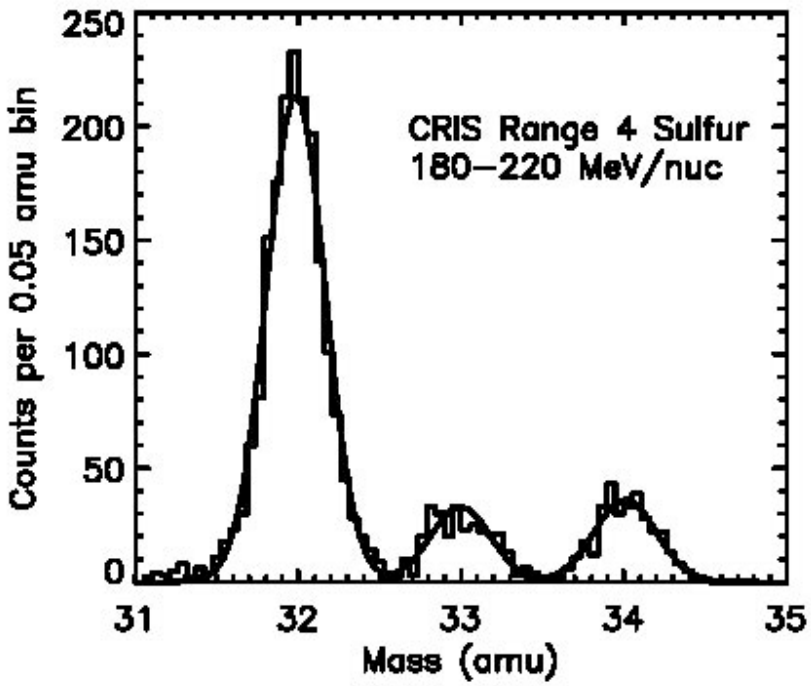
Kurt Marti
2007. 2. 28.
Kmarti@ucsd.edu

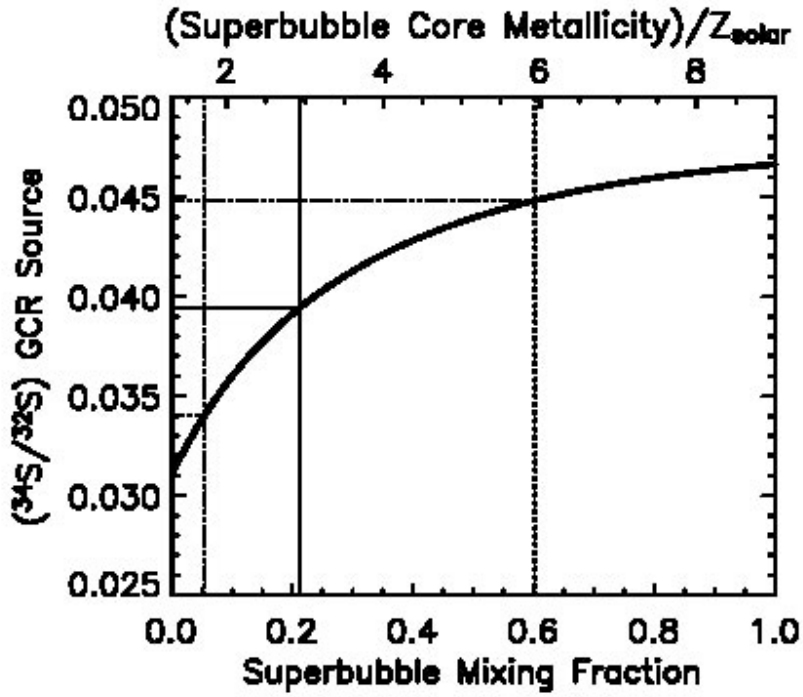
Galactic cosmic ray neon



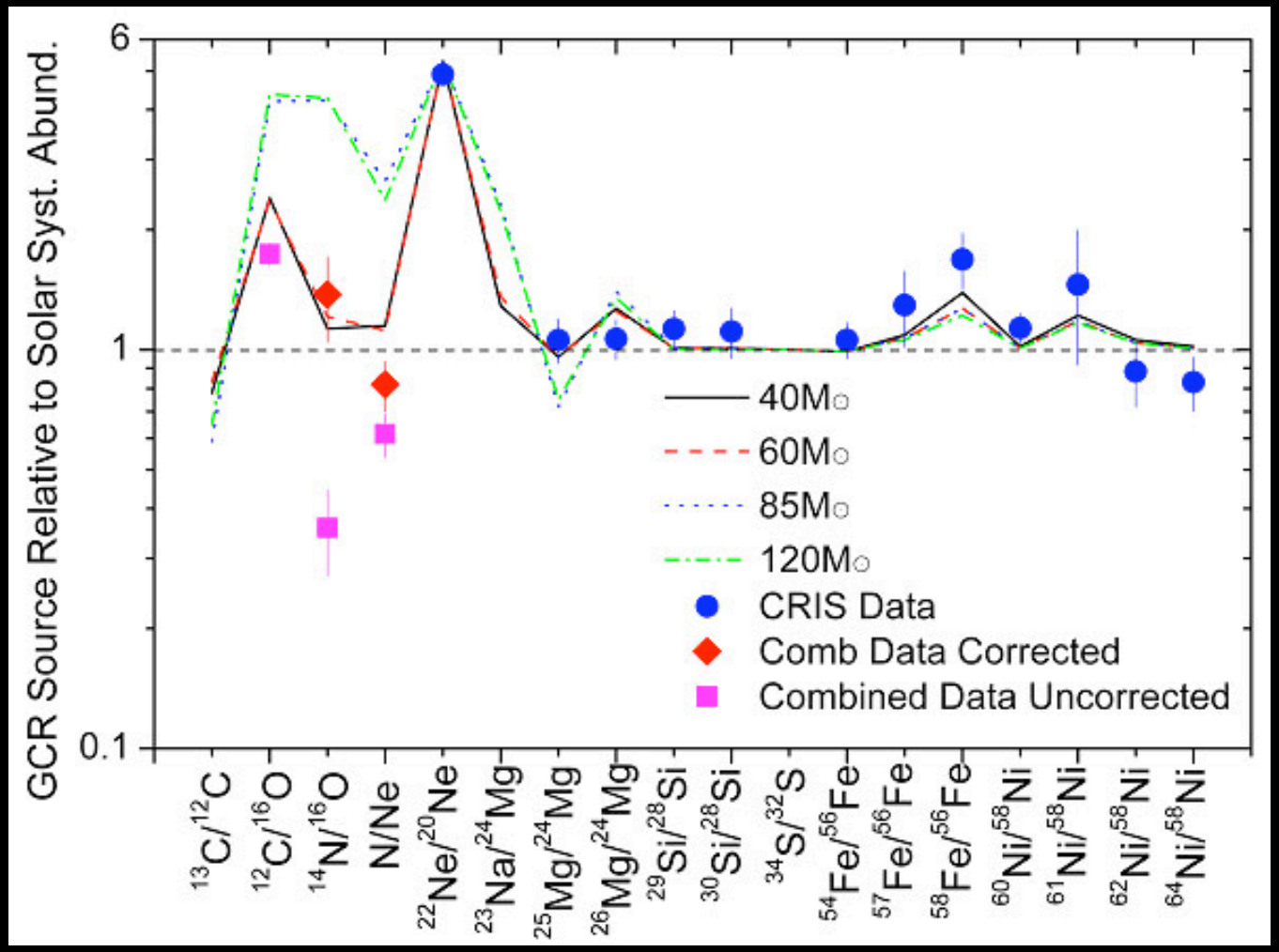
Kurt Marti
2007. 2. 28.
Kmarti@ucsd.edu

Superbubble Origin of Galactic Cosmic Rays Supported by Supernova-Produced Isotopes

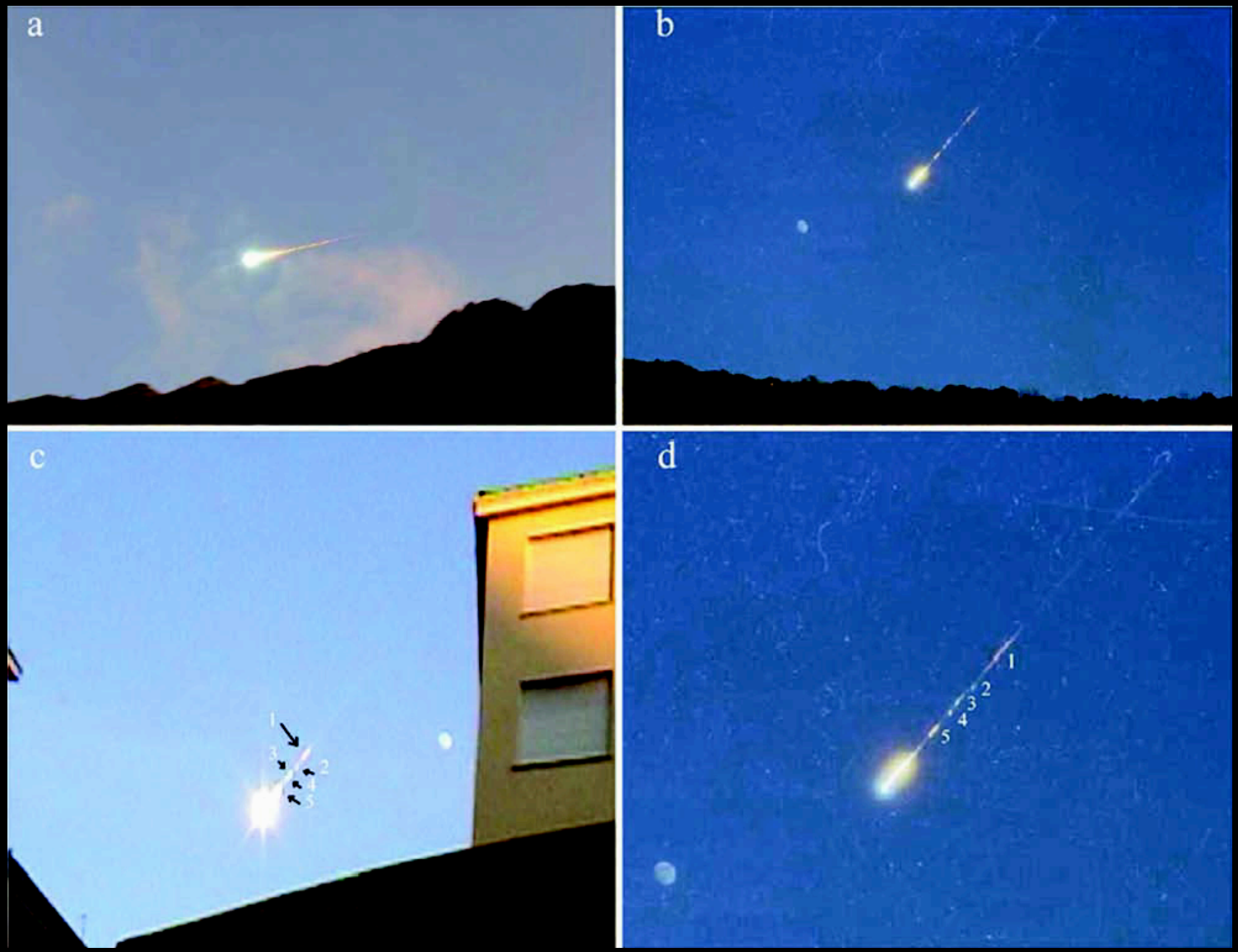




Support for origin of GCR in O-B association



The Villalbeto de la Peña meteorite fall




NASA

Iron meteorite on Mars?

Length of exposure to GCR: CRE ages of meteorites

Chronometer: ^{81}Kr-^{83}Kr

$T_{1/2}(^{81}Kr)=0.228Ma$

$^{81}Kr(t) = (P_{81}/\lambda_{81})\ (1 - \exp(-\lambda_{81}\ t))$

$F(T_{CRE}) \equiv [^{83}Kr_c] / [^{81}Kr]$

$= (P_{83}/P_{81})\ \lambda_{81}\ T_{CRE}/[(1 - \exp(-\lambda_{81}\ T_{CRE})]^{-1} - 1$

Chronometer: ^{36}Cl-^{36}Ar

$T_{1/2}(^{36}Cl)=0.30Ma$, $P(^{36}Cl)/P(^{36}Ar)=0.83$

$^{36}Cl(t) = (P\ (^{36}Cl)/\lambda_{36})\ (1 - \exp(-\lambda_{36}\ t))$

$F(T_{CRE}) \equiv [^{36}Ar]/[^{36}Cl]$

$= P_{36}(^{36}Ar)/P_{36}(^{36}Cl)\ \lambda_{36}\ T_{CRE}/[1 - \exp(-\lambda_{36}\ T_{CRE})]^{-1} - 1$

Length of exposure to GCR: CRE ages of meteorites

Chronometer: ^{53}Mn-^{53}Cr

$T_{1/2}(^{53}Mn)=3.7Ma$

$^{53}Mn(t) = (P(^{53}Mn)/\lambda_{53})\ (1 - \exp(-\lambda_{53}\, t))$

$F(T_{CRE})=[^{53}Cr]/[^{53}Mn]$

$=\lambda_{53} T_{CRE}[P(^{53}Cr_c)/P(^{53}Mn)]\ [1 - \exp(-\lambda_{53}\, T_{CRE})]^{-1} -1$

Chronometer: ^{129}I-^{129}Xe

$T_{1/2}(^{129}I)=15.7Ma$

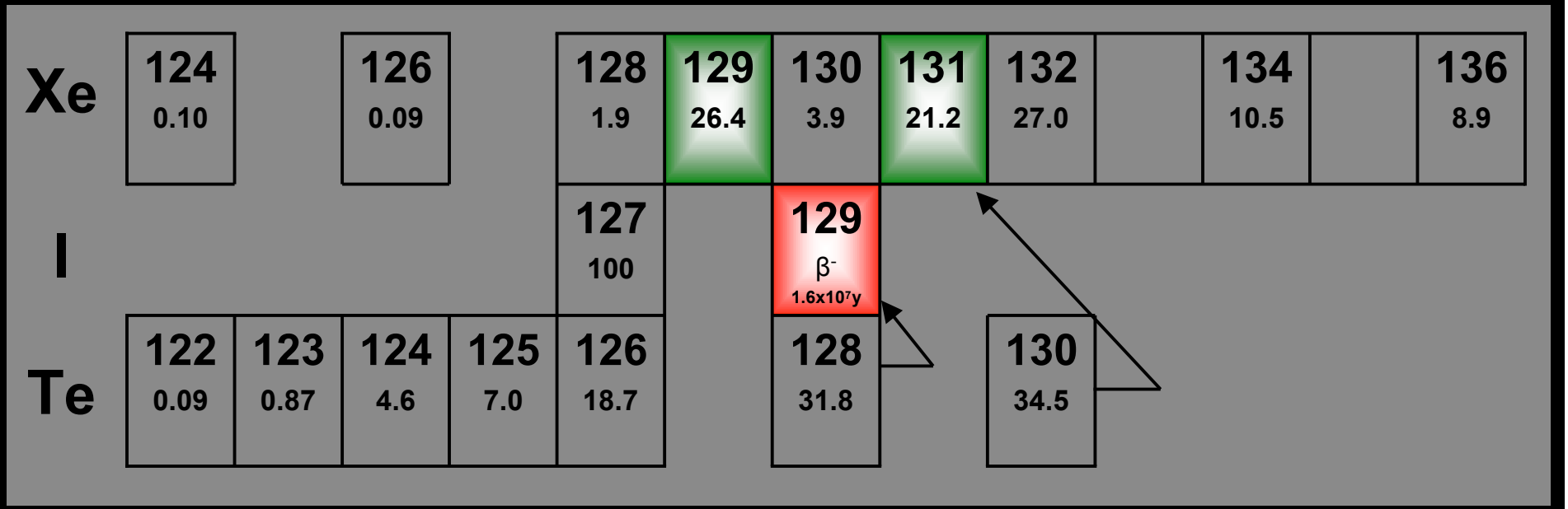
The ^{129}I concentration is given by:

$^{129}I\ (t) = P_{129}/\lambda_{129}\ [1 - \exp(-\lambda_{129} t)]$,

$F(T_{CRE})\equiv[^{129}Xe_c]/[^{129}I]$

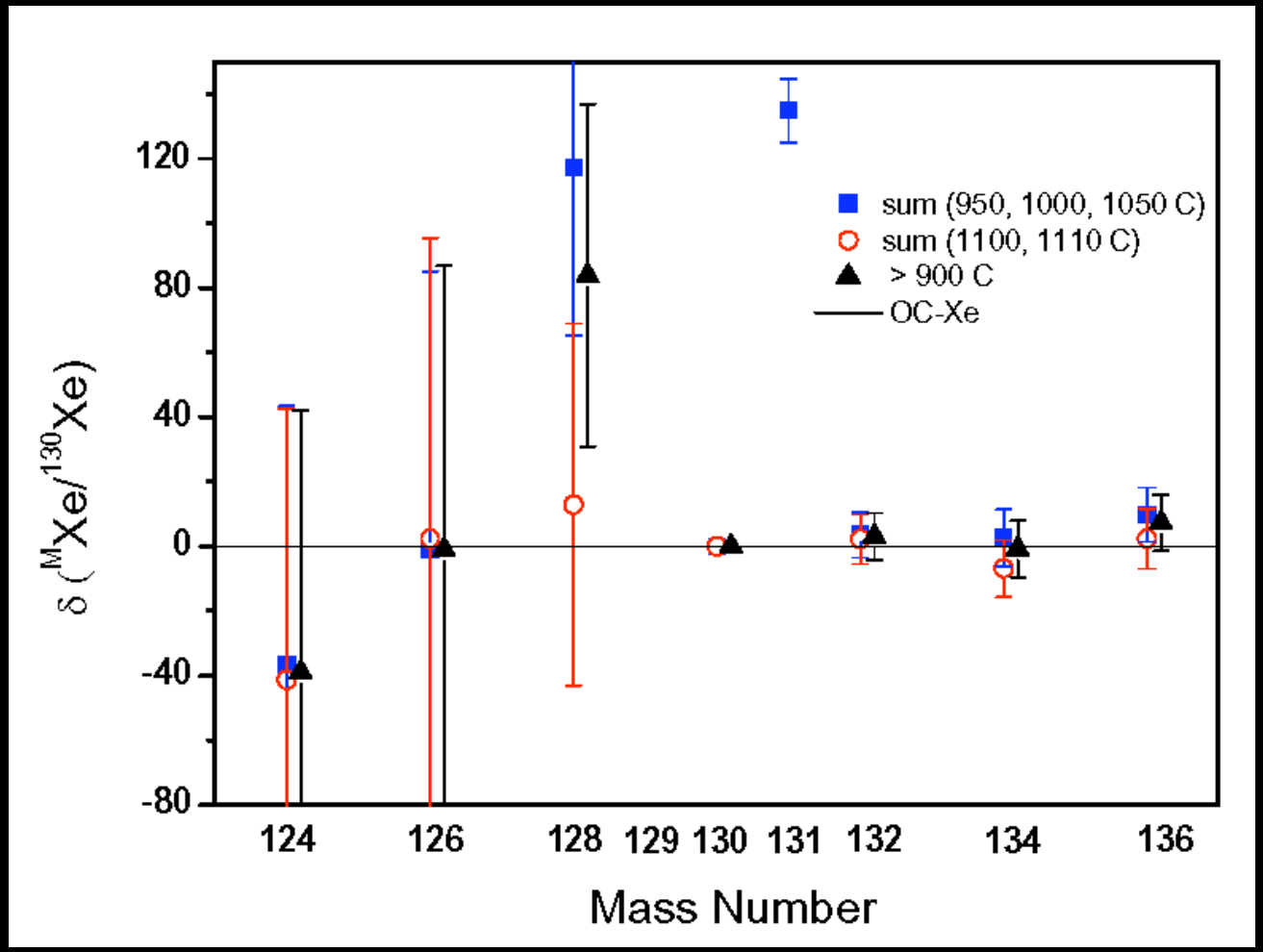
$=\lambda_{129}\, T_{CRE}\ \ [1 - \exp(-\lambda_{129}\, T_{CRE})]^{-1} -1$

I-Xe chronology



Kurt Marti
2007. 2. 28.
Kmarti@ucsd.edu

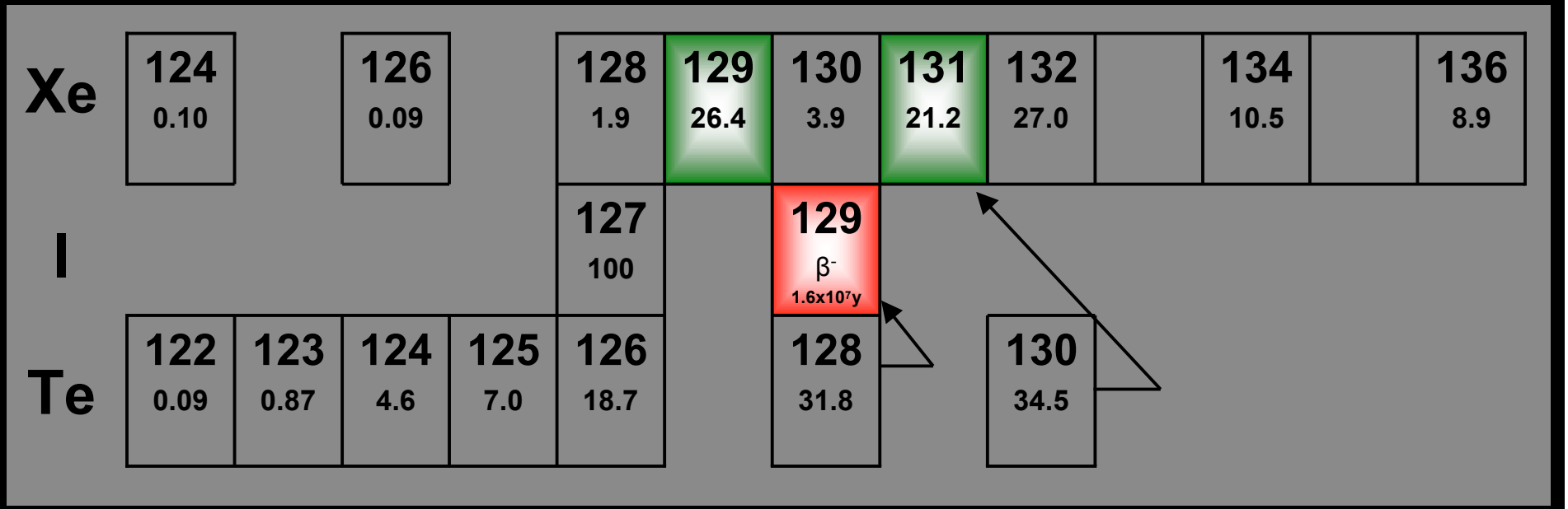
Xe in Cape York troilite



Cape York troilite Xe is normalized to OC-Xe

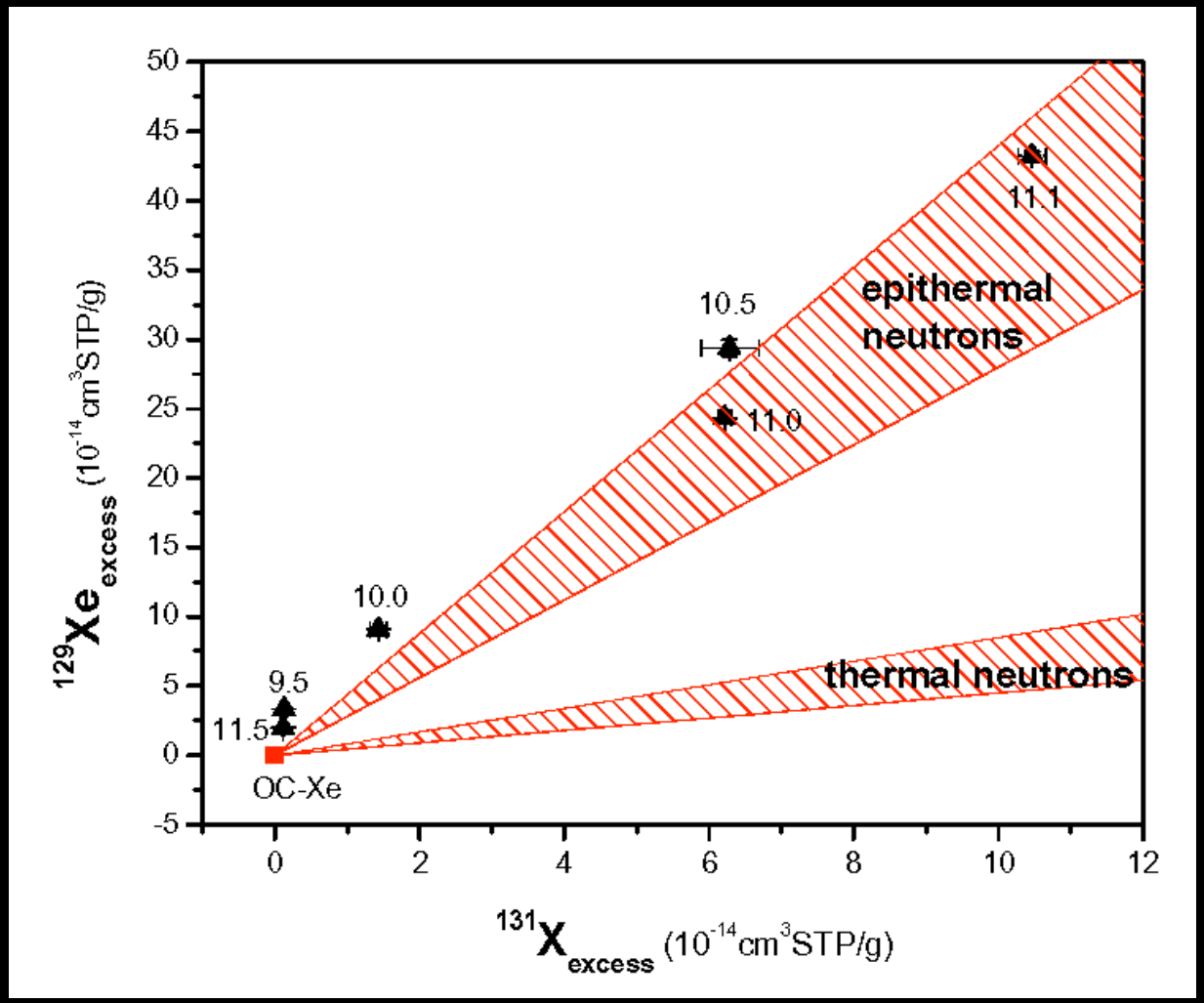
Kurt Marti
2007. 2. 28.
Kmarti@ucsd.edu

Neutron capture in Te



Kurt Marti
2007. 2. 28.
Kmarti@ucsd.edu

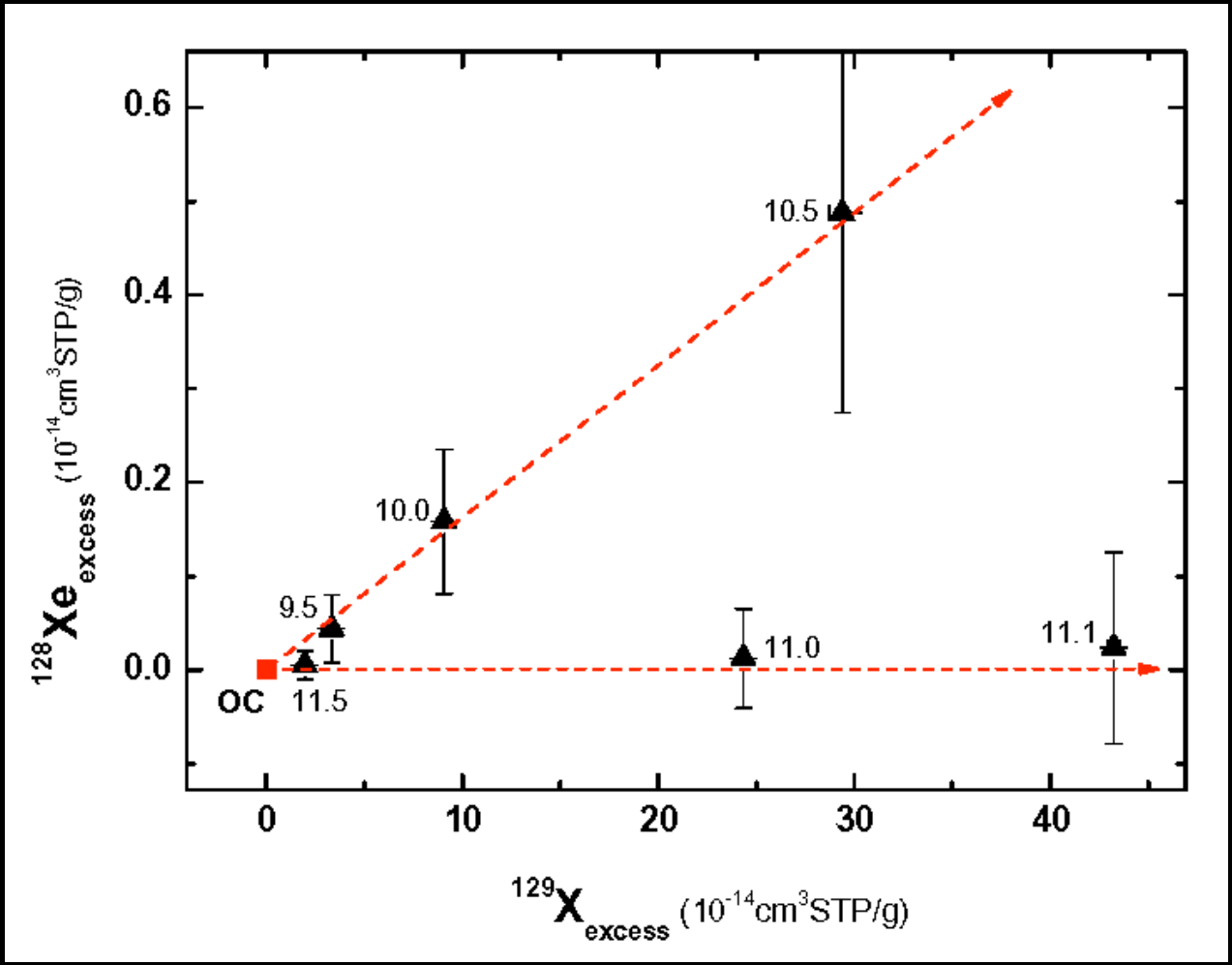
Neutron excesses in Troilite D4



Shifts due to thermal and epi-thermal neutron capture

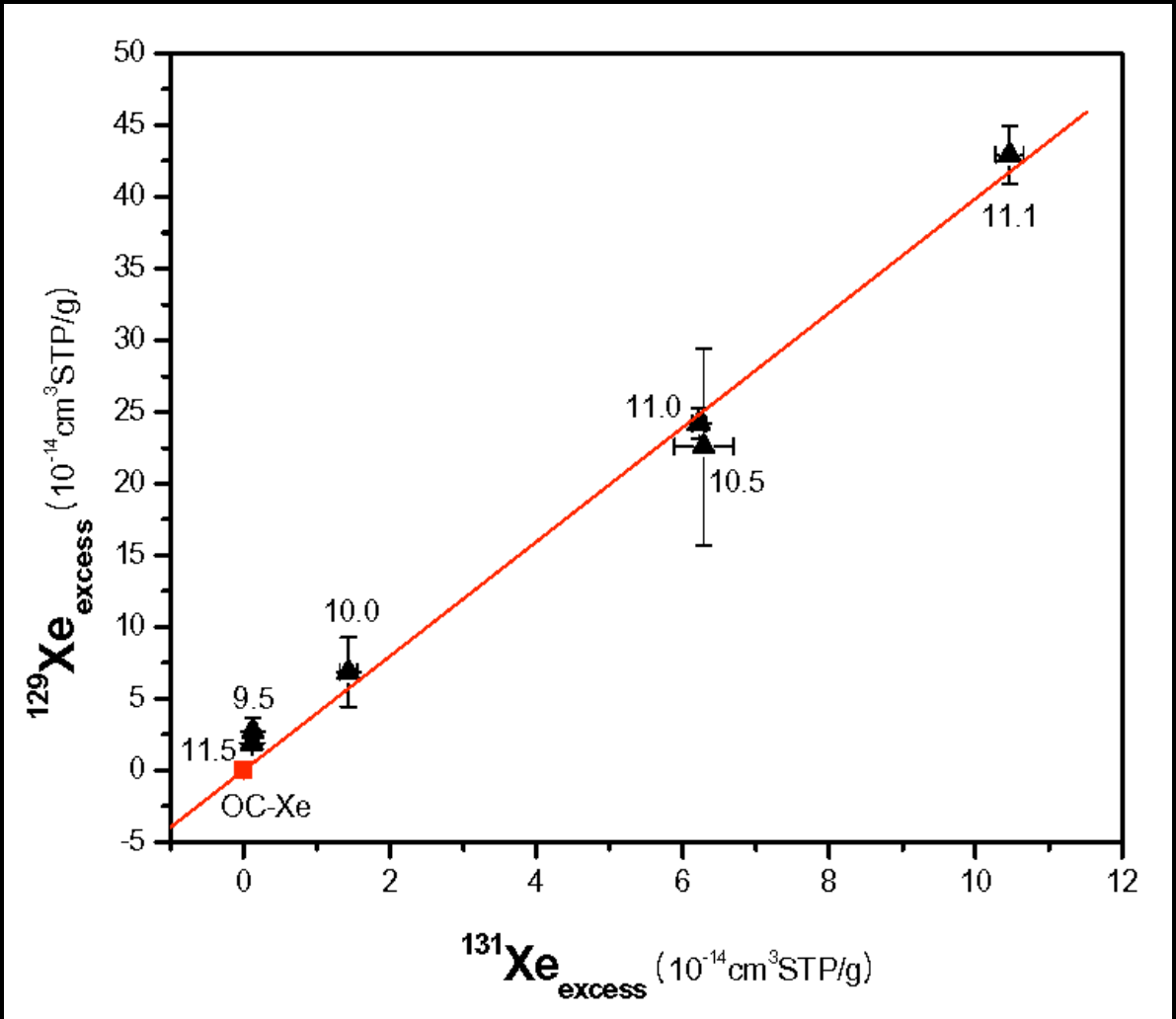
Kurt Marti
2007. 2. 28.
Kmarti@ucsd.edu

Troilite D4, Cape York



Kurt Marti
2007. 2. 28.
Kmarti@ucsd.edu

Xe produced in Te of Cape York troilite

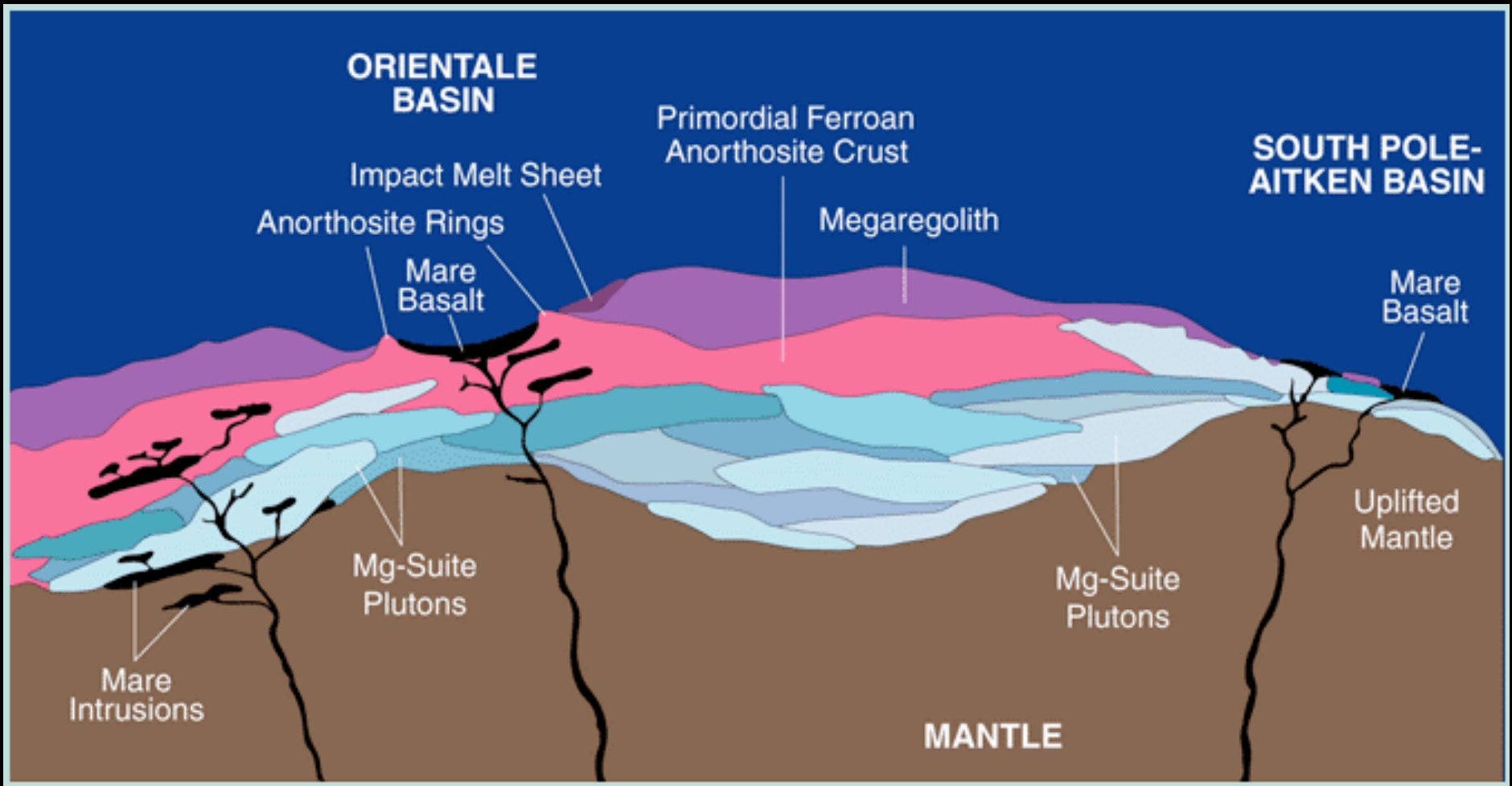


Kurt Marti
2007. 2. 28.
Kmarti@ucsd.edu

^{129}I-^{129}Xe CRE age of Cape York

Troilite	$^{129}Xe_c$ (10^6at/g)	^{129}I (10^6at/g)	$^{129}Xe_c/^{129}I$	CRE age (Ma)
D4	26.5 ± 1.5	9.74 ± 0.55	2.72	**82** ± 7
U1 (Murty and Marti, 1987)	26.8 ±3.2	8.34 ±1.33	3.21	**94** ± 20

[λ_{129} = 4.41 x 10^{-8} a^{-1}]



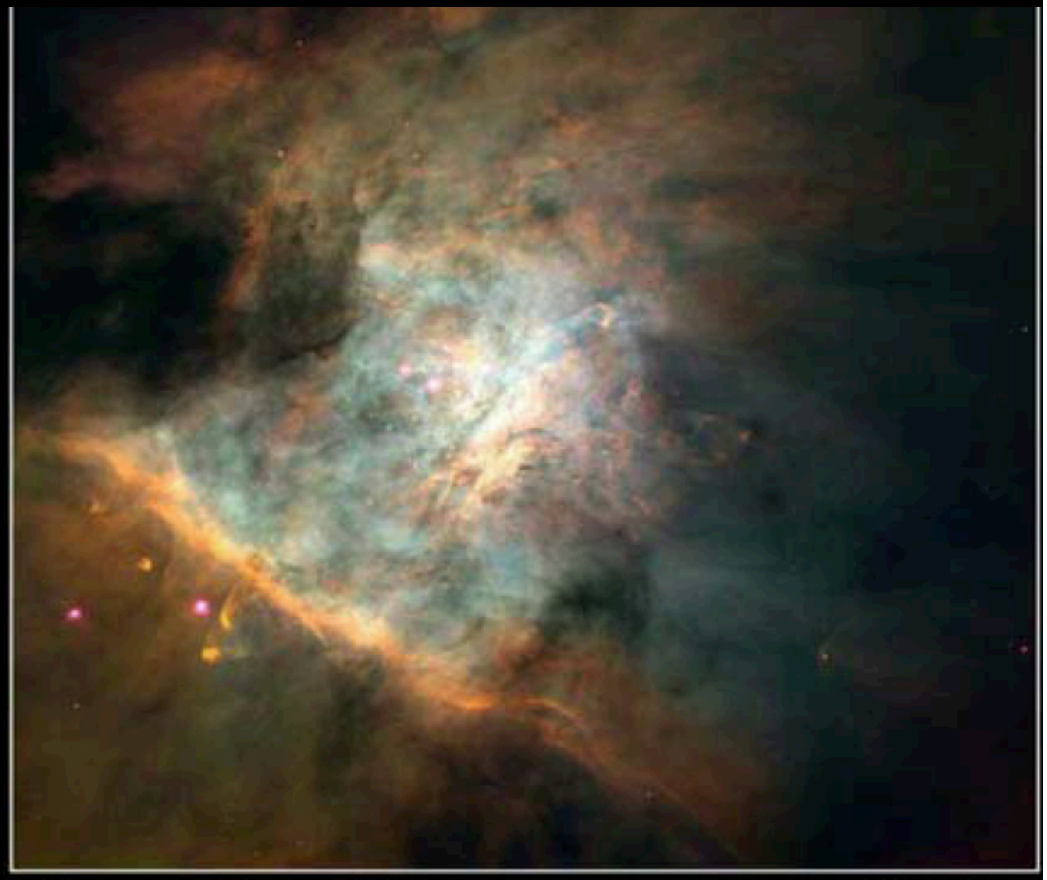
(Graphic by Nancy Hulbirt for PSRD based on a concept by Paul Spudis, APL.)

Graphic by Nancy Hulbirh for PSRD based on a concept by Paul Spudis, APL.

Conclusions

-The intensity of cosmic rays in the inner solar system is observed to vary with time over a variety of time scales. The Sun is the cause of some of these variations, but the observed longer-term variations reflect changes in the local interstellar medium.

- Galactic cosmic rays (GCR) dominate the average intensity of energetic particles above about 200 MeV and are affected by supernova shock waves.



Orion Nebula Mosaic HST • WFPC2

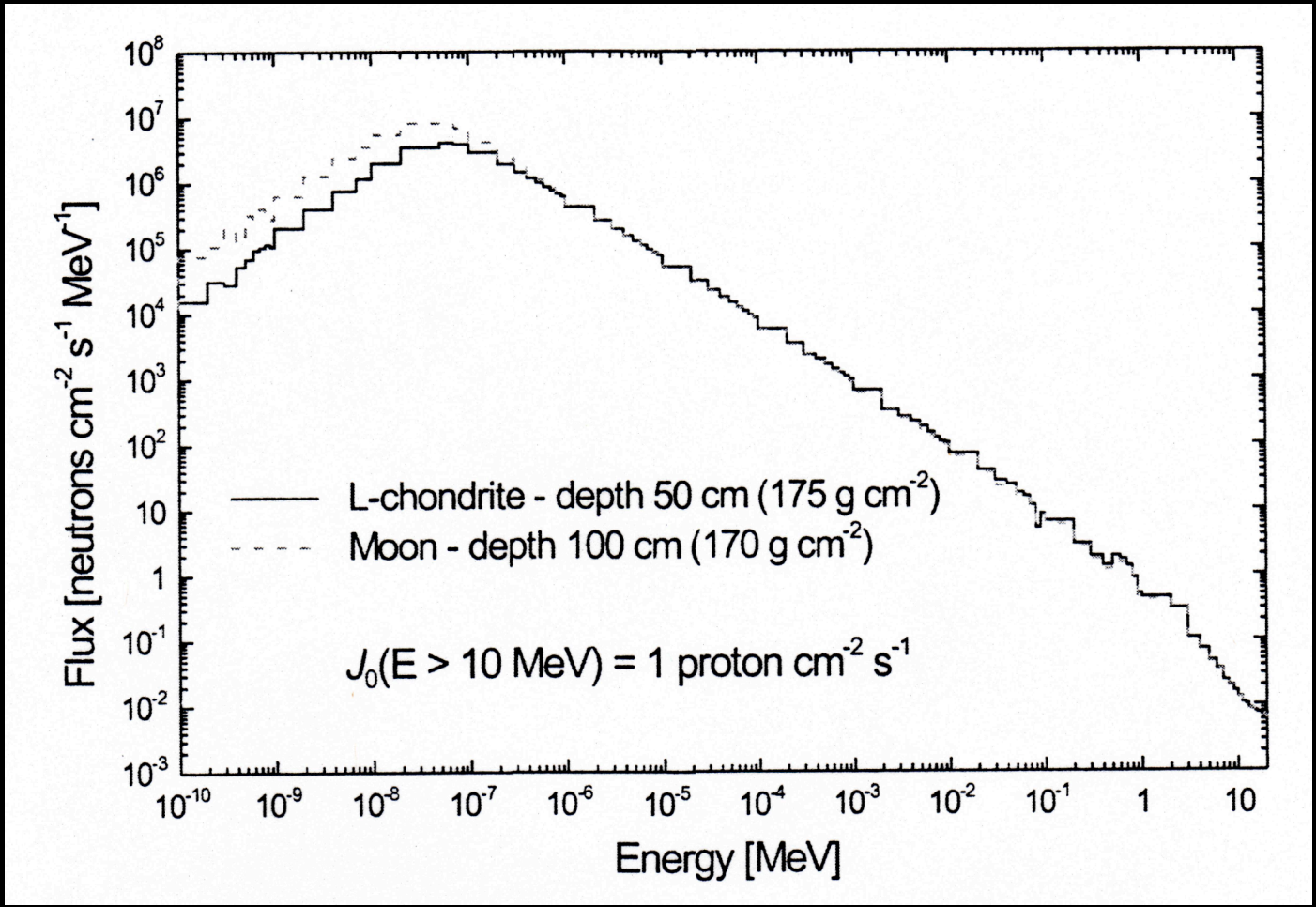
PRC95-45a • ST ScI OPO • November 20, 1995
C. R. O'Dell and S. K. Wong (Rice University), NASA

Conclusions

- The cosmic-ray intensity has been studied using satellites for short-term variations and terrestrial and extraterrestrial materials for the longer-term variations, for the last 1Ma.

- Iron meteorites and lunar rocks are suitable GCR monitors for the last 1 Ga time period. The $^{41}K/^{40}K$ chronometer (1.26 Ga) shows that the flux was smaller than today. $^{81}Kr/^{83}Kr$, $^{53}Mn/^{53}Cr$ and $^{129}I/^{129}Xe$ are studied by the Solar Neighborhood Consortium for flux changes during the past 50 Ma.

Monte Carlo simulation of GCR neutron flux

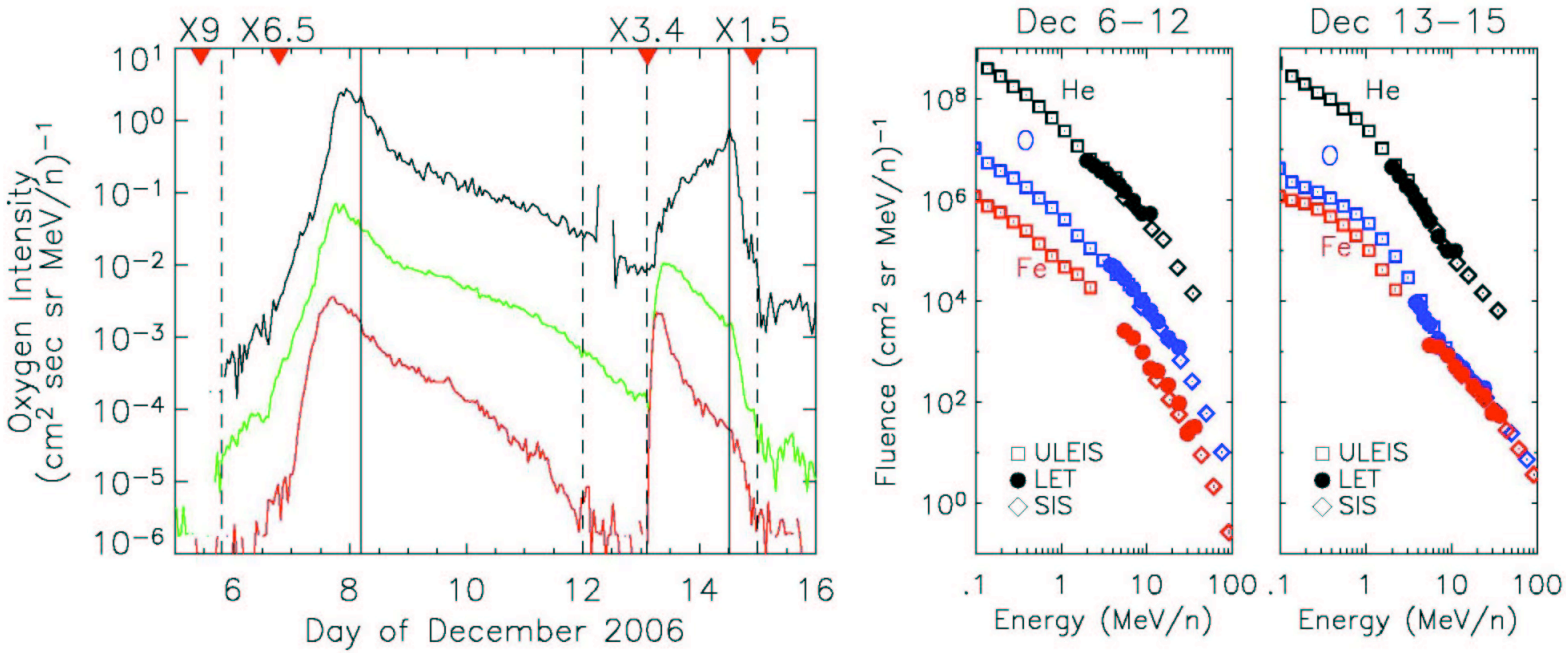


ALH84001

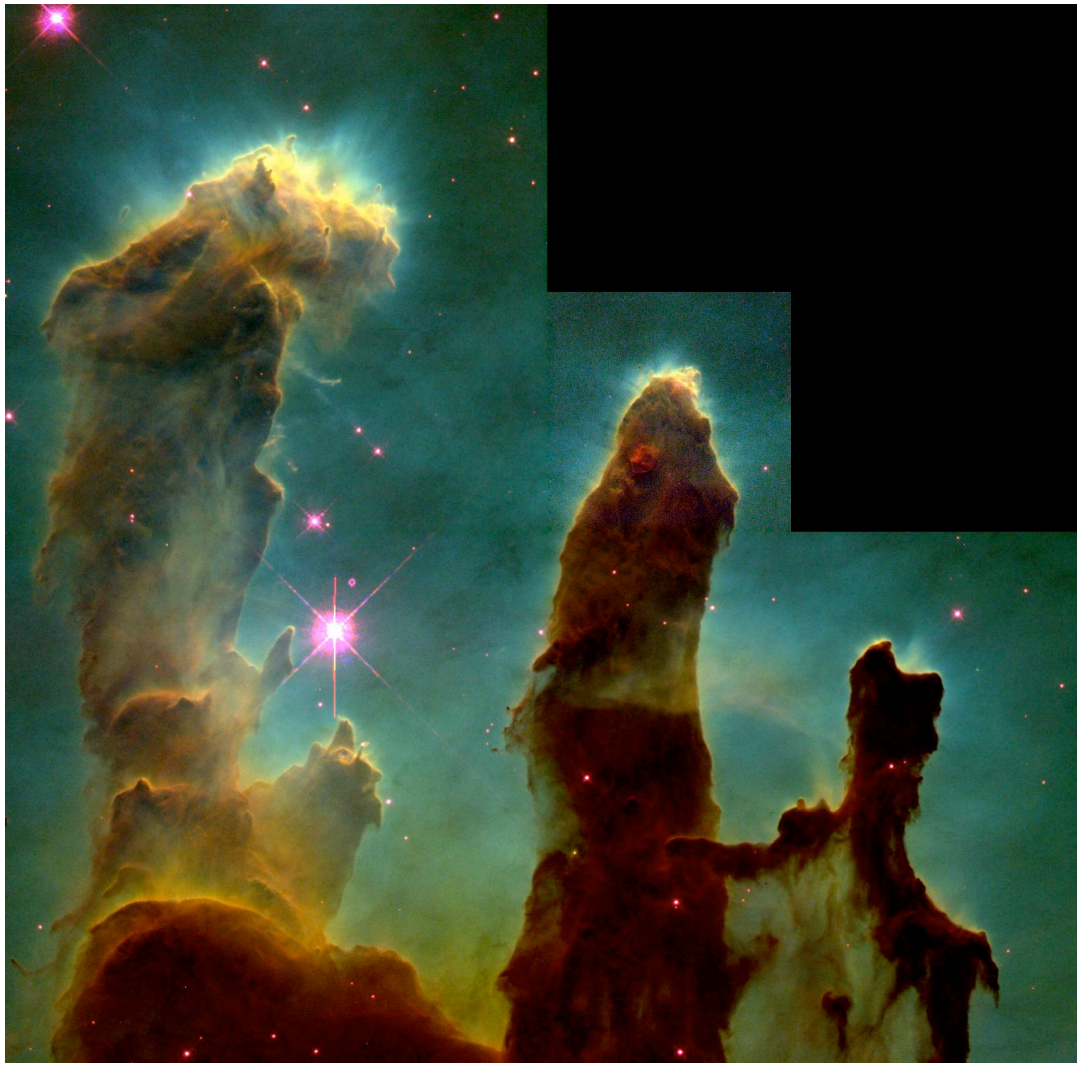
Thank you

Kurt Marti
2007. 2. 27.
Kmarti@ucsd.edu

Kurt Marti
2007. 2. 27.
Kmarti@ucsd.edu



STEREO Joins ACE to Witness the Last (?) Large SEP events of Cycle 23



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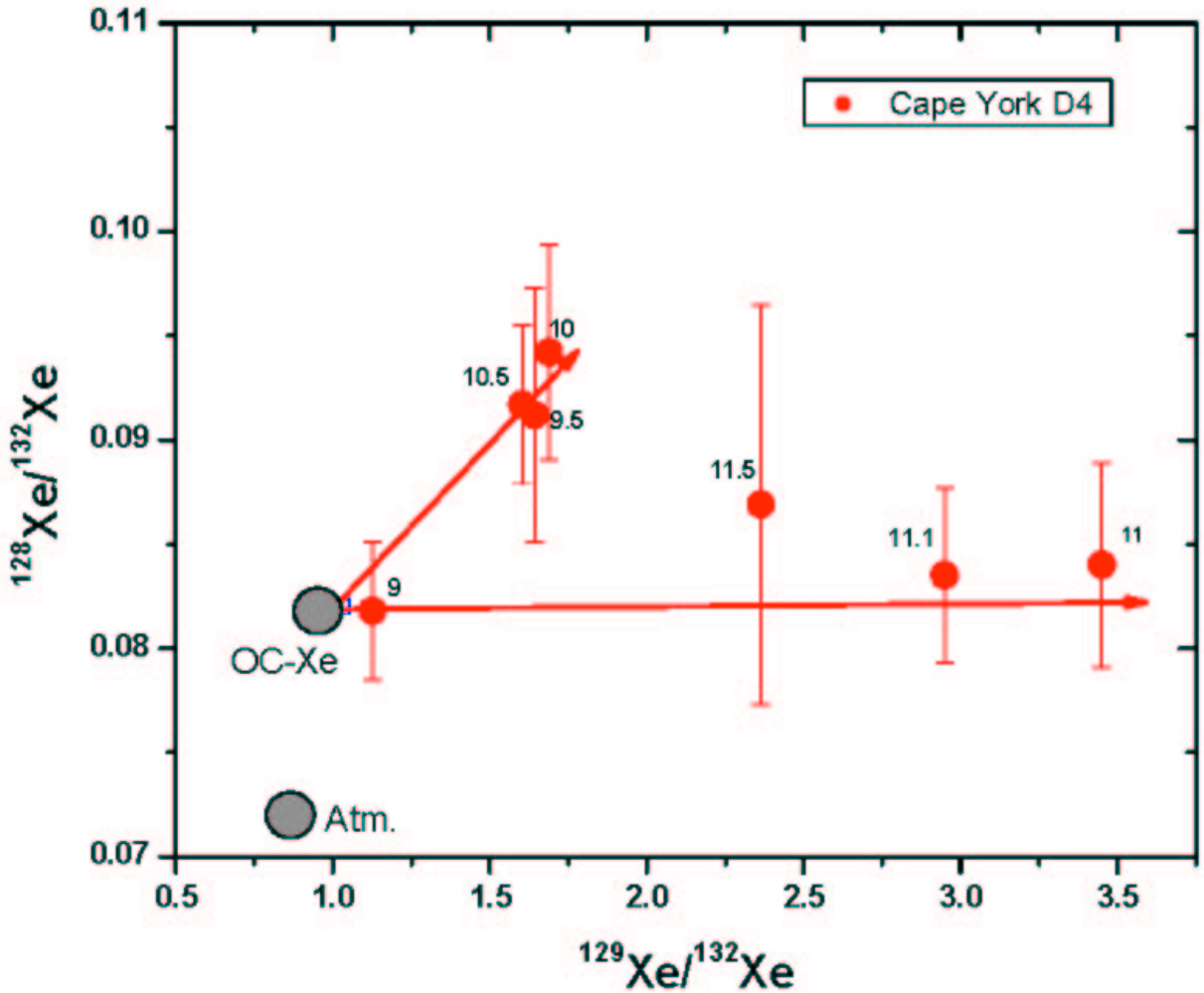
Kmarti@ucsd.edu



Kurt Marti
2007. 2. 27.
Kmarti@ucsd.edu

The Milky Way in Cygnus. Red areas are emission nebulae, where hydrogen is excited by ultraviolet light from hot stars. The one near Deneb, the brightest star, is called the North America Nebula for its shape. A faint curlicue in the lower part is a supernova remnant known as the Veil Nebula.

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