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The Trans-Iron Galactic Element Recorder for the International Space Station (TIGERISS)

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Abstract

TIGERISS is an Ultra-Heavy Galactic Cosmic Ray (UHGCR) detector to be proposed to the NASA Astrophysics Pioneers program capable of measuring the abundance relative to $_{26}$Fe of every element from $_{5}$B to $_{82}$Pb. It is evolved from the LDB TIGER and SuperTIGER balloon instruments and the Heavy-Nuclei Explorer SMEX, and compared to its predecessors, TIGERISS will have a greatly improved capability to definitively identify UHGCR nuclei. This has been demonstrated in component accelerator tests at CERN, including silicon strip detectors in place of scintillators. The geometry factor for TIGERISS is estimated to be from 1.1 to 1.7 m^2 sr depending on the ISS attachment point, compared to 0.6 m^2 sr for TIGER. Within one-year TIGERISS would observe $\sim$27 $_{56}$Ba nuclei, a 20% statistically significant result comparable to the current SuperTIGER data set. Not requiring corrections for atmospheric interactions and scintillator saturation effects the TIGERISS results would be cleaner, and they would also make preliminary measurements to higher charges that will test models for cosmic-ray origins and acceleration. TIGERISS will measure UHGCR nuclei resulting from neutron-capture nucleosynthesis in heavy stars, supernovae, and binary neutron-star mergers and will probe the relative contribution of r-process elements to the cosmic rays.

Ultra-Heavy Galactic Cosmic Ray Science

The TIGERISS goal is to investigate two critically important aspects of the grand cycle of matter in the galaxy:

- The nature of the astrophysical reservoirs of nuclei at the galactic cosmic-ray (GCR) sources (GCRS).
- The mechanisms by which nuclei are removed from the reservoirs and injected into the cosmic-ray accelerators.

Evidence from Galactic cosmic rays indicates their source is drawn from older ISM and the fresh nucleosynthetic products of younger stars, accelerated in shock waves from stellar deaths, support galactic magnetic fields and feed-back into the process of new star formation, as depicted in Figure 1.

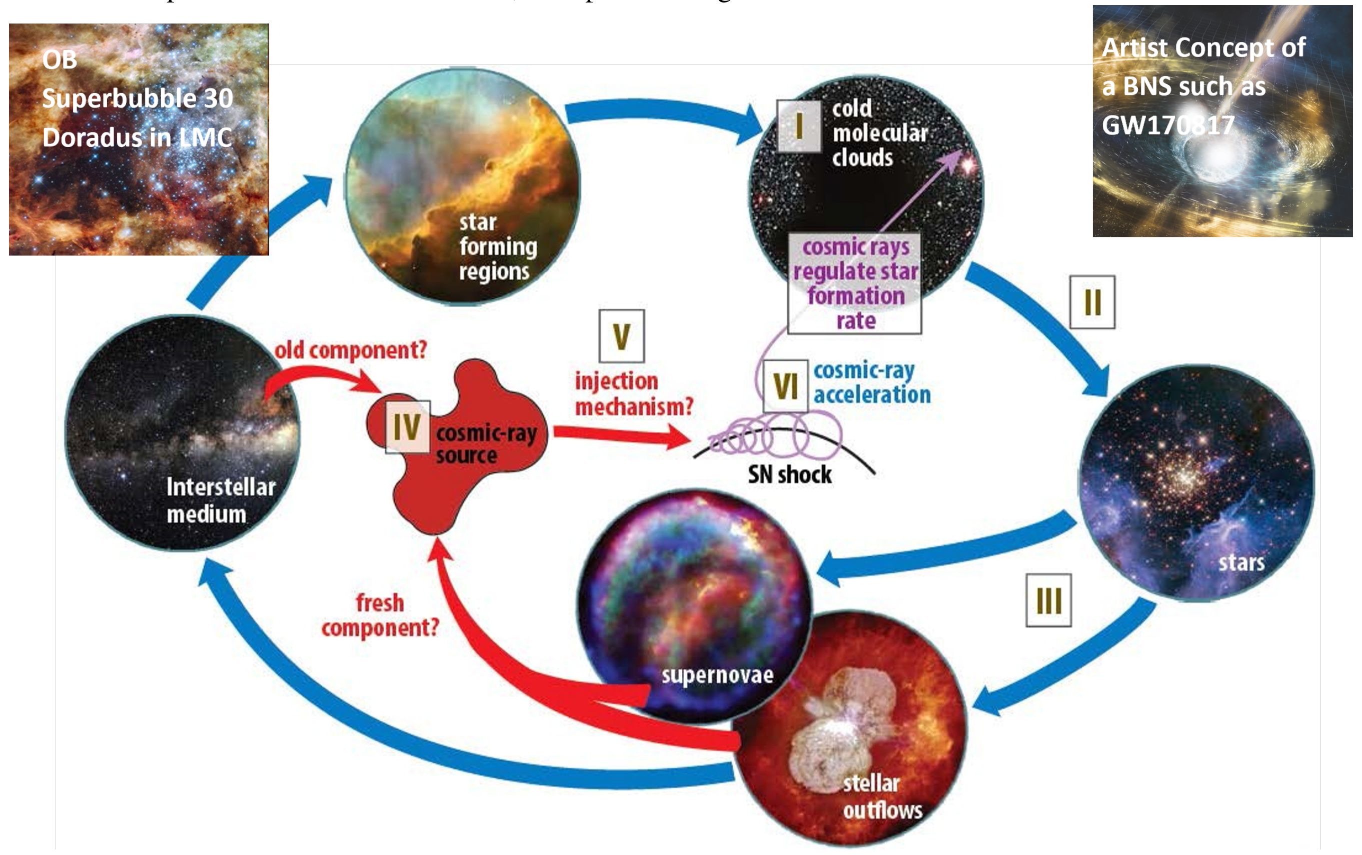

Figure 1: Cosmic cycle of synthesis and distribution Galactic matter showing cosmic rays as both a messenger of fresh nucleosynthetic material and a driver of the cycle.

TIGERISS Instrument

TIGERISS, shown in the left of Figure 2, is an evolutionary development of the TIGER family of instruments that utilizes two basic detector subsystems to unambiguously measure the charge of all GCRs from $_{5}$B to $_{82}$Pb with energies greater than $\sim$ 0.2 GeV/nucleon:

- Silicon strip detector (SSD) arrays in x- and y-layers at the top and bottom of the instrument measure particle trajectories and ionization energy deposits (dE/dx).
- Two Cherenkov (CK) detectors measure nuclear charge (Z) and velocity (β): C1 with an acrylic radiator (optical index of refraction $n = 1.49$) and C0 with a silica aerogel radiator ($n = 1.04$).

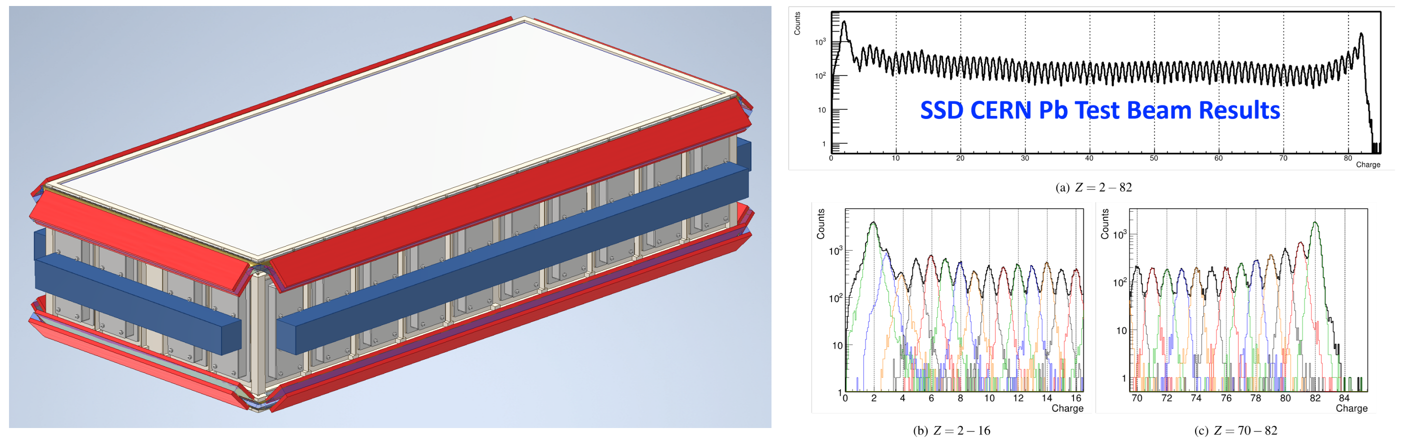

Figure 2: Technical model of TIGERISS detector stack (left). Silicon strip detector (SSD) performance demonstrated in CERN SPS beam tests.

The SSD layers replace the use of scintillators in previous TIGER instruments, as well as the scintillating fiber hodoscopes. The right plot in Figure 2 shows the excellent charge resolution of the SSD.

TIGERISS Science Goals

TIGERISS would be able to address important science goals in the $\sim$1 year it would have on ISS under the NASA Astrophysics Pioneers program, in which time it would make the case for continuing operations under other funding.

- Extend GCR measurements to $_{82}$Pb to test GCRS model in OB associations with preferential injection into the accelerator for refractory elements brought into doubt by preliminary SuperTIGER results through $_{56}$Ba, shown in Fig. 3.
- Determine r- and s-process neutron capture nucleosynthesis contributions to the GCRS and probe for signatures of binary neutron star merger r-process material.

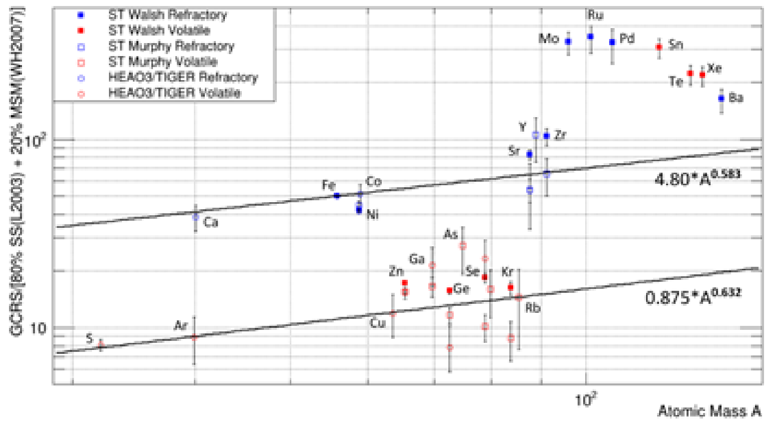

Figure 3: SuperTIGER-2 results through $_{56}$Ba showing that existing model is insufficient for elements above $_{40}$Zn.

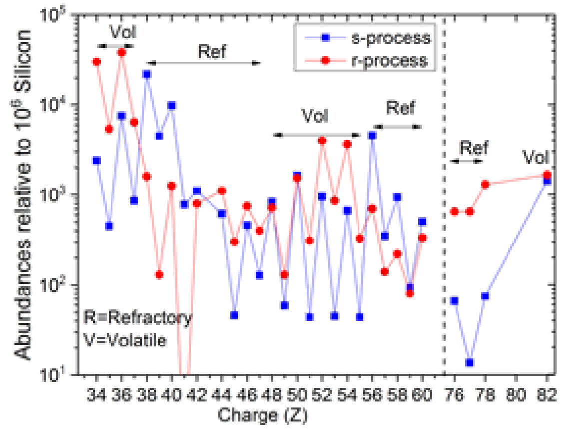

Figure 4: The potential to probe s- and r-process composition

Predicted TIGERISS Results After 1 Year

- The nature of the astrophysical reservoirs of nuclei at the galactic cosmic-ray (GCR) sources (GCRS).
- The mechanisms by which nuclei are removed from the reservoirs and injected into the cosmic-ray accelerators.

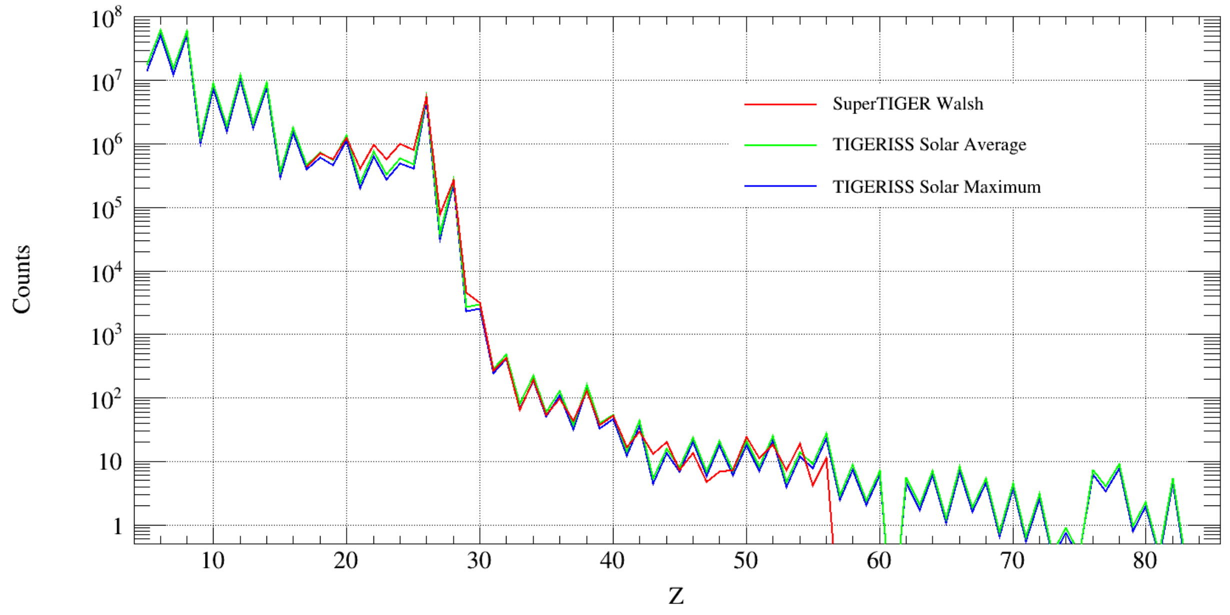

Figure 5: Predicted abundances measured by TIGERISS after 1 year of operation are comparable to those measured by SuperTIGER over its 55 day long-duration-balloon flight [1].

Predicted Abundances After 5 Years

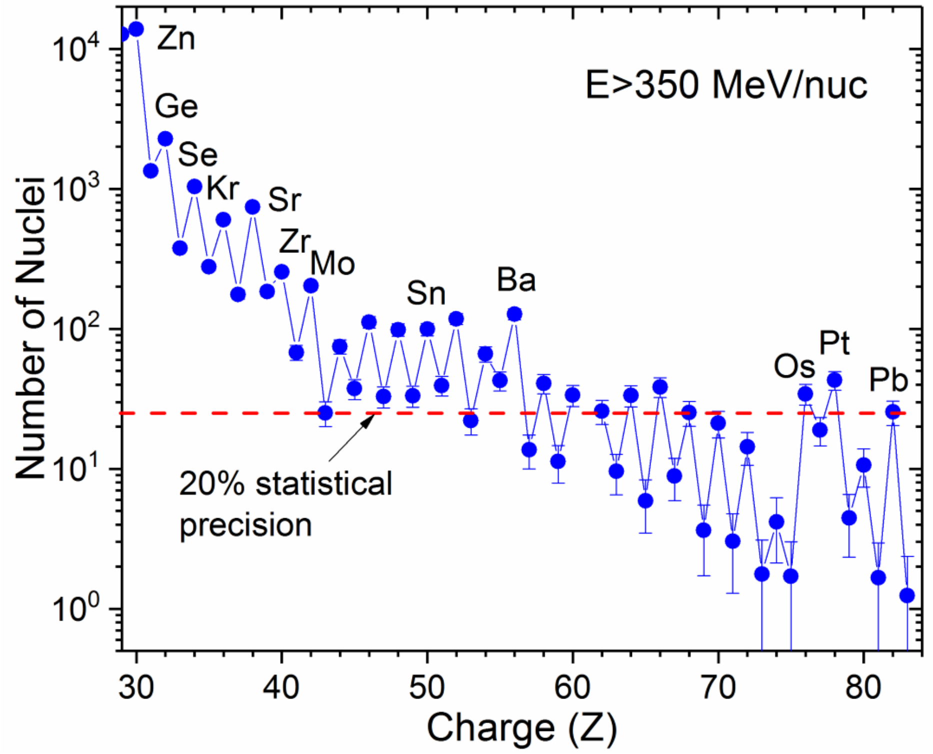

Figure 6: Predicted abundances measured by TIGERISS after 5 years of operation.

References

[1] N. E. Walsh. *SuperTIGER Elemental Abundances for the Charge Range 41 ≤ Z ≤ 56*. PhD thesis, Washington University in St. Louis, 2020.