SuperTIGER: Probing Galactic CR Origins

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SuperTIGER Collaboration

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Goddard

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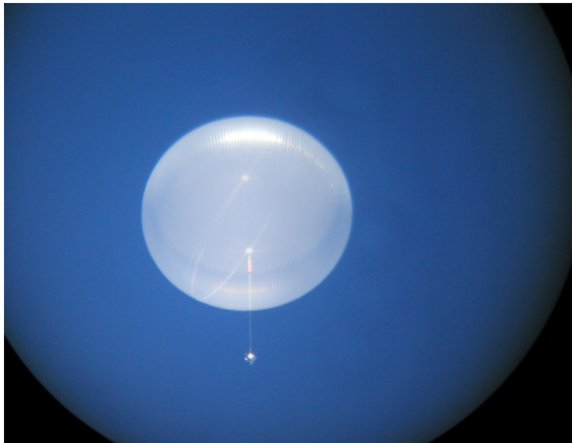
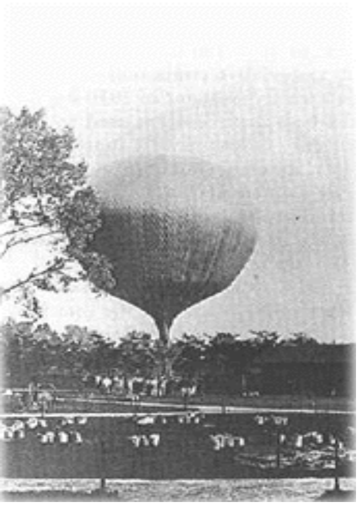




Origins?

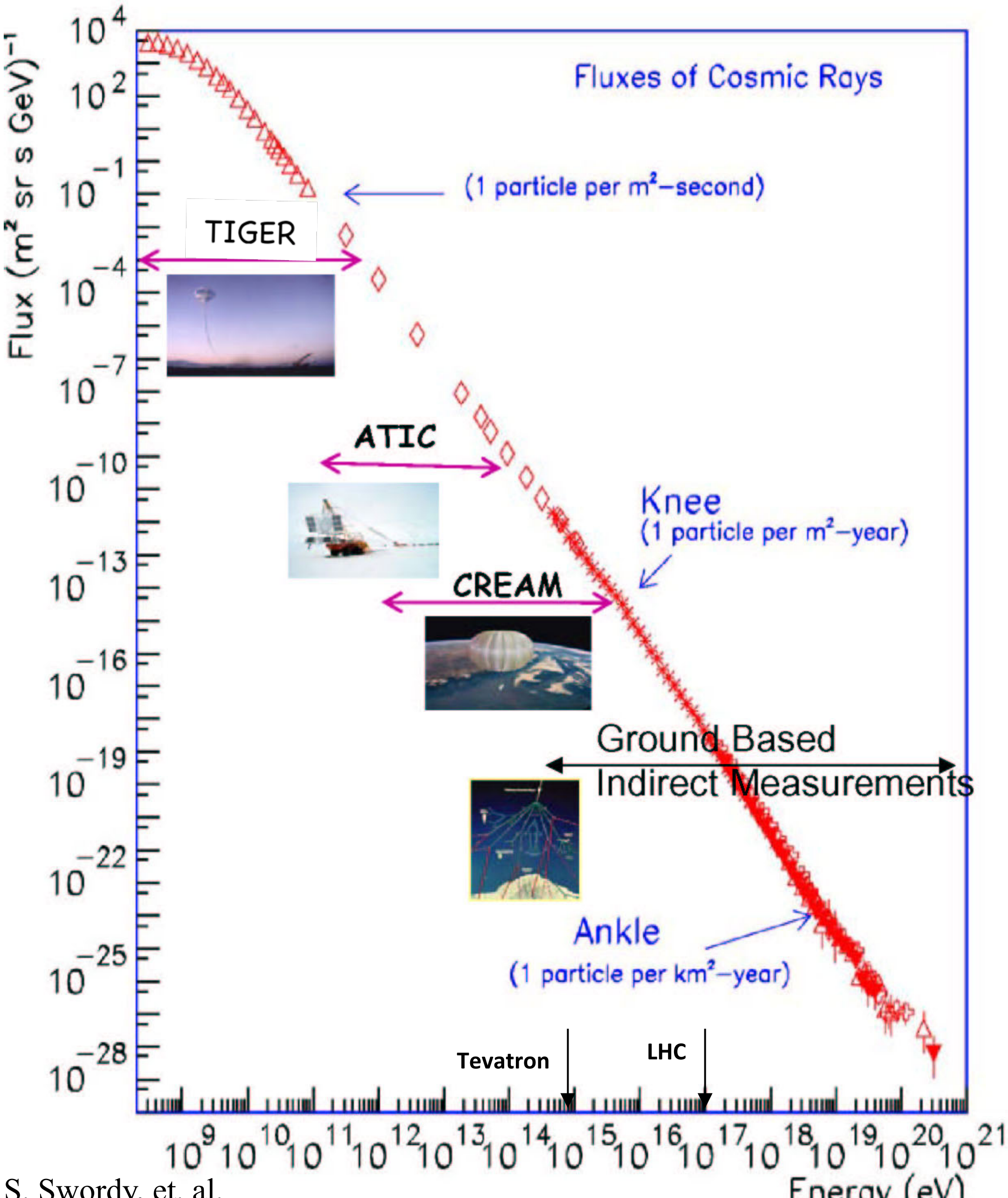
TIGER launch

Acceleration?

Propagation?

National Geographic

All-Particle CR Spectrum



S. Swordy, et. al.

Cosmic rays are:

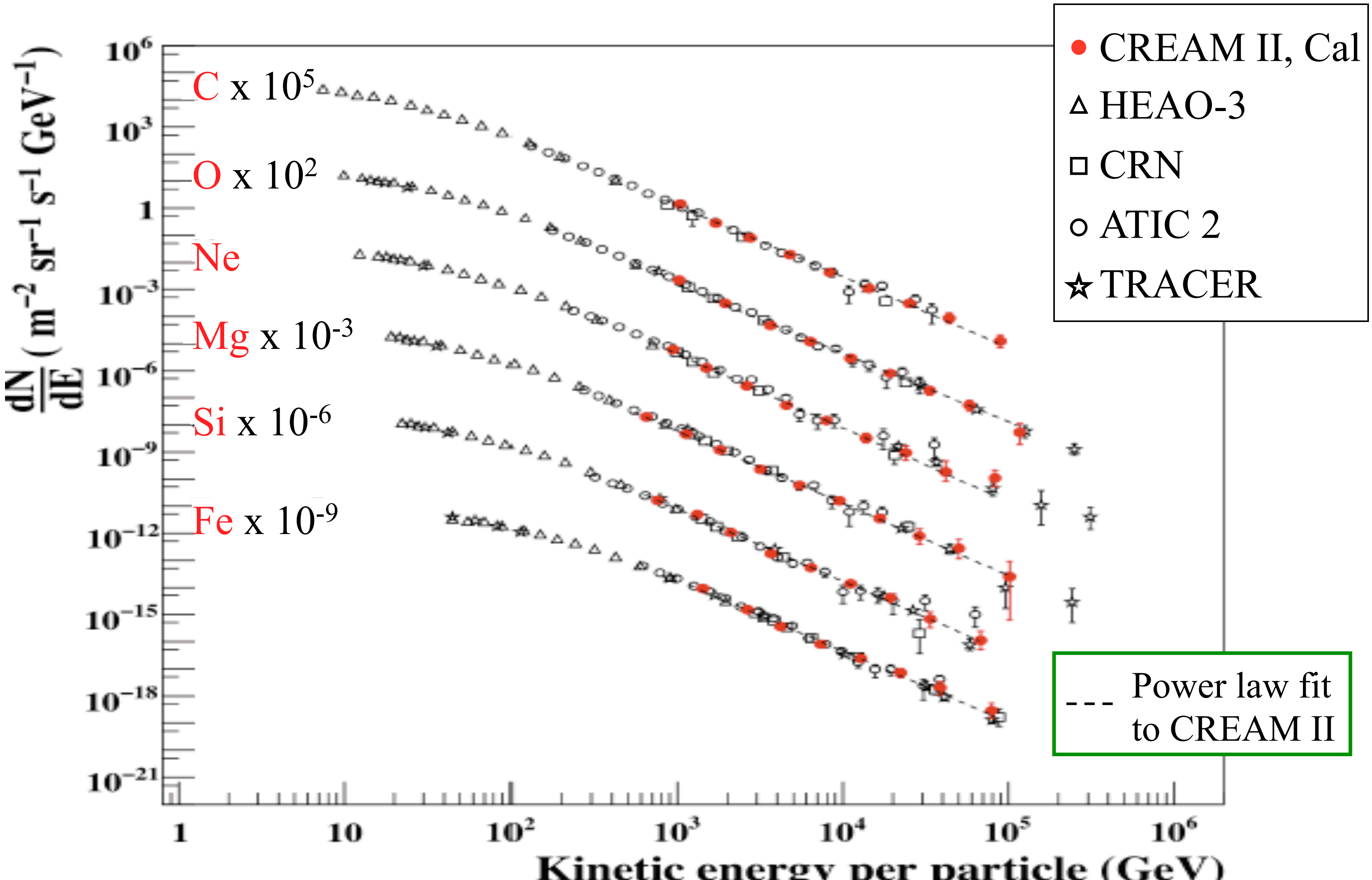
- charged nuclei from outer space (V. Hess, 1912)
- { ~90% Hydrogen; ~9% Helium; ~1% $Z > 2$ }

Spectrum falls as:

- **$dF/dE \propto E^{-\alpha}$**
- $\alpha \approx 2.7$

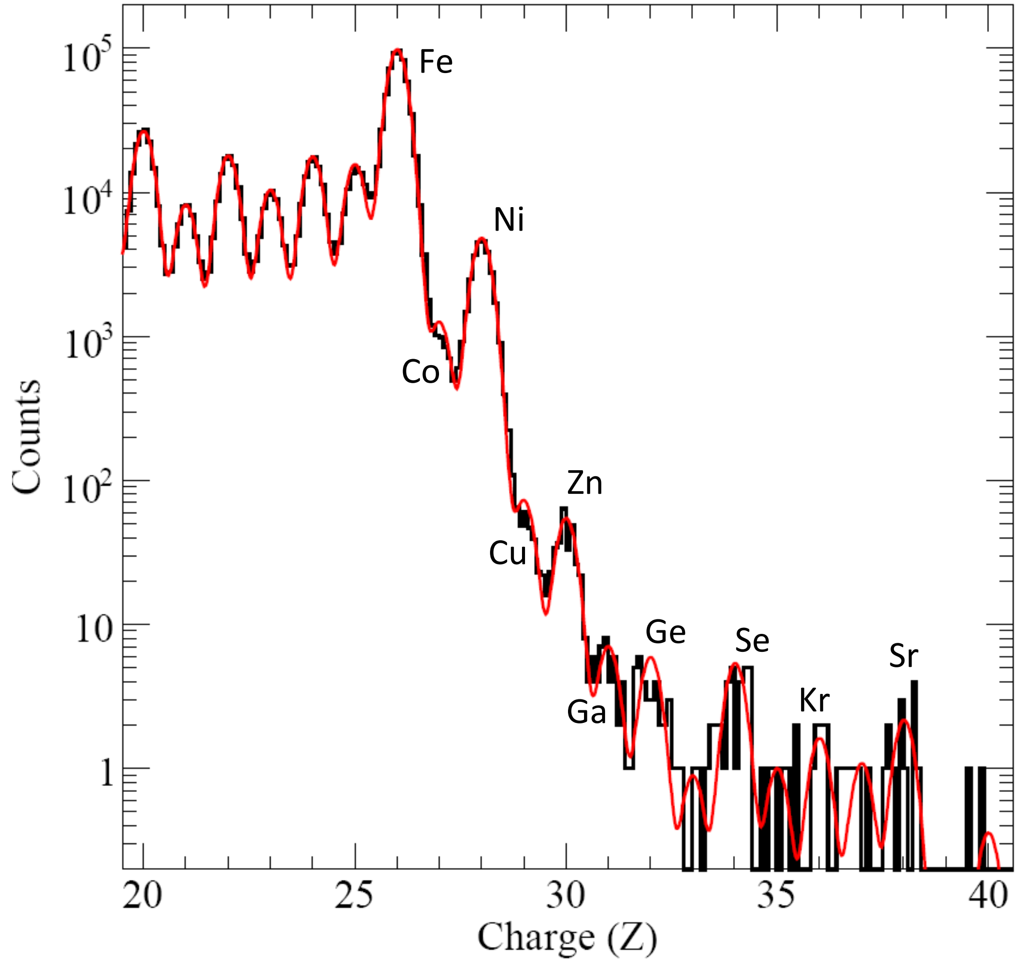
for $\sim 10^9$ eV $< E < 10^{15}$ eV

Primary Nuclei Spectra



Ahn, et al. ApJ 2009

TIGER Results: 50 days' Data



TIGER:

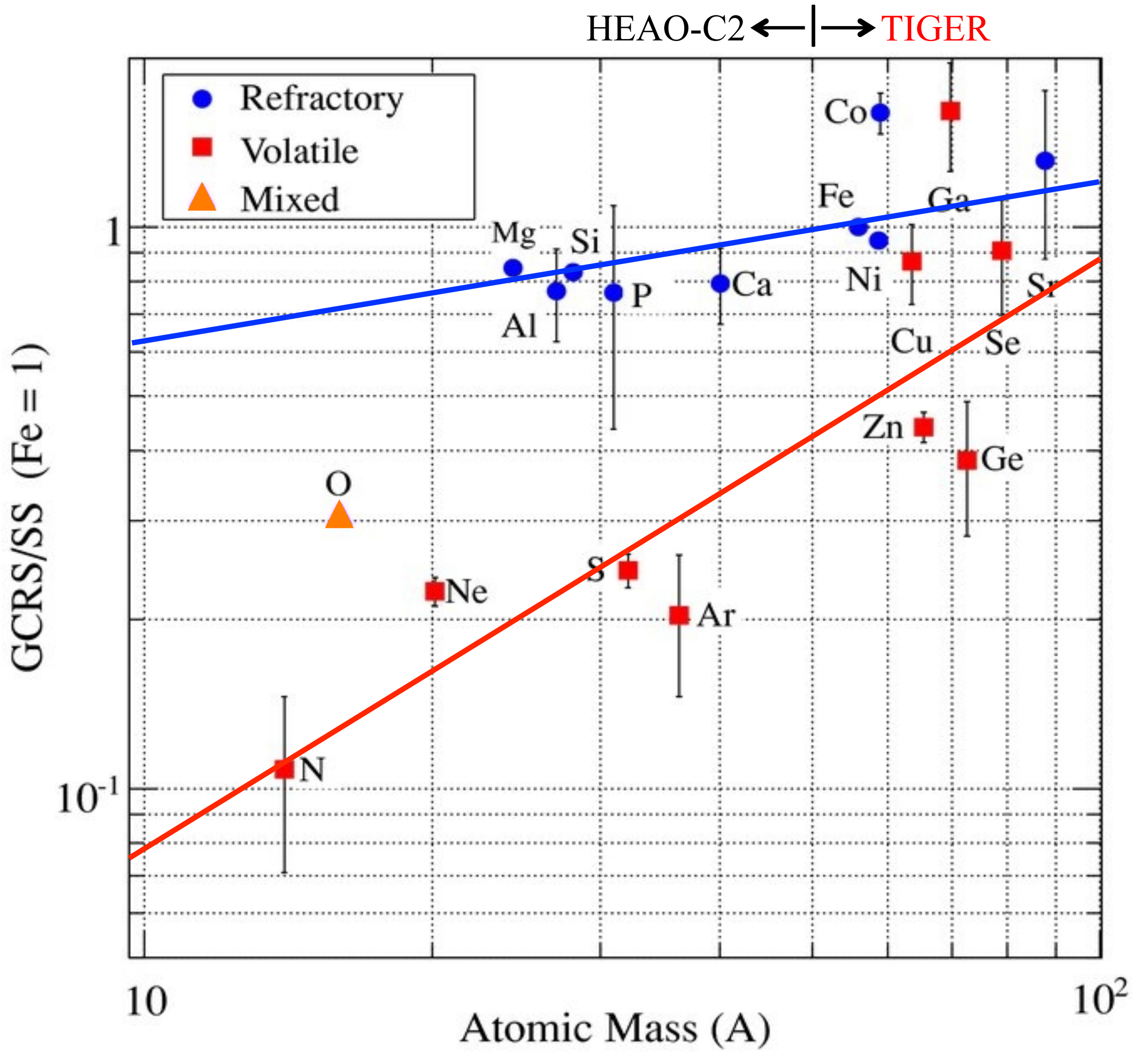
- good charge resolution: σ=0.23
- ~10 Sr events (Z=38)
- Continued even-odd effect => stellar origin
- Poor statistics at higher charges

Super-TIGER:

- ~8.7x TIGER events

B. F. Rauch et al. 2009 ApJ 697

TIGER Results: 50 days' Data



- Refractory: found in interstellar dust
- Volatile: low boiling point

CR Source:

- ~ solar system

Acceleration:

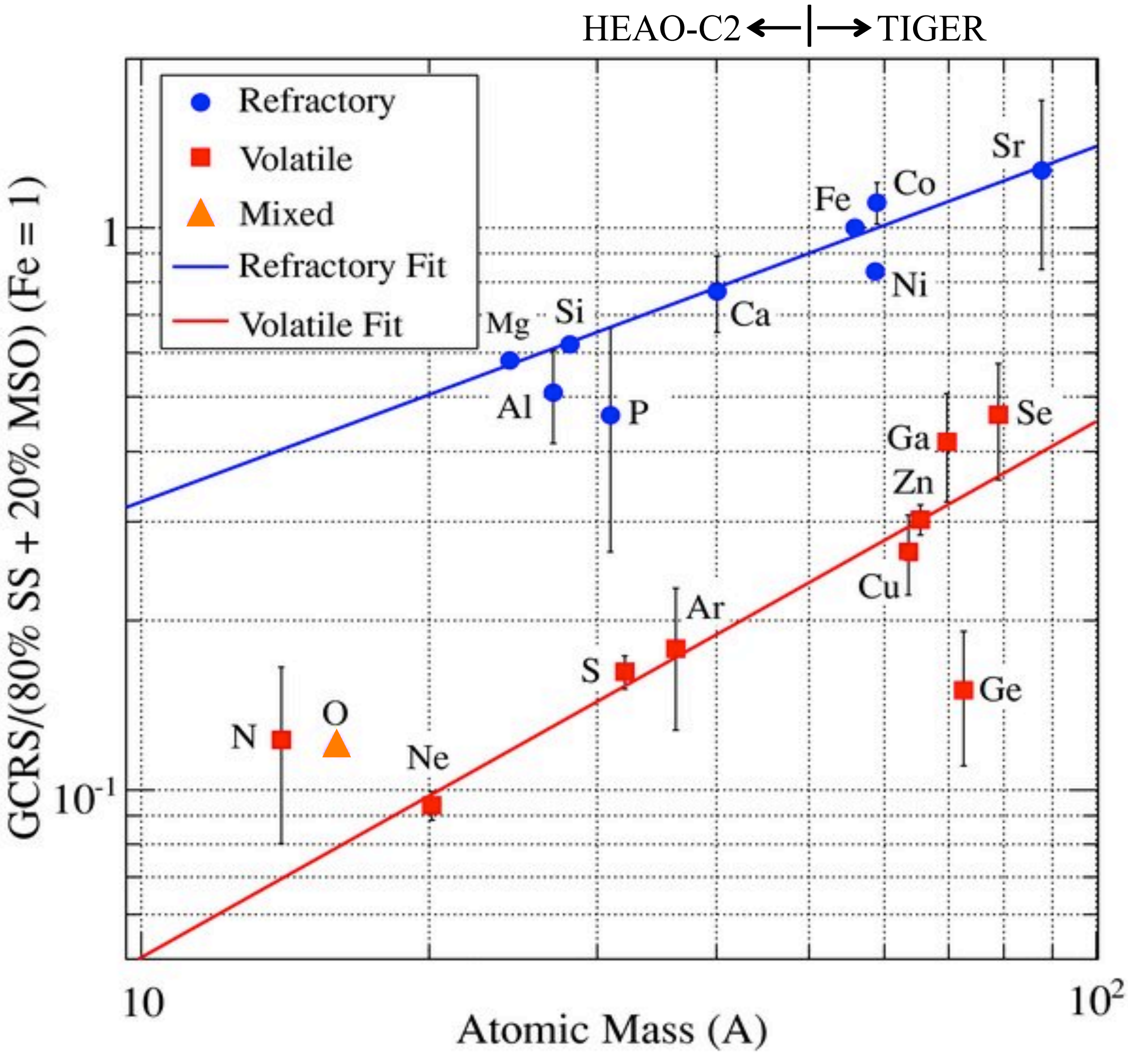
- Preferential acceleration of refractories… ?
- Mass-dependent acceleration of volatiles… ?

Fix?

- Higdon+Lingenfelter (ApJ '03) showed ACE-CRIS $^{22}Ne/^{20}Ne$ consistent w mix ~80% SS + 20% massive star ejecta

B. F. Rauch et al. 2009 ApJ 697

TIGER Results: 50 days' Data



- Refractory: found in interstellar dust
- Volatile: low boiling point

CR Source:

- ~ 20% massive star ejecta
- ~ 80% solar system

Acceleration:

- More efficient for refractories than volatiles
- Mass-dependent:
  - refractory ~ $A^{2/3}$
  - volatile ~ A^1

Check:

- ~12% O sequestered in dust grains
- O excess is ~12% of the expected abundance for a refractory at A=16

T. J. Brandt

B. F. Rauch et al. 2009 ApJ 697

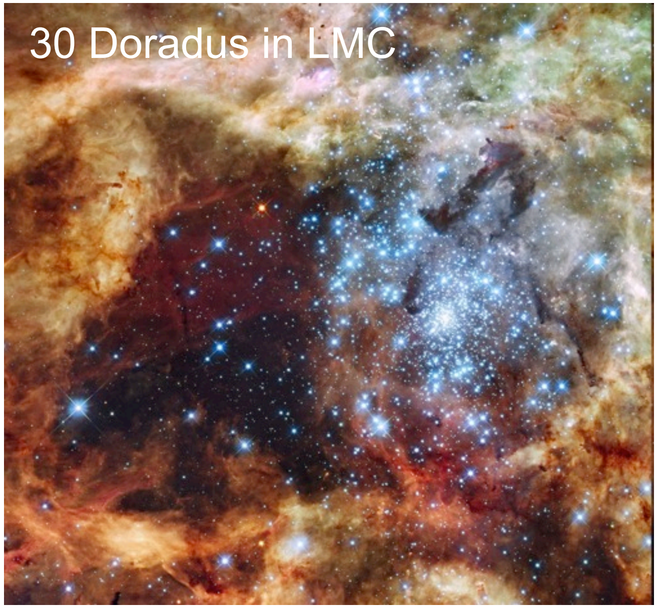
SuperTIGER Science Objectives

Primary objectives:

- Determine origin of galactic CRs by
  - measuring composition of CRs $26 \leq Z \leq 42$ with good statistics and individual element resolution
  - making exploratory measurements to $Z \approx 56$
- Test mass-dependent acceleration
- Test the OB association source model for galactic CRs

Secondary objectives:

- Measure energy spectra of CRs $10 \leq Z \leq 28$ with $E = 0.3 - 10$ GeV/nuc
- Search for evidence of nearby microquasars



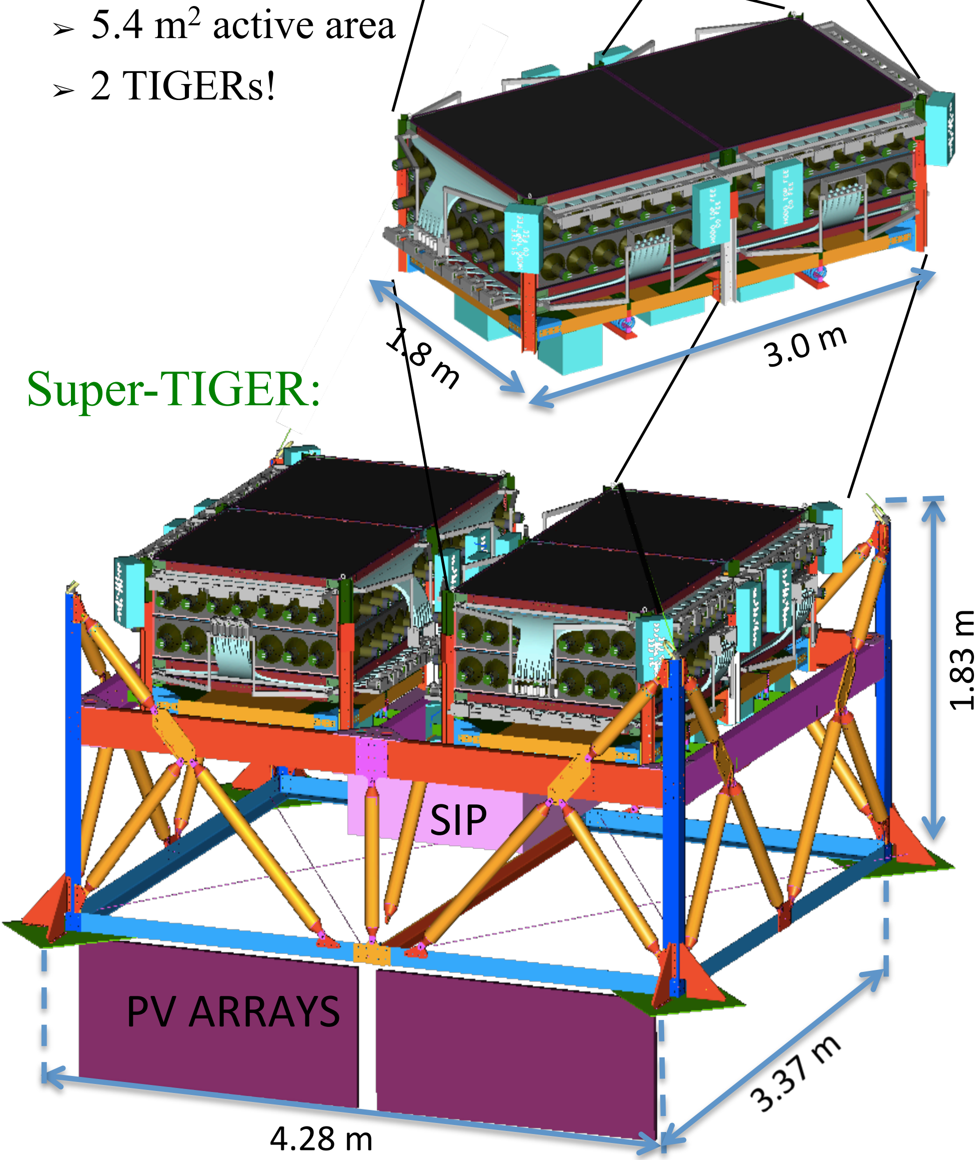
NASA, ESA, F. Paresce, R. O'Connell, & the HST WFC3HST SOC

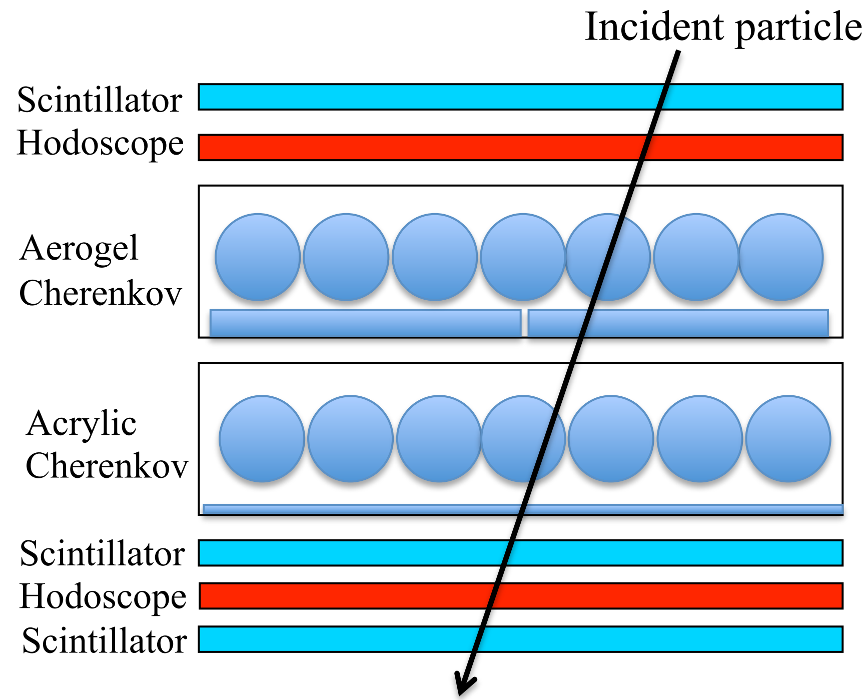
Gemini Observatory, AURA, NSF

(Super-)Trans-Iron Galactic Element Recorder

Single Super-TIGER module:
- 5.4 m^2 active area
- 2 TIGERs!

TIGER



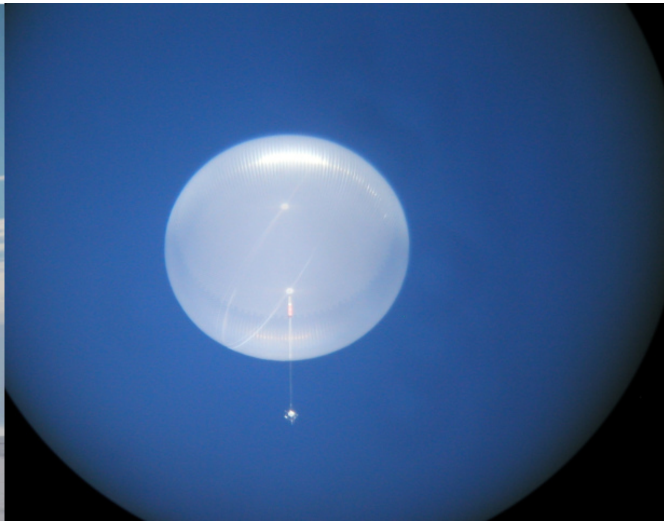


Scintillator:
- $dE/dx \propto Z^2/\beta^2$

Cherenkov:
- $dE/dx \propto Z^2/(1-n_i/\beta^2)$

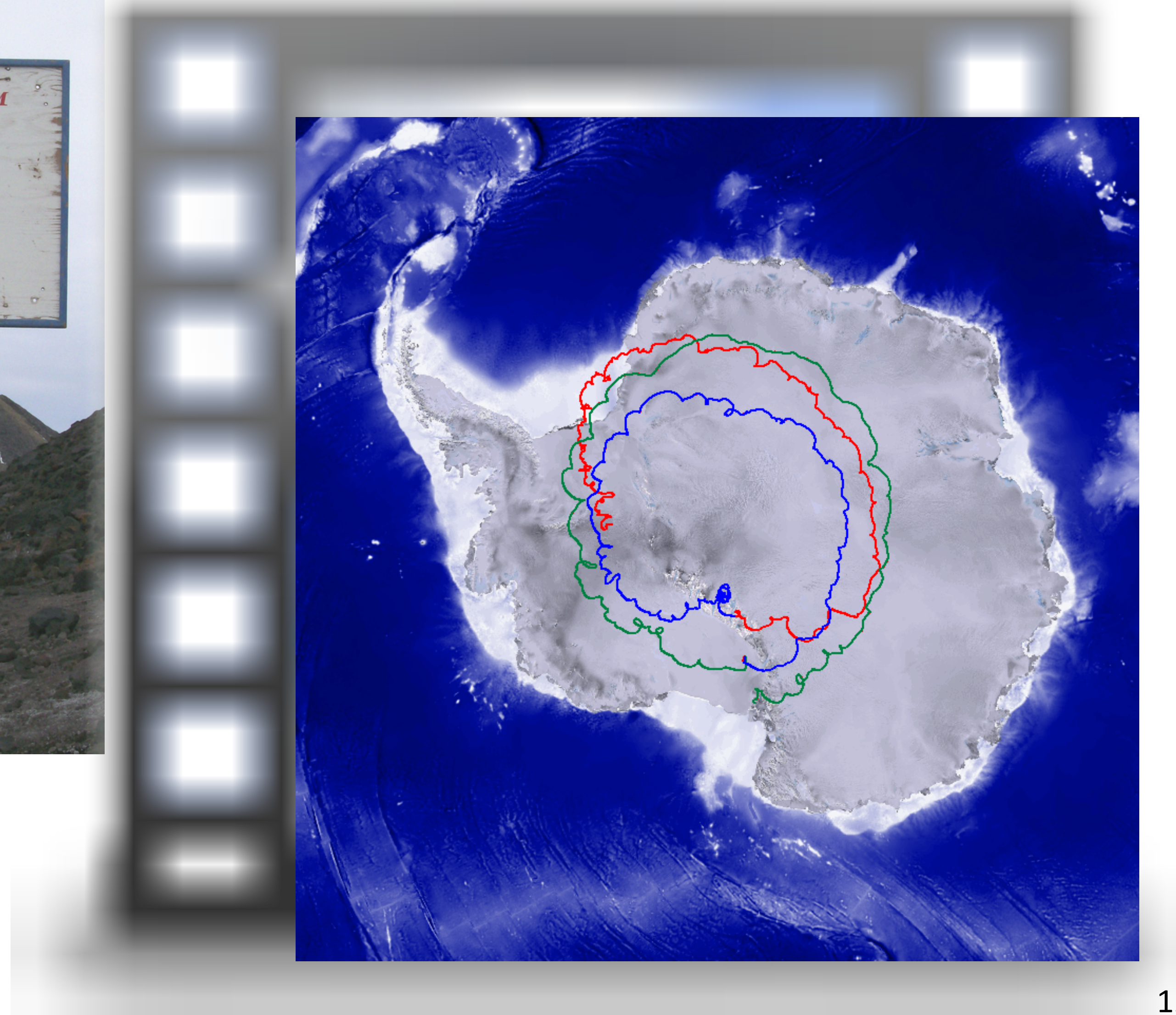
Extract Z, β from combinations of Scintillator and Cherenkov signals

SuperTIGER Launch



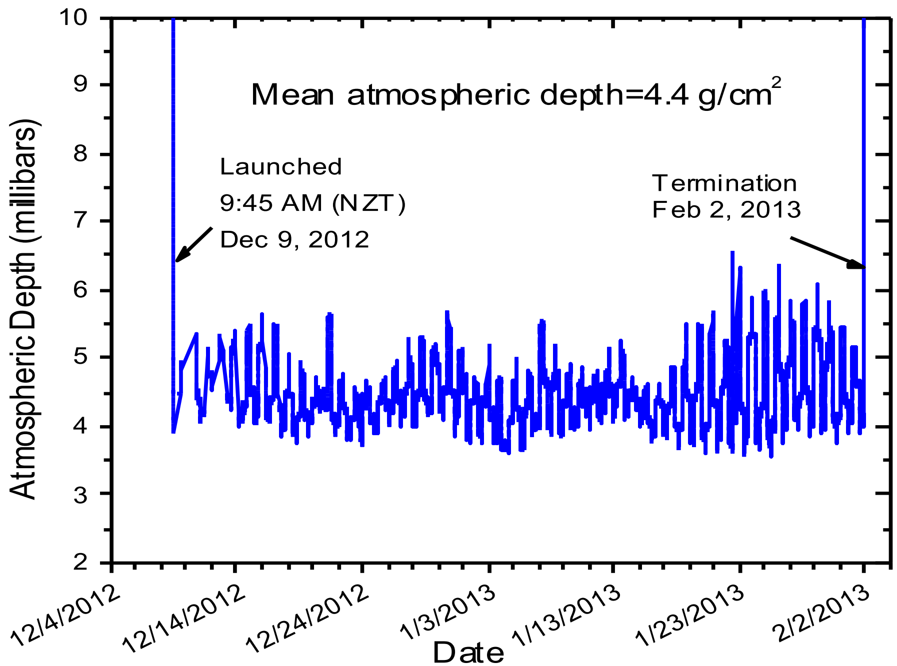
Liftoff at 09:45 am NZDT Dec 9th, 2012—A perfect launch day!

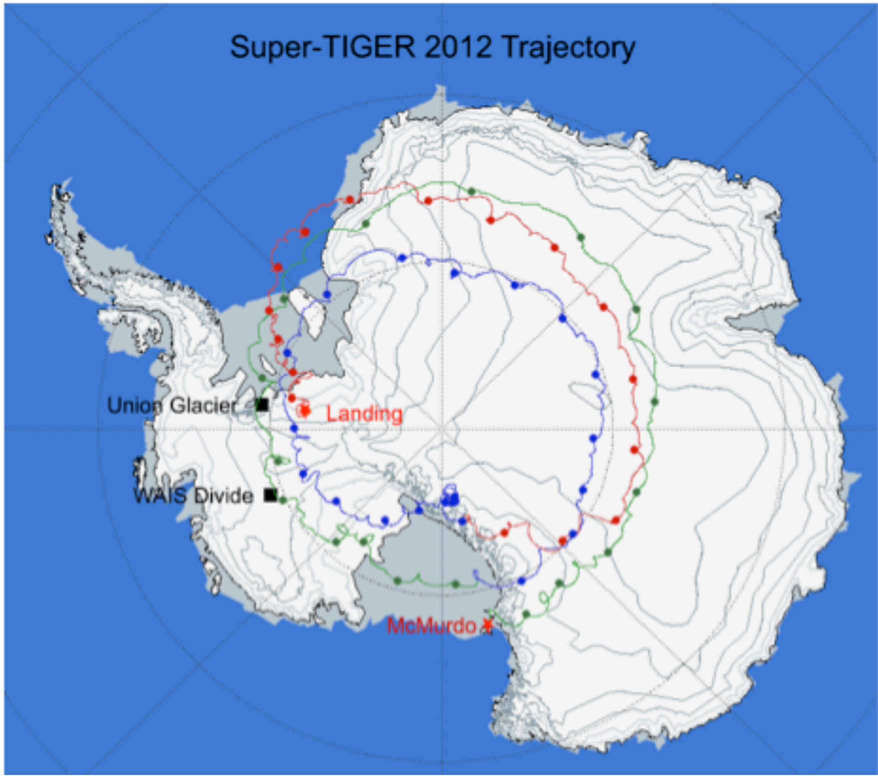
Record-breaking 55 Day Flight!



SuperTIGER Flight

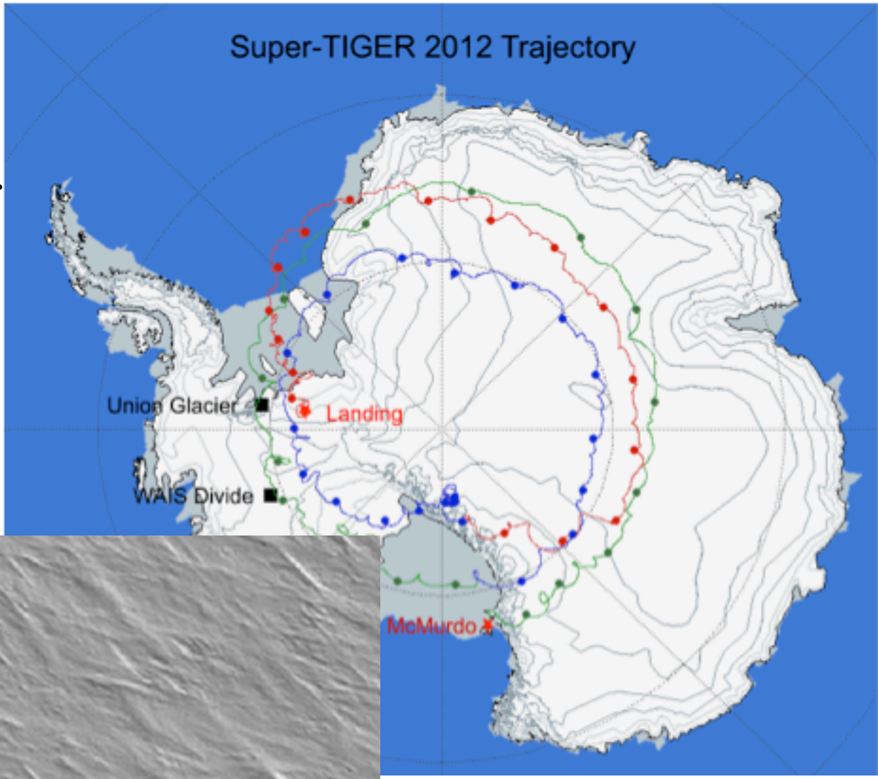
- SuperTIGER flew 55 days, 1 hr, and 34mins.
- Failure of on-board solid state disks resulted in 44 equivalent days' data.
- Record long-duration balloon flight for heavy-lift balloon!
  - Previous record: CREAM I ~42 days
  - NASA Super Pressure Balloon Test ~54 days

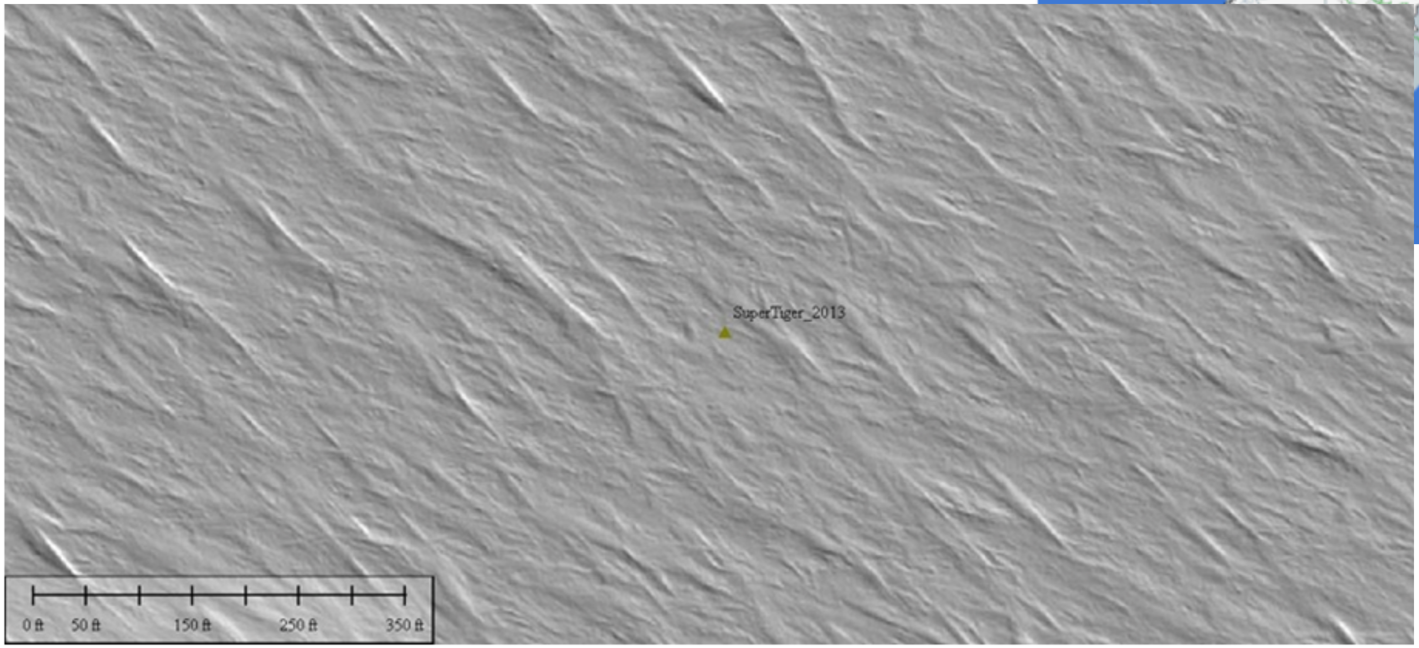




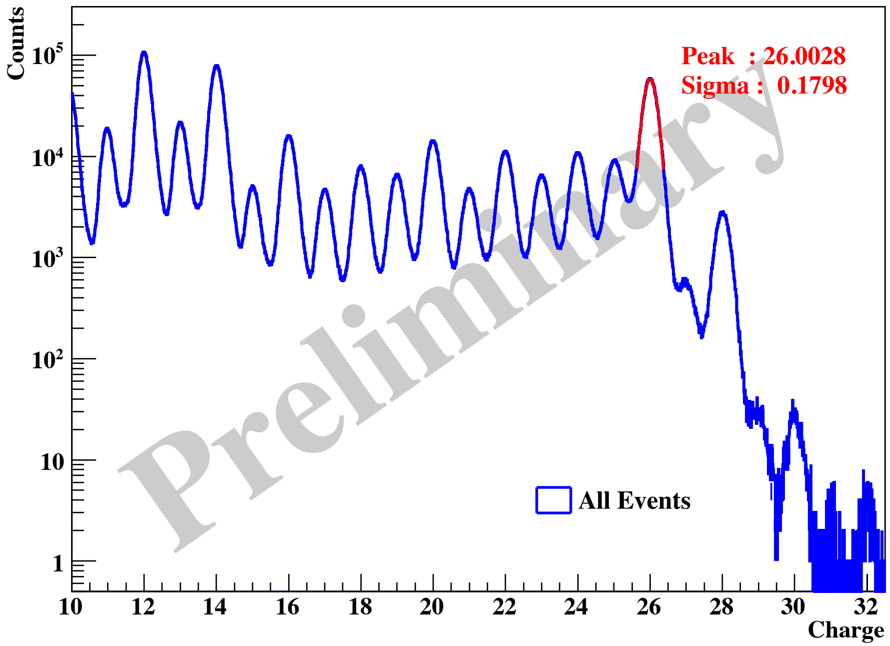
SuperTIGER Recovery

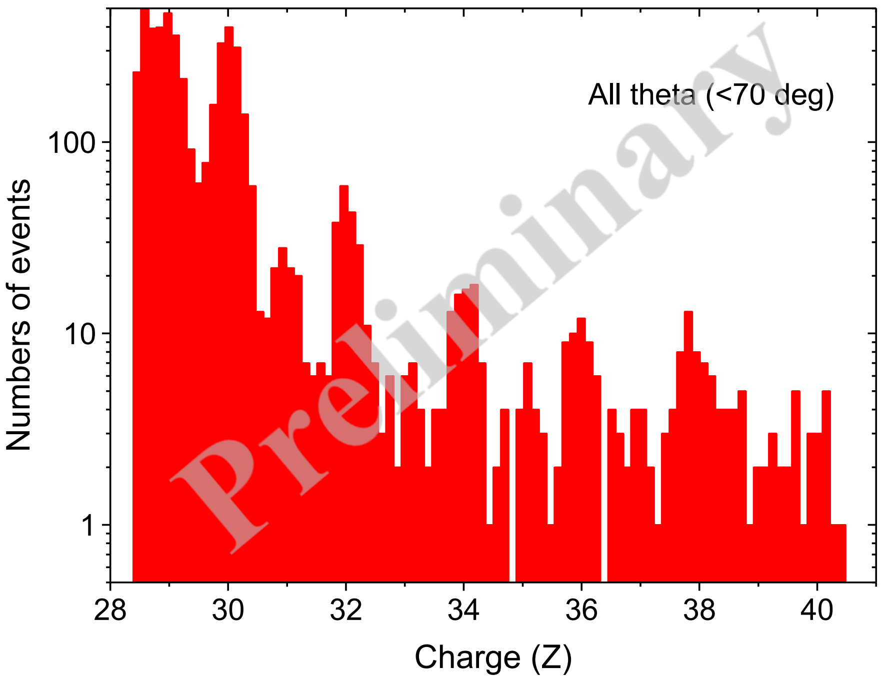
- SuperTIGER landed at 82°14.80'S, 81°54.72'W
- On track for recovery in Jan 2014!
- Recovery crew arrived in McMurdo Jan 4, 2014.
- Will fly out, rdv w prep crew and payload, dismantle instrument, return, and pack & ship SuperTIGER to US for refurbishment.





Preliminary Results



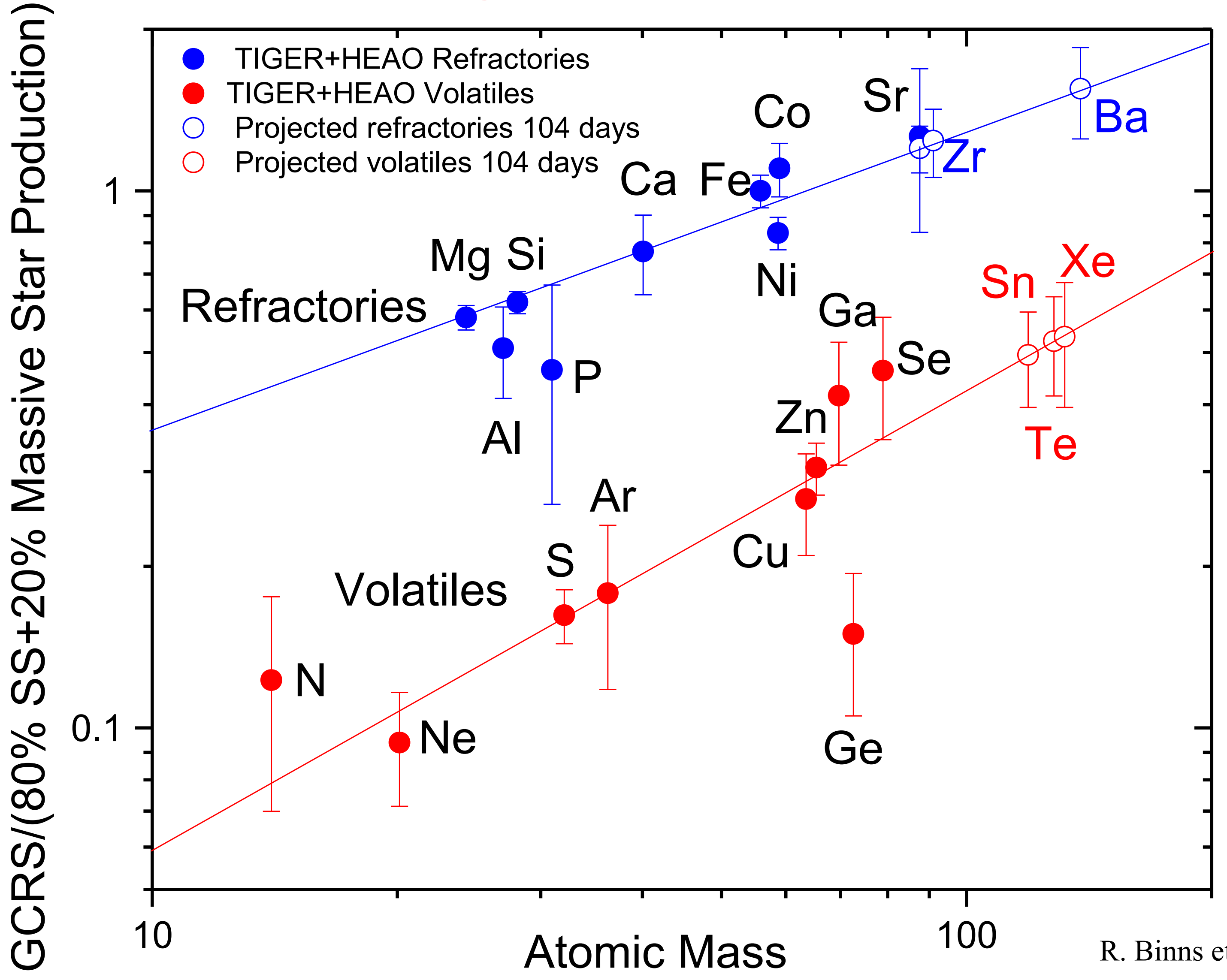


- All events
- σ_Z = 0.18 charge units resolution at Fe (compared to ~ 0.23 for TIGER)

- Events w Z > 30, analysis underway
- Expect improved resolution w better models of velocity and charge-dependent scintillator saturation

R. Binns et al. ICRC, Como 2013

HEAO-C2, TIGER, & Expected High-Z SuperTIGER Results



R. Binns et al. ICRC 2013

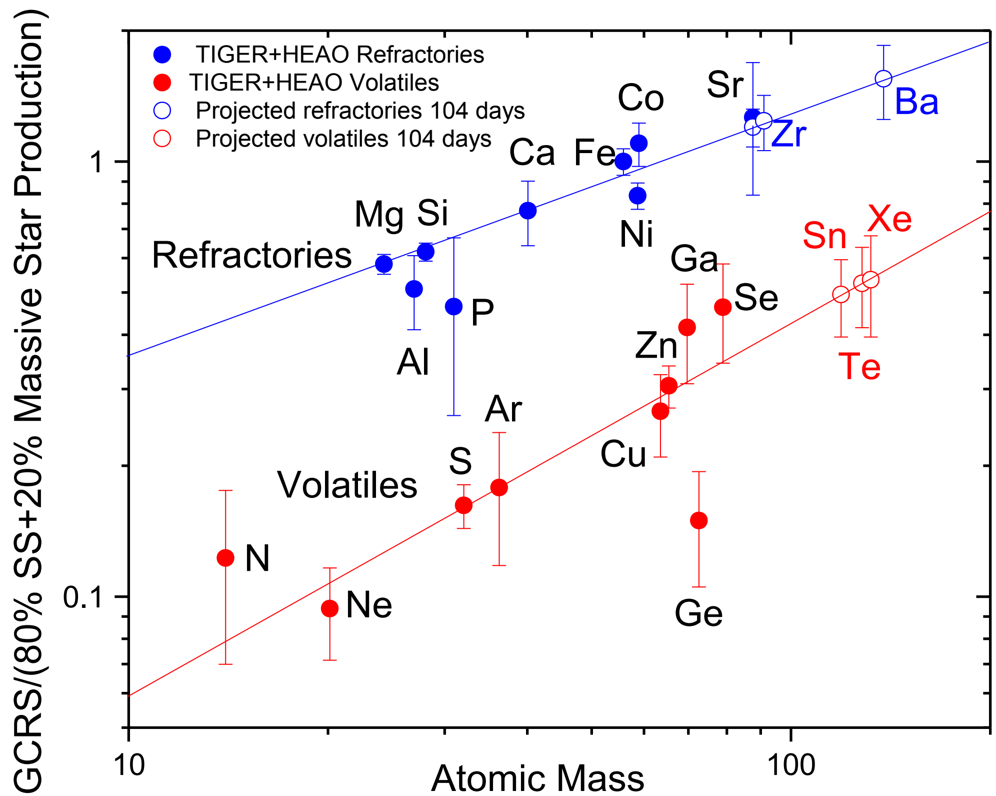
Expected SuperTIGER Results

First SuperTIGER flight increased statistics more than x4 TIGER:

- $_{30}$Zn, $_{31}$Ga, $_{32}$Ge, $_{34}$Se, and $_{38}$Sr statistical uncertainties will be reduced by more than 2x
- will have sufficient statistics to add data!
  - $_{36}$Kr (highly volatile)
  - $_{37}$Rb (moderately volatile)
  - $_{40}$Zr (refractory)

TIGER, HEAO, and expected SuperTIGER data:

- Estimate heaviest nuclei assuming current 44 days' data + 60 days' from future flight(s)



measured TIGER data

estimated error bars for heavier elements with 104 days of SuperTIGER data

Future Missions/Directions

- SuperTIGER II – 2015/6?
  - Increase statistics of current heavy (and bonus light) nuclei
  - Measure heaviest CRs yet
  - Learn about CR origins, acceleration
- DragonTIGER/HNX/Similar concept – continuing development
  - Cherenkov and segmented Silicon/scintillator detectors with glass track detectors
  - Ideally space-borne (satellite, commercial launch vehicle, station, or …)
- Indirect detection – leverage on-going experiments
  - Fermi Gamma-ray Space Telescope, AGILE, …
  - ACTs, e.g. H.E.S.S., VERITAS, …
  - HAWC, IceCube, …
- Potential platforms:
  - Balloons, inc. ULDB (2015+?); Sounding rockets; high altitude airplane flights
  - Satellite; ISS; commercial launch vehicle
  - Microsatellites, …

Community cohesion and promotion combined with innovative ideas are likely our best chances for continued (improved?) funding to answer questions of CR origin, acceleration, and propagation.