# Voyager 1 Observations of the Composition of Enhanced MeV Ion Fluxes at 85 AU

E. C. Stone and A. C. Cummings
*California Institute of Technology, Pasadena, CA 91125, USA*

## Abstract

We examine the energy spectra of H, He, C, and O for the period of 2002/209-364 when Voyager 1 observed an unusually large enhancement of low energy ions. We find that the composition is consistent with a mixture of two types of material: accelerated singly-ionized pickup ions (~25%) and solar/interplanetary ions typical of corotating interaction regions (~75%).

## 1. Introduction

Beginning in mid-2002 the Cosmic Ray subsystem (CRS) [7] on Voyager 1 (V1) recorded a large intensity increase in low energy particles that was not observed at Voyager 2 (V2) (see [1,2,4,5]). In this paper we present an analysis of the composition of the accelerated particles during the period 2002/209-364.

## 2. Observations

In the Low Energy Telescopes (LETs) on CRS there are two types of analyses: single detector events and multi-detector events. For multi-detector events, conventional dE/dx vs E techniques [6] are used to determine the energy and charge of the incident ions. Analysis of events in which only the front detector recorded an energy-loss signal requires simulation of the observed pulseheight distribution using a Monte Carlo technique to input incident energy spectra of a variety of ions on the telescope. Corrections are made for the background from high energy galactic cosmic rays by scaling and subtracting the pulseheight distributions from a quiet period (2002/79-104) when there was no low energy particle increase. The scaling factor of 1.15 was based on a high energy penetrating particle rate in the High Energy Telescopes.

The results for the single detector analysis are shown in Figure 1. The right panel shows the incident spectra that were input for the simulation. The points represent spectra from the multi-detector analysis of various ions observed during 2002/209-364, corrected for background. The solid lines represent the actual input spectra to the Monte Carlo calculation.

 

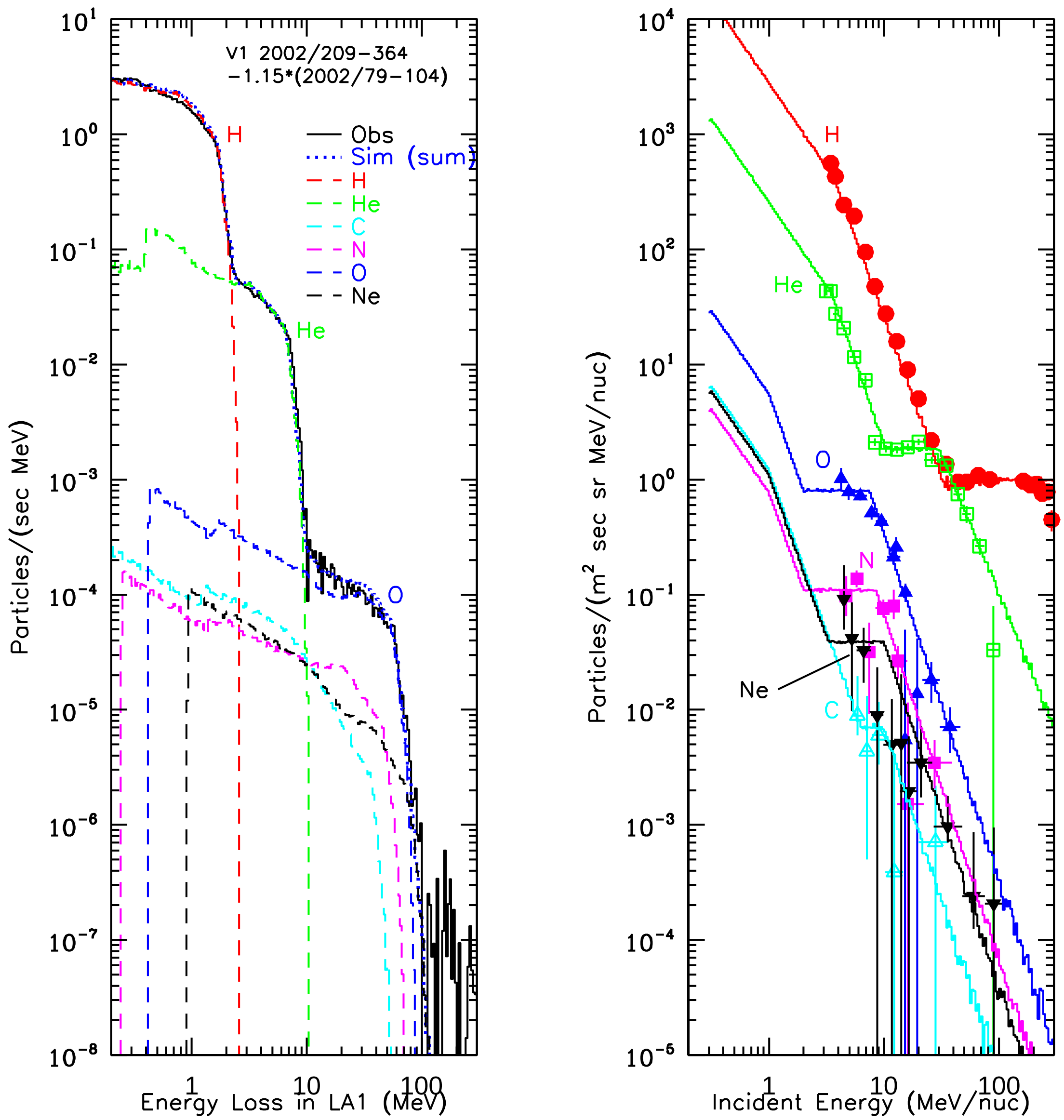


**Fig. 1.** The left panel shows the results of the simulation of the response of the front LET detector to the input spectra shown in the right panel as described in the text.

The left panel shows the observed distribution of energy losses and the simulated contributions of the different ions, along with the sum of the contributions. The observed distribution is reproduced reasonably well by the simulation.

In Figure 2 the points represent the observed energy spectra of H, He, C, and O at V1 from the multi-detector analysis during 2002/209-364 (i.e., without subtracting the background interval), and the solid line segments are from the single-detector analysis at energies below the multi-detector analysis threshold. The dotted lines in the left panel are the He spectrum scaled to H, C, and O

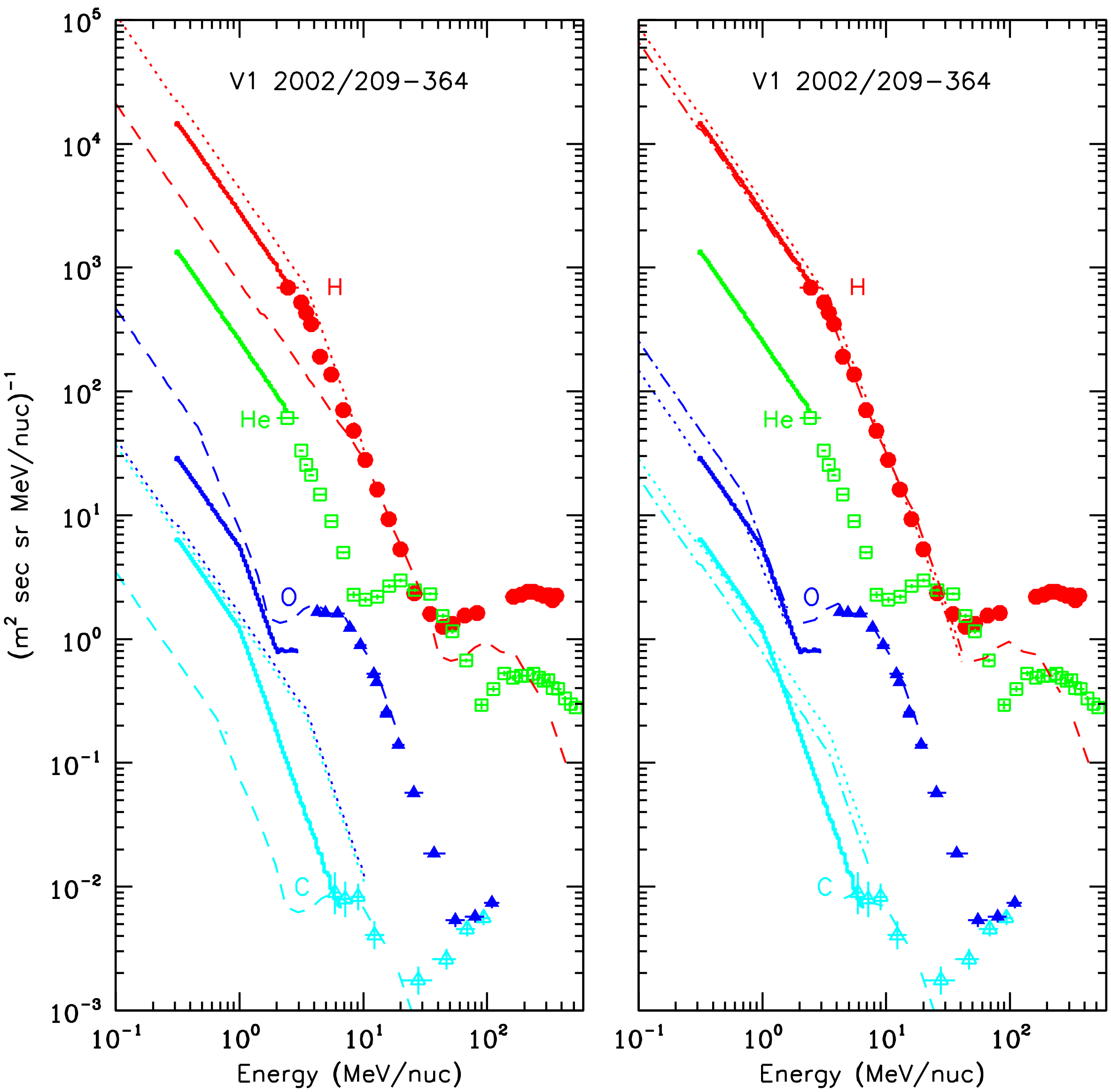


**Fig. 2.** (left) Observed energy spectra (points and solid lines). The C spectrum at <5 MeV/nuc is an upper limit. Also shown are energy spectra scaled from He assuming the composition of CIR (dotted lines) or singly-ionized (dashed) ions. (right) The dotted lines represent a mixture of 75% CIR and 25% ACR ions, scaled to He, and the dot-dash line illustrates an equal mixture of CIR and ACR ions in the low energy component. The dashed lines at higher energies represent a pure ACR composition.

using the solar minimum corotating abundances from Richardson et al. [3]. The dashed lines are scaled by factors in energy and intensity from the He spectrum in such a way as to match the anomalous cosmic ray (ACR) portion of the energy spectra, which has local intensity peaks at ∼5 MeV/nuc for O, ∼7 MeV/nuc for

C, and ∼100 MeV for H. The energy scaling factors from He to H, C, and O were 4.9, 0.28, and 0.20, respectively, and the intensity scaling factors were 0.32, 0.003, and 0.65, respectively. The energy scaling for ACRs differs for the different ions because the particles are singly ionized and the peak intensity for each type of ion occurs at an energy corresponding to the same value of the diffusion coefficient.

As apparent in the left panel of Figure 2, the observed composition at low energies differs from that of either CIRs or ACRs. As shown in the right panel, the composition is better matched by a mixture of ion sources that is 75% CIR-like and 25% ACR-like in composition. The agreement with H and O is reasonable, but it appears that the 75/25 mixture may overestimate C, for which the observations provide only an upper limit. As shown, there is less C in a 50/50 mixture, but there is more O than observed.

## 3. Discussion

The origin of the unusual enhancement of low energy ions in late 2002 is of interest because Voyager 1 is in the vicinity of the termination shock that is the source of ACRs and likely reaccelerates other other low energy interplanetary ions. Reacceleration at the termination shock has been suggested as a possible origin of this new component, as has interplanetary acceleration [2]. The composition of the new component appears to be a mixture of singly-ionized pickup ions and highly ionized solar or interplanetary ions. If the termination shock is the source, this suggests the possibility of transient periods of reacceleration of a mixture of lower energy solar/interplanetary and pickup ions.

## 4. Acknowledgements

We thank R. Leske for helpful discussions. This work was supported by NASA under contract NAS7-1407.

## 5. References

1. Cummings, A. C., and Stone E. C. 2003, this conference
2. McDonald F. B., Cummings, A. C., Stone, E. C., Heikkila, B., Lal, N., and Webber, W. R. 2003, this conference
3. Richardson, I. G., Barbier, L. M., et al. 1993, J. Geophys. Res., 98, 13
4. Stone, E. C., and Cummings A. C. 2003, this conference
5. Stone, E. C., and Cummings A. C. 2003, this conference
6. Stone, E. C., Cohen, C. M. S., et al. 1998, Space Sci. Rev., 86, 357
7. Stone, E. C., Vogt, R. E., et al. 1977, Space Sci. Rev., 21, 355