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Long-Term Temporal Behavior of Interplanetary and Trapped Anomalous Cosmic Rays

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Abstract

New measurements of the long-term temporal history of anomalous cosmic rays (ACRs) at 1 AU are presented, based on data from SAMPEX and ACE. Over the period from 1992 to 1997 the interplanetary intensity of 8 to 27 MeV/nuc ACR oxygen increased by a factor of ~5 as solar minimum approached. The intensity of ACR oxygen trapped in the Earth's magnetosphere showed a corresponding time history. Early in 1998 both the interplanetary and trapped intensities suddenly decreased with the onset of solar activity leading to the next solar maximum. We discuss the relation of the time-delay between changes in the interplanetary and trapped fluxes, possible solar/interplanetary causes of these changes, and the lifetime of trapped ACRs in Earth's magnetosphere.

1 Introduction

The interplanetary intensity of anomalous cosmic rays (ACRs) is known to be especially sensitive to the effects of solar modulation. Indeed, it has been shown that variations in the long-term intensity of 8 to 27 MeV/nuc ACRs observed in interplanetary space scale approximately as the 25th power of neutron monitor counting rates (Mewaldt et al. 1993, 1998). Although the trapping of anomalous cosmic rays in Earth's magnetosphere was predicted soon after their discovery (Blake and Friesen 1977), it was not until the early 1990's that the first evidence for trapped ACRs was presented (Grigorov 1991), and the composition and spatial distribution of these trapped interstellar ions was explored (Cummings et al. 1993, Selesnick et al. 1995). Interplanetary ACRs become trapped when they are stripped of their electrons in the upper atmosphere, It was recognized that long-term variations in the intensity of trapped ACRs were correlated with those of their interplanetary source (Grigorov et al. 1991, Selesnick et al. 1995, Mewaldt et al. 1996), which has implications for both the trapping mechanism and the loss processes of these ions.

In this paper we present new observations of the interplanetary intensity of 8 to 27 MeV/nuc ACR oxygen from the MAST instrument on SAMPEX and the SIS instrument on ACE, and compare these with the >16 MeV/nuc trapped ACR intensity measured over the period from 1992 to 1998. Of particular interest are sudden decreases in both the interplanetary and trapped intensities observed in late 1997 and early 1998.

2 Anomalous Cosmic Ray Intensities

The interplanetary intensity of 8 to 27 MeV/nuc ACR oxygen has been monitored over the years since 1972 by instruments on IMP-7&8 and SAMPEX, supplemented by earlier data from OGO-5 (Mewaldt et al. 1993, 1998). The ACR intensity varied by a factor of ~100 over this time period due to the effects of solar modulation. Recently, this long-term record has been supplemented by data from the SIS instrument on ACE, permitting studies with higher time resolution. Beginning in mid-1992, the MAST instrument on SAMPEX began monitoring the intensity of trapped ACR oxygen at L≈2, as described in Selesnick (1995). A comparison of the interplanetary and trapped intensities is shown in Figure 1. Note that the interplanetary and trapped intensities are highly correlated, and that the trapped intensity is ~100 times that in interplanetary space.

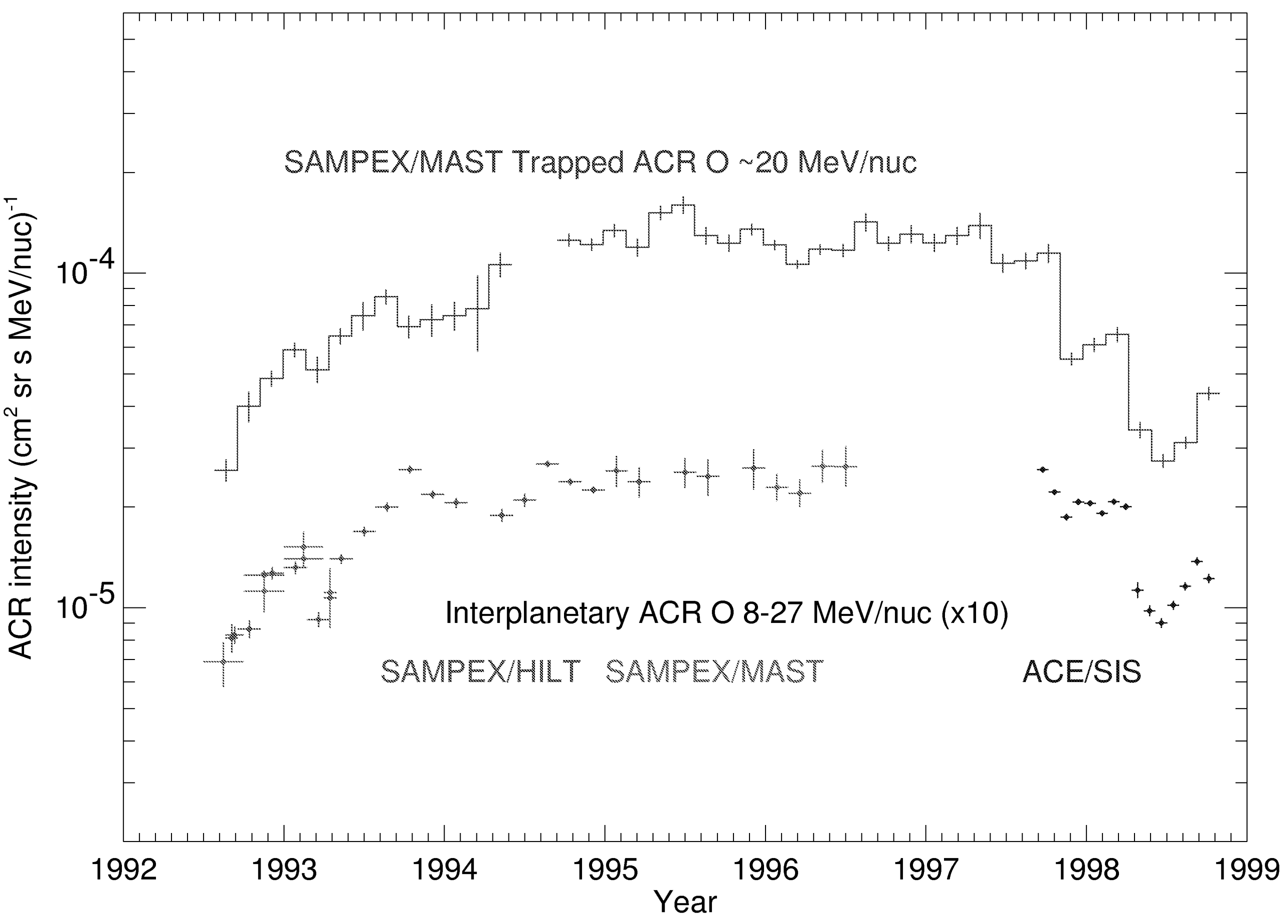

Figure 1: The time history of interplanetary ACR oxygen from SAMPEX and ACE is compared with the intensity of trapped ACR oxygen measured by SAMPEX at L~2. Note that the interplanetary values are multiplied by x10.

During the period from 1992 to 1997, as solar minimum approached, both the interplanetary and trapped intensities increased by a factor of ~5. The large, sudden decreases in the interplanetary intensity observed in November, 1997 and in May 1998 correspond to large interplanetary disturbances that marked the onset of solar activity leading to the next solar maximum. Note that the trapped intensity showed very similar decreases. Surprisingly, the onsets of the interplanetary and trapped decreases are indistinguishable with the 52-day resolution shown here. By contrast, a theoretical estimate of the trapping lifetime, which assumed that the dominant loss mechanism is energy-loss in the upper atmosphere, ranged from ~0.4 years to ~8 years, for pitch angles ranging from 70 to 90 deg (Selesnick et al. 1997). Although it is tempting to conclude from the data in Figure 1 that the trapping lifetime is less than 52 days, there is another possibility. In both cases (especially in May 1998) the solar activity that caused the decreases in interplanetary ACRs also resulted in geomagnetic storms that may have affected the trapped particle populations. We are presently trying to determine whether the dominant trapped-particle loss mechanism is energy degradation in the upper atmosphere or disruption of trapping due to geomagnetic effects.

During the coming few years we can expect the interplanetary ACR intensity to decrease by a factor of ~100. It will be interesting to see if the ACR radiation belt decreases below detectable limits, or levels off at some lower intensity.

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