Journal of Special Topics

P4_7 Cumulative GCR Dose of Nostromo Survivors

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February 15, 2011

Abstract
This paper explores the cumulative galactic cosmic ray (GCR) dose of the crew of a fictional spacecraft whilst they are in a state of suspended animation for a period of 57 years. Shielding against such high energy radiation is assumed to be impossible, and the resultant dose is high enough to cause serious illness or death. This is a potential hazard for real life space travellers as well as fictional ones.

Background

At the end of the film *Alien* [1] two survivors of an interstellar spacecraft are cast adrift in a small shuttle. Expecting to be picked up within weeks, the survivors are discovered at the beginning of the sequel *Aliens* [2] after having spent 57 years in deep space.

Given the small size of the shuttlecraft, and assuming that the shuttlecraft (named *Narcissus* in the novelisation of the film) cannot maintain a strong enough magnetic field for 57 years to deflect the charged particles, the shuttlecraft has no ability to protect its occupants from high energy galactic cosmic rays (GCRs). The fictional crew may possess some unknown technology to protect them from this radiation, but given that their ships are seen to use cathode-ray tubes, this is considered unlikely.

It is also assumed that the flux of GCRs in deep space is comparable to the flux of this radiation in interplanetary space far enough away from Earth to not be protected by our planet's magnetic field.

The GCR flux

For a first-order approximation the GCR flux is approximated as 10 000 particles per square meter per second [3] with an energy of 1GeV, consisting entirely of protons. In reality most (~90%) GCRs have energies of 1GeV or less, and are protons [4] so this is not unreasonable for a first-order approximation.

The type of radiation is highly penetrating; the PSTAR program provided by the US National Institute of Standards and Technology shows the projected range of a 1GeV proton in aluminium (given a density of 3 g/cm^3 for aluminium) to be over 3 metres [5] and none of the other materials available for analysis in PSTAR fare much better. This is why shielding against this form of radiation is considered incompatible with spacecraft design, which is generally confined to a mass budget.

Biological Impact

When radiation interacts with living tissue, it causes damage through ionisation, and in response living cells attempt to repair that damage[6]. Because, in this case, the subjects of this damage are in suspended animation, it must be assumed that the mechanisms which perform this repair are suspended along with other biological functions. Thus, from the point of view of the cell, the radiation damage caused during the 57 year journey manifests itself as a single dose received the instant the subject is revived.

To calculate the effect of the radiation, we need the amount of energy per unit volume that the radiation deposits in living tissue. Running PSTAR using MS20 Tissue substitute [5] gives a total stopping power at 1GeV of 2.143 MeVcm^2/g, and assuming mammal tissue is the same density of water this gives:

$$E = 2.143 MeVcm^2 g^{-1} \times 100cm \times 1gcm^{-3} = 214.1 MeV / proton \quad (1)$$

Given the above flux of 1 proton per cm^2 per second, the absorbed dose of radiation (measured in Gray, an SI unit equivalent to joules/kg) per second is

$$\frac{d}{dt} Dose = \frac{214.1 MeV / proton \times 1 proton / cm^2 / s}{100cm \times 1gcm^{-3}} = 3.430 \times 10^{-10} Gy / s \quad (2)$$

for both survivors. As the path length does not feature, the dose rate for Jonesy is the same. To assess the biological effect, a quality factor *Q* Is needed. This factor represents the effectiveness of different types of radiation at damaging living tissue. The quality factor for protons is *Q*=10 [5] which allows us to compute the dose that both Ripley and Jonesy receive in Sieverts (Note that the Gray and Sievert both have dimensions J/kg; they are kept as separate SI units to differentiate absorbed from effective dose)

$$Dose = 3.430 \times 10^{-10} Gy / s \times 57 yr \times 10 = 6.166 Sv \quad (3)$$

which represents the amount of radiation damage done to both survivors during the voyage. This is a substantial dose of radiation, which as explained above will be seen by the body as a single instantaneous dose. The effects are described as follows:

Survival depends on stringent medical intervention. Bone marrow is nearly or completely destroyed, requiring marrow transfusions. Gastrointestinal tissues are increasingly affected. Onset of initial symptoms is 15-30 minutes, last a day or two, and are followed by a latency period of 5-10 days. The final phase lasts 1 to 4 weeks, ending in death from infection and internal bleeding. Recovery, if it occurs, takes years and may never be complete.[7]

Conclusion

Ripley is seen in a hospital immediately after her spacecraft is recovered, so it is possible she was treated for this severe radiation exposure. The severity of the dose, however, does highlight a potential pitfall of using the speculative technology of suspended animation in real life human spaceflight

References

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