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BENCHMARK SOLUTIONS FOR THE GALACTIC ION TRANSPORT EQUATIONS WITH SPATIAL AND ENERGY COUPLING

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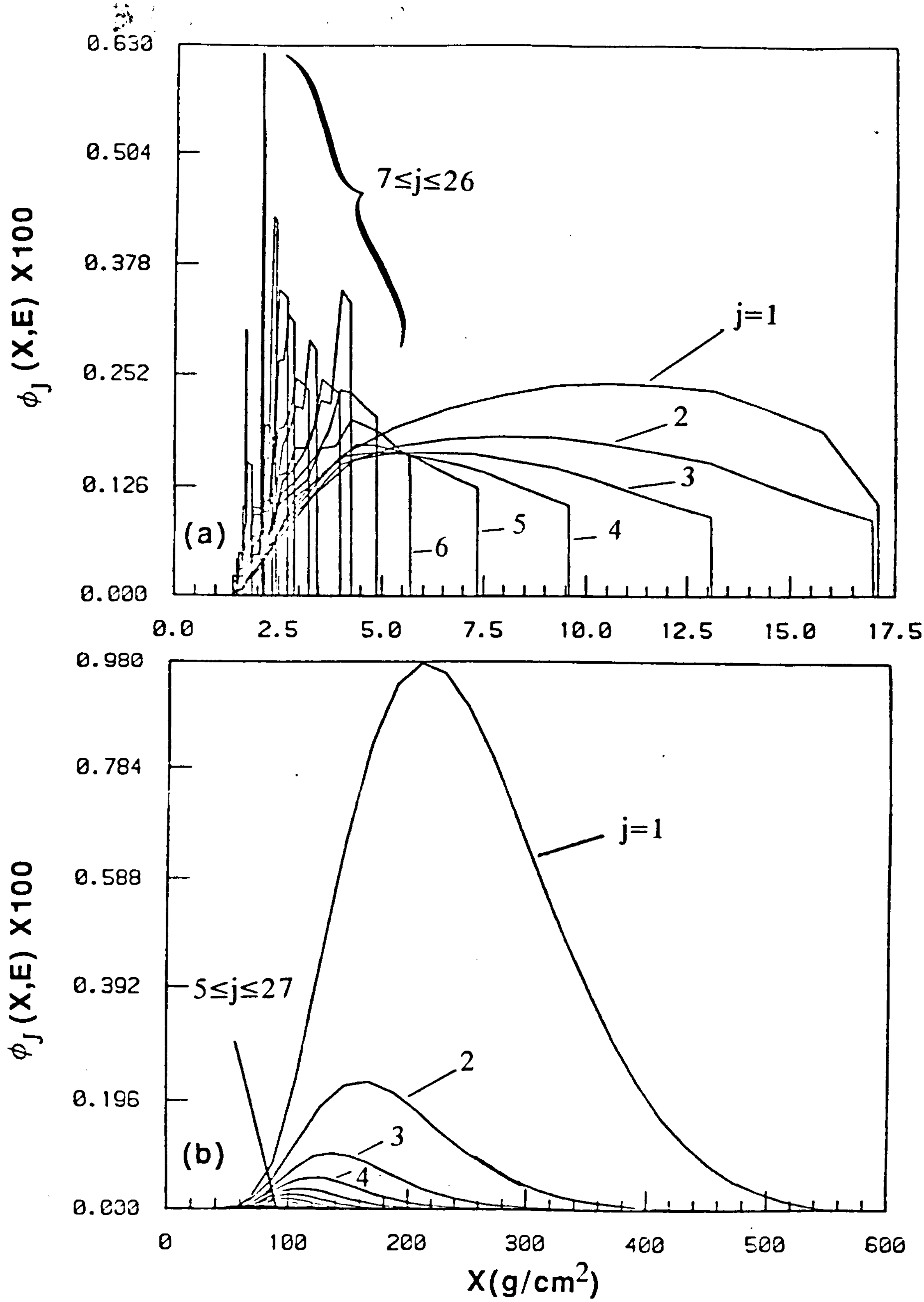
With our ever-increasing interest in establishing mankind's presence in space, the protection of personnel from energetic radiation in the space environment has become a relevant issue. As high energy radiation, composed of heavy ions called galactic cosmic rays (GCR's) originating in deep space and/or protons from solar flares, interacts with target nuclei, the incident ions undergo nuclear fragmentation and energy degradation. The fragments generated by direct nuclear impact or electromagnetic dissociation form a secondary radiation field which again interacts with target nuclei to prolong the biological hazard engendered by the incident ions. Thus, to ensure that the habitat in the space environment is properly shielded from energetic radiation, a knowledge of the changing nature of the incident radiation field as it penetrates protective spacecraft shielding is required.

In order to anticipate future space shielding requirements, NASA has initiated an effort to formulate computational methods to simulate radiation effects in space. As part of the program, numerical transport algorithms have been developed for the deterministic Boltzmann equation describing GCR interactions with matter. It thus becomes necessary to assess the accuracy of proposed deterministic algorithms. For this reason, analytical benchmark solutions to mathematically tractable galactic cosmic ray equations have recently been obtained. Even though these problems involve simplifying assumptions of the associated physics, they still contain the essential features of the basic transport processes. The solutions obtained are compared to results from numerical algorithms in order to ensure proper coding and to provide a measure of the accuracy of the numerical methods used in the algorithm.

For the first time, mathematical methods have been applied to the galactic ion transport (GIT) equations in the straight ahead approximation with constant nuclear properties. The approach utilizes a Laplace transform inversion yielding a closed form benchmark solution which is also computationally efficient. The spatial flux profiles (ϕ_j for ions of charge number j) at high and low energies resulting from an incident GCR beam composed of ions from Flourine to Iron is shown in the accompanying figure. The rather discontinuous behavior at high energy is a direct reflection of the singular source of the incident ions. In contrast, the much smoother variation at low energy with the proton field dominating and the heavy ions almost totally depleted provides a demonstration of the changing nature of the radiation field. This solution will prove useful in assessing the numerical GCR algorithms currently under development.



Flux profiles for GCR beam (composed of F - Fe ions) (a) near source energy (b) at low energy.