دراسة تأثير انبعاثات الكتلة الشمسية على الأشعة الكونية في الفضاء بين الكواكب

إعداد

مرفت عبدالقادر فدعق

اشراف

أ.د. بدر الدين ظهير أحمد

د. عبدالرحمن علي سعيد ملاوي

المستخلص

تتأثر بنية الفضاء بين الكواكب والأجواء الكوكبية بالشمس والظواهر النشطة المنبثقة عنها. هناك العديد من الظواهر الشمسية التي تؤثر على النظام الشمسي، أحدها هو خروج الكتلة الإكليلية (CMEs) ، وقد لوحظت هذه الظواهر بشكل متكرر على سطح الشمس ، وهذه الظواهر تؤدي إلى انتشار جسيمات عالية الطاقة (الأشعة الكونية) عبر النظام الشمسي ويسبب اضطرابات مغنطيسية في الغلاف الجوي للأرض عند اقترابه منه. تسمى هذه العواصف المغناطيسية الأرضية وغيرها من الأحداث التي تحدث في نظامنا الشمسي بسبب تأثير الشمس بالطقس الفضائي، وهو مصطلح يستخدم لوصف تأثير الطاقة والجسيمات من الشمس على بيئة الفضاء القريبة من الأرض. تعتبر دراسة طقس الفضاء مهمة للغاية بسبب ما يمكن أن تحدثه أسباب الطاقة الشمسية في القضايا الصحية، والاتصالات، وشبكة الطاقة لدينا والتأثيرات الأخرى.

لذلك تركز دراستنا هنا على الانبعاث الكتلي الإكليلي (CMEs) والسحب المغناطيسية (MCs)والهياكل المرتبطة بهم وتأثيرها على شدة الأشعة الكونية والتي تعد مهمة جدًا لدراسة العلاقات الشمسية الأرضية لأنها مسؤولة عن العديد من الاضطرابات الرئيسية في البيئة الفضائية للأرض. حيث ناقشنا التعديل العابر الناتج عن الانبعاث الكتلي الإكليلي (CMEs) والهياكل المرتبطة بها التي تم اكتشافها خلال الجزء الأكبر من الدورة الشمسية ٢٤. ثم درسنا التعديل العابر أثناء مرور السحب المغناطيسية والهياكل المرتبطة بها أثناء الدورات الشمسية ٢٣ و ٢٤. بعد ذلك قمنا بدراسة تأثير الاتجاهات المغناطيسية المختلفة للسحب المغناطيسية على التعديل العابر للأشعة الكونية المجرية.

STUDY OF THE INFLUENCE OF SOLAR MASS EJECTIONS ON COSMIC RAYS IN INTERPLANETARY SPACE

By

Mervat Abdulgader Fadaaq

Supervised By
Prof. Dr. Badruddin Zaheer Ahmad
Associate Prof. Dr. Abdulrahman A. Malawi

Abstract

The aim of this thesis is to study the transient modulation of galactic cosmic rays (GCRs).

Solar modulation of GCRs takes place in the interplanetary space (The heliosphere). Plasma and magnetic field conditions in the interplanetary space are governed by the Sun, solar activity and related changes in the solar wind plasma and field conditions in the interplanetary medium. This thesis is organized as follows: (Chapter-1), provides a basic introduction about the Sun, solar emissions, and their expansion in the interplanetary space in an elementary manner. After this brief overview of the solar phenomena, on our investigation is narrowed to cover three specific cases, organized in three different chapters.

(Chapter-2) studies the transient modulation due to coronal mass ejections (CMEs) and their associated structures detected during most part of solar cycle 24. (Chapter-3) studies the modulation during the passage of magnetic clouds (MCs) and associated structures during solar cycles 23 and 24. Finally, (Chapter-4) studies the short-term modulation of galactic cosmic ray intensity during the passage of magnetic clouds in the same two solar cycles 23 and 24, but with four different magnetic polarities.

To achieve this goal, we employed the method of superposed-epoch analysis to analyze data from the cosmic ray neutron monitor together with various plasma and magnetic field data during the passage of the shock/sheath/magnetic cloud/non-magnetic cloud ejecta. We observe significant differences in the amplitudes and time profiles of transient depressions in cosmic ray intensity due to magnetic regimes of different field strengths and topologies.

In this work, we compare the variations in various interplanetary plasma and field parameters during the passage of ICMEs/magnetic clouds/non-magnetic cloud ejecta. The plasma/field variations are compared with the simultaneous changes in the cosmic ray intensity. Correlation analysis between the changes in the cosmic ray intensity and plasma/field parameters has been conducted to find the plasma/filed parameter best correlated with the cosmic ray intensity. Observed similarities and distinctions during the passage of magnetic clouds of different polarities are discussed both in terms of cosmic ray response and plasma/field variations.

Thus, in Chapter-2, we studied the transient modulation of galactic cosmic rays in a systematic manner, by using the method of superposed epoch analysis, focusing on the study of GCR-effectiveness (effectiveness in modulating the GCR intensity) of:

- Interplanetary coronal mass ejections (ICMEs)
- ICMEs associated with shocks
- ICMEs not associated with shocks
- ICMEs with magnetic cloud (MC) properties (so called, magnetic clouds)
- Non-MC ICMEs

Based on the superposed epoch analysis of cosmic ray, plasma and field data, and systematically changing the epochs as above, it was found that shock-associated MCs are the most GCR-effective among them.

Then, subsequently in (Chapter-3), we concentrated our study exclusively on GCR intensity modulation by MCs, where we studied their GCR-effectiveness, using the superposed epoch analysis, and by systematically changing the epoch as per:

(a) time of shock disturbance,

(b) MC arrival time,

(c) time when magnetic field strength is maximum during passage of shock-associated MC structure and

(d) time when standard deviation in magnetic field vector (σF) is maximum during the passage of such structures.

Such superposed epoch analysis, with additional correlation analysis, provide insights about the GCR-effectiveness of MCs.

However, magnetic field orientation with MCs is an important property of such structures. In general, they have been detected in the near-Earth space with four different field orientations;

(a) North to South turning (NS) MCs,

(b) South-to North turning (SN) MCs,

(c) Fully southward (S) MCs, and

(d) Fully northward (N) MCs.

Being charged particles, while propagating in a magnetic environment (e.g., interplanetary magnetic field, IMF), these particles are likely to get influenced not only by the field strength but by the field orientation also.

Subsequently, our next attempt (i.e., Chapter-4) focuses on the study of the GCR-effectiveness of four different orientations, especially those associated with shock. This study presents an in-depth analysis of GCR intensity, together with plasma and field data, during the passage of MCs of four different magnetic polarities.

The last chapter, Chapter-5, discusses the conclusions drawn from our investigation as well as the summary of the findings.

We come to the conclusion that the high magnetic field regions are particularly effective in modulating the GCRs when the field inside is high and turbulent. Our findings concur with the hypothesis that the transient decreases/Forbush decreases (FDs) in GCRs are mainly caused by turbulent high field regions due to the scattering of the GCR particles.