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The study of secondary X-rays produced by the Cosmic rays and solar energetic particle's interaction with the atmosphere of Mars during its close approach to the Earth.

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There has been a major current motive of NASA exploration to gather knowledge regarding the radiation environment on the Mars for the quest of long term human precursor mission. In the context of radiation interaction with the atmosphere and shielding materials of the Mars, a large number of studies are required to obtain new measurements (data), predictive models for the impact of Galactic Cosmic rays (GCRs) and Solar energetic particles (SEPs). Since high energy GCRs and SEPs spectra have been well characterized for the production of consequent secondary radiation, it is believed recently that the current active research of secondary radiation would contribute large information and required data for the absorbed dose in Mars atmosphere.

We took advantage of recent close approach of the Mars to the Earth in the month of August 2003 and observed spectra of secondary radiation aiming ground based scintillation detector towards Mars. We obtained regular observation from 29th Aug. to 29th Sept. 2003. We here report interesting observation of secondary radiation fields in the range of soft and hard X-rays as a result of interaction of GCRs & SEPs with the atmosphere of the Mars. Analysis showed variation in x-rays flux, which might have concern with system and human safety for successful mission to Mars.

1. Introduction

Towards the Earth, electromagnetic radiation of wide range of wavelength from extra terrestrial space (Sun & Galaxies) is primary energy source. Collectively, the ground and the space based radiometric measurements of total radiance of primary radiation in the past two decades have begun to establish the nature, magnitude and origin of its variability. The ultra-violet, visible and infrared spectral region, all show this variation but with little more changes at shorter wavelength extending from soft x-rays to gamma rays. Such a well characterized observed spectrums immediately point out all new changes which are brought in by any celestial object during their transit & interruption in the path of primary radiation's towards the earth. Primary radiation spectrum are modulated by the physical properties of celestial objects and detected variability may be attributed to the results of interaction of their atmosphere, magnetic field etc. with primary radiation. The substantial irradiance variations in spectrum provide lots of information, which requires a rigorous analysis with appropriate model for understanding the physical properties associated with celestial body.[2],[9]

The significance of secondary radiation at the ground has been realized recently under deriving uncertainty of the high variability of the atmospheric conditions. The ground-based observations taken with the support of sophisticated instruments would greatly help to understand the status of the atmosphere at the time of detection. The impact of solar and cosmic rays on the earth atmosphere is manifested by the generated secondary radiation (fluorescence, cerenkov, mu-mesons, gamma and x-rays) and provide an indirect way to deduce energy, trajectory, composition of the primary radiation.[8]

Now it is well established that a wide variety of solar system bodies (Earth, Jupiter, Venus, Saturn, Mars) are know to radiate in x-ray energy (<100 Kev) region. The generation of x-ray in their atmosphere has been attributed to several different mechanism such as fluorescence and electron bremstrahlung processes.[1] On July 2001, X-rays from Mars were detected for the first time with ACIS-I detector on board CHANDRA with high spatial and temporal resolution.[4]

It has been observed that cosmic rays and solar x-rays during flares, light up the planets like Earth, Mars etc. by Thomson coherent scattering from the electrons in the atomic and molecular constituents of their respective atmosphere. Another mechanism for secondary x-rays emission is proposed that the absorption of incident solar x-rays followed by the emission of characteristic K-lines of gases available in the planetary atmosphere. [7] [12]

Secondary x-rays energy band spectrum has been important for planetary remote sensing because almost all planetary system including Earth are known to shine at the x-ray wavelength. Although earth's thick atmosphere absorbs x-ray radiation at lower altitude, but very merger small amount of flux of x-ray photon are emitted dominantly in the direction of precipitating electron bremstrahlung. Consequently majority of x-ray photons in the earth's atmosphere are directed towards the surface of the earth. These downward propagating x-rays, therefore cause additional ionization and excitation in the atmosphere at very low altitude close to the ground. The fraction of these x ray emission can be studied using ground based scintillation detector.[10] [13]

It is suggested that dominant process of x-ray production on Mars [3] is due to the absorption of primary solar and cosmic radiation in K-shell of atmospheric atoms which yield fluorescent emission of Mars x-rays.[6]

Recently, in one of the study the solar wind charge exchange processes to the x-ray emission from Mars have been computed by hybrid stimulation of heavy ion trajectories near Mars.[5]

The resent historic celestial event of close approach of Mars to the Earth just after 58380 years has proved the hypothesis of modulation of extra terrestrial irradiance from the sun and galaxies. The substantial variation in spectrum have been reported during the close approach of the Mars in ground based observation of short wavelength irradiance.

We took advantage of recent close approach of the Mars to the Earth in the month of August 2003 and observed spectra of secondary radiation aiming ground based scintillation detector towards Mars. We here report interesting observation of secondary radiation fields in the range of soft and hard X-rays as a result of interaction of GCRs & SEPs with the atmosphere of the Mars.

2. Observation & results

Lead shielded NaI crystal Of 5mm thick and 44.5mm in diameter optically coupled with photomultiplier tube (PMT) RCA8575, was used in scintillator detector to detect secondary radiation produced by primary solar and Galactic radiation in the atmosphere of the Mars during its closest approach on 27th August 2003 near the Earth. Scintillation integral line was connected to a high tension voltage of 1100 volt D.C. and the negative signal of about 0.5 volt was amplified to 5 volt positive pulse using negative polarity of spectroscopic amplifier ORTEC model 451. This signal was fed to analog digital converter (ADC) model 917 to provide appropriate input to ADCAM 100 ORTEC for data acquisition and analysis.

The data were collected over a month, daily at 10pm pointing detector (based on ground) towards Mars site in the sky from 29th August to 29th September 2003. For normalization, background observation were also taken everyday and appropriate lead shielding around detector eliminated unwanted background from the surface of the Earth.

Figure 1 shows some of the observations of secondary x-rays observed for Mars. Figure (a), (b), (c), (d) represent x-ray energy spectrum of Mars taken on 30th Aug, 31st Aug., 1st Sept., 3rd Sept. respectively and each is normalized by normal (non-cloudy) day of 26th Sept. 2003.

Observations showed a prominent peak of specific x-ray 9.573keV almost in every spectrum over an entire month Aug-Sept observations. We observed other x-ray energy peaks also but systematic temporal variation has been observed only for 9.573keV x-rays which is assumed to follow a typical model of non linear equation of polynomial (apparently an exponential decay) in counting rate during Mars recession from the Earth after its closest approach.

This proposed model could be expressed by the following exponential equation,

$$I = I_0 + A_1 \exp[-(x-x_0)/t_1]$$

Where I represents x-ray luminosity flux, here it is assumed proportional to the counting rate at any day (x) of the observation of 9.573keV x-ray, I_0 shows constant background, A_1 is maximum amplitude of x-rays luminosity flux (i.e. counting rate) at $x=x_0$.

The best fit of experimental data points (dark squares) using exponential model has been obtained and is represented by red line in figure (e). The least chi-square fit yielded parameters $I_0=7$, $A_1=92$, $X_0=2$ and $t_1=18.2$ with chi-square value 3.25.

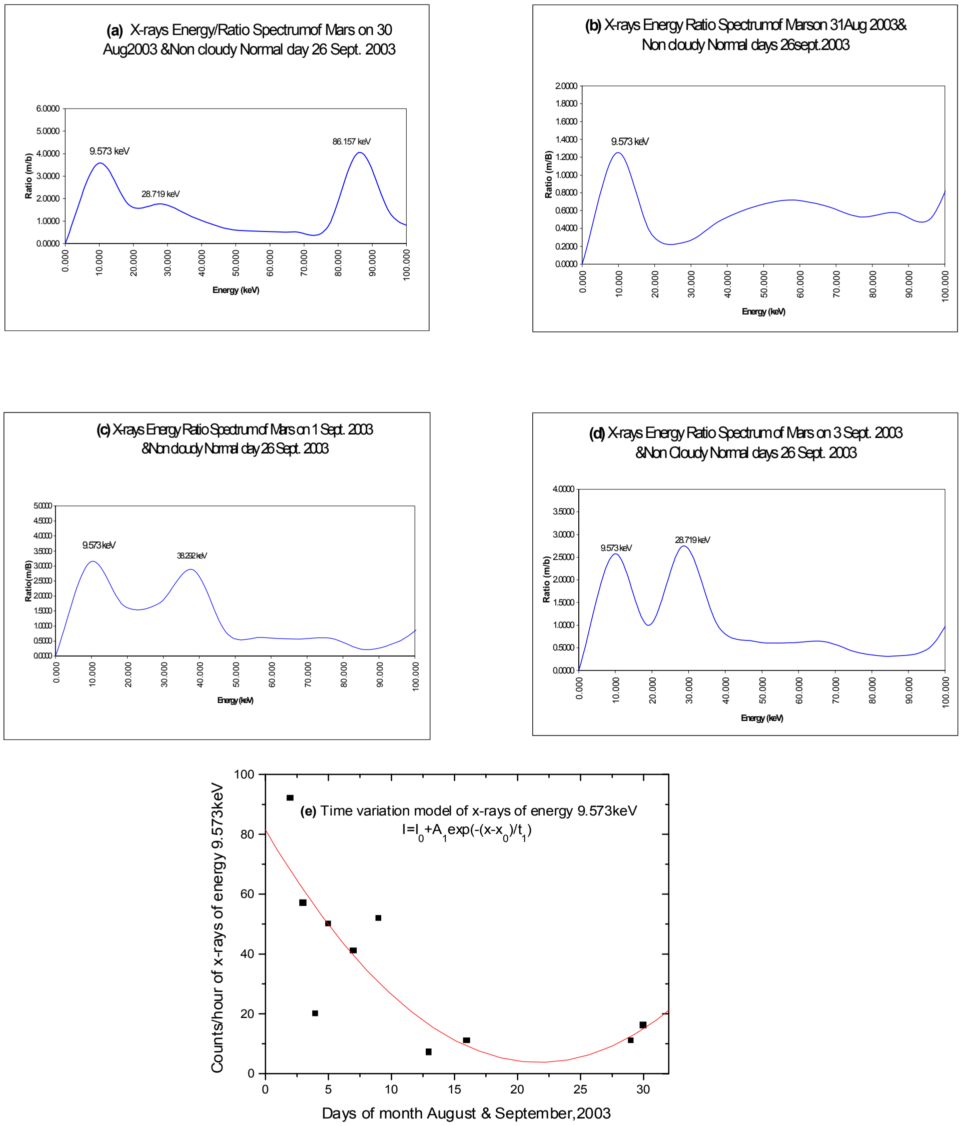

Fig (a), (b), (c), (d) show time varying energy spectra of x-rays (normalized by background) over a month of August- September 2003, starting from the date of closest approach of the Mars to the Earth on 27th August2003.Figure (e) shows variation in counting rate of specific x-ray of energy 9.573keV over entire period of the month August-September 2003.

Consistent results may be justified with the simple concept of revolution of two planets, Earth and Mars in solar system. The Earth and Mars have position vectors $\mathbf{r_e}$ & $\mathbf{r_m}$ respectively at the time of their closest approach bearing an angle θ_{min} and revolve around the Sun with w_e & w_m angular velocities.

The orbit of Mars & the Earth are not perfect circle and the distance between them varies due to the different orbital periods and the plane of the orbits are inclined at an angle 1.84°. On 27th August 2003, Mars was closest to the Earth at $5544*10^7$ m distance. The x-ray luminosity flux from the Mars would vary as function of time x (in days) and is given by,

$$I = A_1 \exp[-\{ (4r_m r_e \theta_{min}(w_e-w_m)/2(r_m-r_e)^2 \cos(1.85^o) \}(x-x_0)]$$

Where $r_m=22794*10^7$m., $r_e=14959*10^7$m, $w_e-w_m=0.936*10^{-7}$ radian/sec.

x = in days, $4r_m r_e \theta_{min}(w_e-w_m)/2(r_m-r_e)^2 \cos(1.85^o) = 1/t_1$

After simplification it reduces to, $I = I_0 + A_1 \exp[-.05203 (x-x_0)]$

Constant background term I_0 is added to match the exponential model equation fitted in data.

Here we obtain from calculation $t_1=(1/.05203)=19.21$. This estimated value is in good agreement with the fitted value 18.2. It explains the Temporal variation of x-ray luminosity flux during observation of Mars over a period of month from the date of closest approach of the Mars to the Earth.

3. Conclusions

Ground based observations have fair degree of uncertainty due to atmospheric variability. We tried to study the secondary x-rays flux produced by the cosmic & solar energetic particles interaction with the atmosphere of the Mars during its closest approach to the Earth. We found that 9.573keV x-rays was present almost in all observed spectrum over entire one month observation irrespective of cloudy day and presence of Moon near the site of Mars. It indicated that 9.573keV is originated in the atmosphere of the Mars after interaction of primary solar and cosmic radiation with atoms of Zn, Ne, Cu, Cr available in dust storm of the Mars.

It is evident from the data of 9.573keV x-ray flux that it exponentially decreases as a function of time during recession of the Mars after its closest approach to the Earth on 27th August 2003.

It is desirable now to study, with more accuracy, the x-rays produced in the atmosphere and the dust storm over the surface of the Mars. It will be very beneficial in quest of long term human precursor with large human safety mission on the Mars.

4. References

[1] A. Bhardwaj et. al. Proc. ESLAB 36 Symposium, 3-8 June,215 (2002).
[2] B. Cantor et.al., J. Geophys Res., 107, 5014 (2002).
[3] T.E. Crarens et. al. Geophys.Res.Lett.,28(2001).
[4] K. Dennerl, A&A, 394,1119,(2002).
[5] H. Gunell, et. al. Geophy.Res.Lett. 31(2004).
[6] m. Holmstram et. al. Geophys.Res.Lett. 28, 1287,(2001).
[7] D.L.McKenzie et. al, 44,499,(1982).
[8] V, Roberto et.al. Astroparticle physics 21 (2004).
[9] N.O.Renno et.al., J. Geophys.Res. 30,2140 (2003).
[10] J.R.Sharber et.al. Geophys.Res.Lett.,20,1319 (1993).
[11] P.H.Smith et.al. , J.Geophys ,104,8975 (1999).
[12] S.L.Snowen et. al. Astrophys. J.,404,403 (1993).
[13] J.D.Winningham et.al.J.Geophys.Res.,98,10649 (1993).