Light Flashes Observations On Board Mir And ISS With Sileye Experiments

M. Casolino,[1] V. Bidoli,[1] L. Di Fino,[1] G. Furano,[1] M. Minori,[1] A. Morselli,[1] L. Narici,[1] M.P. De Pascale,[1] P. Picozza,[1] E. Reali,[1] A. Rinaldi,[1] R. Sparvoli,[1] V. Zaconte,[1] C. Fuglesang,[2] W.G. Sannita,[3] P. Carlson,[4] G. Castellini,[5] A. Galper,[6] M. Korotkov,[6] A. Popov,[6] N. Vavilov,[6] S. Avdeev,[7] V. Benghin,[8] V. Salnitskii,[8] O. Shevchenko,[8] M. Boezio,[9] W. Bonvicini,[9] A. Vacchi,[9] G. Zampa,[9] N. Zampa,[9] G. Mazzenga,[10] M. Ricci,[10] P. Spillantini,[11], and R. Vittori[12]

(1) Department of Physics, University of Rome "Tor Vergata", INFN, Sez. Rome, Italy
(2) European Astronaut Centre, ESA, Cologne, Germany
(3) Neurophysiopathology-DISMR, University of Genova, Genova, Italy and Department of Psychiatry, SUNY, Stony Brook, NY, USA
(4) Royal Institute of Technology, Stockholm, Sweden
(5) IROE of CNR, Florence, Italy
(6) Moscow State Engineering Physics Institute, Moscow, Russia
(7) Russian Space Corporation "Energia" Korolev, Korolev, Moscow, Russia
(8) Institute for BioMedical Problems, Moscow, Russia
(9) Department of Physics, University of Trieste and INFN, Italy
(10) L.N.F.-INFN, Frascati, Rome, Italy
(11) Department of Physics of Univ. and Sez. INFN, Florence, Italy
(12) INFN Perugia, ESA - European Space Agency

Abstract

In this work we report on Light Flashes (LF) observations performed on board Mir space station in the years 1995-1999 with the SilEye-1 and -2 experiments. LF were originally predicted by Tobias in 1952 and observed for the first time on Apollo 11 mission; subsequently there were studied on Apollo, Skylab, and Apollo-Soyuz missions. LF consist of visual sensations in the eye by subjects exposed to high energy particles. A number of dedicated observations in space and on ground accelerators have provided a wealth of data which - due to the elusive and subjective nature of this effect - could not provide a clear answer to this phenomenon. A total of 18 hours of observation in 19 sessions resulted in the observation of 145 LF. LF rate is significantly lower than what observed in previous experiments but consistent with an increased shielding (geomagnetical and hull) of Mir; in addition there is evidence of a reduction of LF observation with time of permanence in Space.

pp. 4161–4164

1. Introduction

Light Flashes (LF) are abnormal visual perceptions thought to originate from the interaction of cosmic radiation with the human visual system. They are perceived in a variety of shapes (streaks, star-like flashes, etc.) apparently differing from the diffuse glow from X-ray exposure. This phenomenon was originally predicted by Tobias [15] in 1952 and observed for the first time on board Apollo 11. In the '70s a number of investigations in space on board Apollo [12, 13], Skylab [11] and Apollo-Soyuz Test Project [6, 7] (ASTP) confirmed the observation without, however, identifying the precise cause and mechanism involved in this phenomenon. At the same time a number of ground experiments was also performed using low intensity particle beams on human subjects. Due to the complex and time dependent radiation environment in space it is difficult to identify the cause (or the concurrent causes) of LF and the possible relation to long-term radiation risks to the astronauts.

2. The SilEye Project

LF investigation was again performed in the second half of the '90s inside Mir Space Station with the SilEye-1 and -2 experiments as part of a wider research program involving the study of cosmic rays, and ranging from the research of antimatter component of cosmic rays [14], to solar-terrestrial phenomena [8], to radiation environment in space and its effects on the human nervous system. The Sileye project has up to now gathered data in more than 30 hours of observation in 33 sessions using three different experimental devices, representing the longest LF investigation ever performed to our knowledge. Sileye-1 allowed real time monitoring of LF and particle rate without charge identification, while with SilEye-2 [2, 4] it was possible to correlate LF observations [1] with cosmic ray abundances measured in real time by a device capable of nuclear identification; the Sileye-3/Alteino [5, 9] experiment, combining an advanced silicon detector with an ElectroEncephaloGraph (EEG) has been placed on board the ISS on April, 27th 2002. Further investigations will continue with the ALTEA facility [3], a wide area silicon detector telescope covering most of the head of the astronaut to correlate incoming cosmic rays with LF perception. ALTEA is scheduled for launch on the ISS by middle 2004.

3. Results

In Table 1 are shown Dark Adaptation (DA) times for three cosmonauts (SA, VA, YB) in agreement one another and with other measurements performed on Skylab ($\simeq$ 10 minutes) and ASTP ($\simeq$ 15 minutes); the value of Apollo (average of 19 minutes) is consistent for the translunar sessions (11 min) but higher for the transearth session (22.6 min). The value for GP is higher than the other three cosmonauts but again within statistical error of the DA time of SA. The reason the high DA time rms is due to a session of SA with a DA time of 37.9 minutes (during which only one LF was observed); if this value is removed we obtain an average DA time of 11 ± 5 min.

To confirm the hypothesis that LF are caused by cosmic rays and thus obey Poisson statistics we plot in Figure 1(left) the histogram of the elapsed time between subsequent LF with an exponential fit superimposed: it is possible to see the good agreement with the fit with μ=4.3±1.1 min (258 s), to be compared - for instance - with the much smaller Apollo value [16] of μ=0.645 min (38.7s), reflecting again the lower occurrence of LF inside MIR. In Figure 1(right) we show LF occurence as function of orbit position: it is possible to observe the higher rate corresponding to higher latitudes and SAA regions.

As shown in Table 1, LF rate inside Mir is not only slightly lower than observed with the previous SilEye-1 sessions but much lower than what observed on Apollo, Skylab and ASTP experiments. This effect is most probably due to the combined effect of the higher geomagnetic shielding and the reduction of low energy particle rate by the material of the hull of Mir ($>$ 3mm Al) and all equipment in it. Recent results have identified the existence in space of almost two component contributions to LF frequency [10].

1. Avdeev S. et al. 1997, Acta Astronautica 50 , 8, 511
2. Bidoli V. et al. 1997, NIM A 399, 477
3. Bidoli V. et al. 1999, ESA SP-433, 505
4. Bidoli V. et al. 2001, J. Phys. G 27, 2051
5. Bidoli V. et al. 2002, J. Rad. Res. 43, Suppl., S47-S52
6. Budinger T.F. et al. 1976, NASA TM X-58173, 13-1
7. Budinger T.F. et al. 1977, NASA SP-412, 193
8. Casolino M. et al. 2001, Proc. 27th ICRC, 2314
9. Casolino M. et al. 2002, Nucl. Phys. B, 113, 71
10. Casolino M. et al. 2003, Nature 422, 680
11. Hoffman R.A. et al. 1977, NASA SP-377, 133
12. Osborne W.Z. et al. 1975, NASA SP-368, 355
13. Pinsky L.S. et al. 1974, Science 183, 957
14. Spillantini P. et al. 2001, Proc. 27th ICRC, 2215
15. Tobias C.A. et al. 1952, J. Aviat. Med. 23, 345
16. Tobias C.A. et al. 1972, Proc. of COSPAR Life Science and Space Research XI, 233

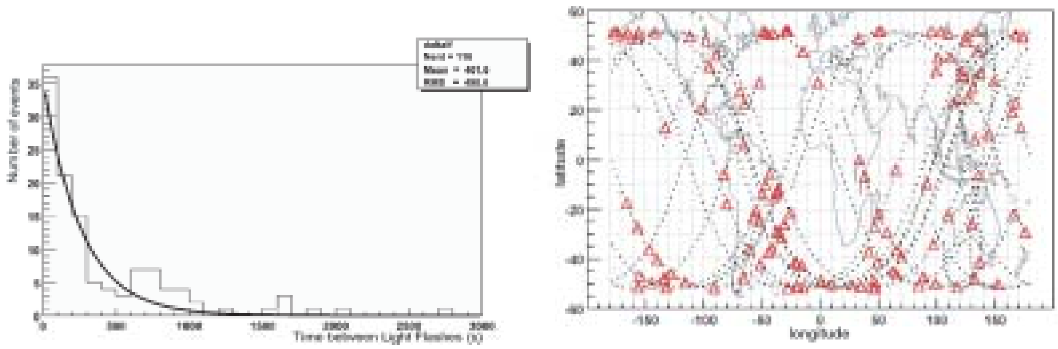

Fig. 1. (Left) Histogram of the elapsed time (s) between subsequent LF. The continuous line represents a Poissonian fit with μ=4.3+1.1min. (Right) Positions of LF observed on Mir with Sileye-2 (Triangles). Small points show the orbit of the station during LF sessions.

Cosmonaut / Mission	Numb. sess.	Dark adapt. time (min)	Sess. length (after DA) (min)	LF Observed	LF rate (LF/min)	Shielding (g/cm2) / height (km)
YB GP VA SA	2 1 5 11	12±7 23 13±3 13± 9	112 26 239 673	28 9 20 79	0.25±0.04 0.34±0.11 0.08±0.02 0.12±0.01	
Sileye-2 tot. (1998-1999)	19	13.5±8	1050	145	0.13±0.01	$>$ 0.81 300-400 [2,10]
Sileye-1 tot. (1995-1996)	9		492	87	0.18±0.02	$>$ 0.81 300-400 [1]
ASTP (1975)	2	$\simeq$ 15	180	82	0.46±0.05§	3-3.5 (0.27π sr) 3.5-5.5 (0.77 π sr) 225 [7]
Skylab-4 (1974)	2	$\simeq$ 10	125	168	1.3±0.1	1.5-2.0 (1.5π sr) 443 [11]
Apollo 14-17 (1971-1972)	20	19±9‡	1161	268	0.23±0.1†	3-3.5 (0.27πsr) 3.5-5.5 (0.77π sr) (Earth-Moon) [13]

Table 1. Sileye-2 LF results obtained with the four cosmonauts involved. Combined data are compared with previous missions. *Notes: §112 LF were observed in the 12 min transit in SAA. ‡ Translunar coast sessions had a lower DA (11.0 min) and higher LF rate (mean time between events 2.58 min) than transearth coast sessions (DA 22.6 min, mean time 2.91). † Takes into account that during Apollo 17 transearth session there were no LF observations by the three astronauts. If these three sessions are excluded the rate rises to 0.27±0.02 LF/min.*