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The Living Record of Science

《自然》百年科学经典

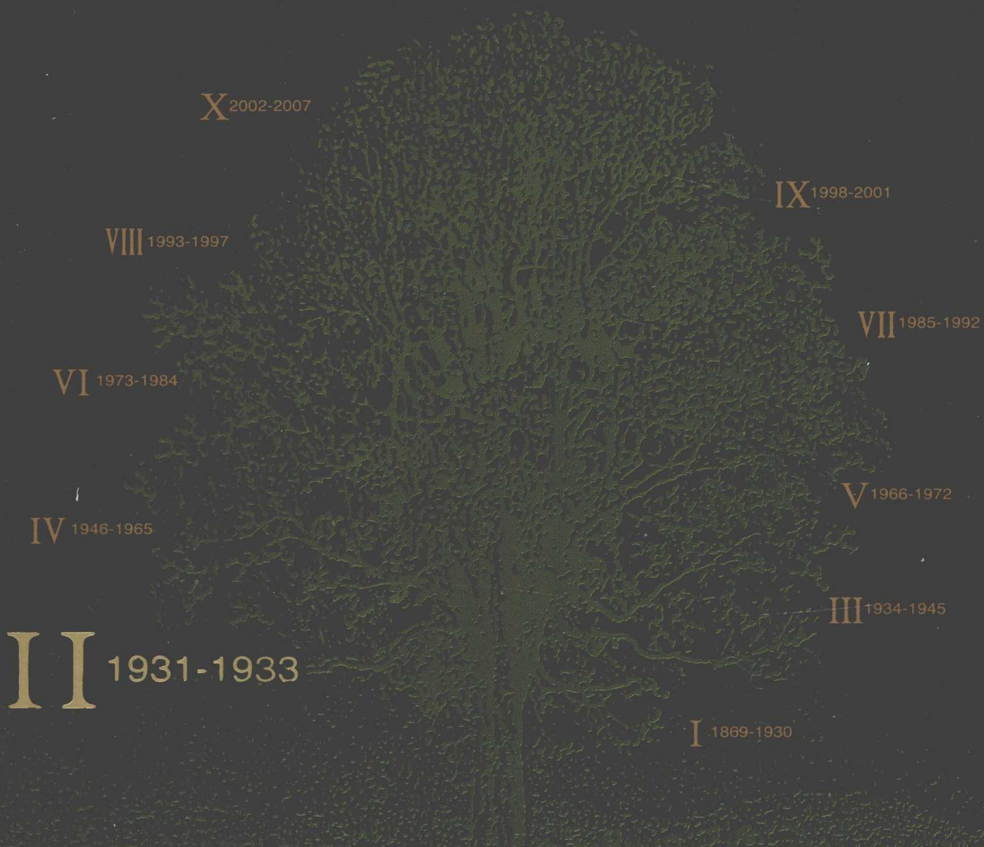
（英汉对照版）

第二卷

总顾问：李政道（Tsung-Dao Lee）

英方主编：Sir John Maddox
Philip Campbell

中方主编：路甬祥



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II

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Volume II
(1931-1933)

Evidence for a Stellar Origin of the Cosmic Ultra-penetrating Radiation

V. F. Hess

Editor's Note

Physicists were still pondering the nature of cosmic rays. Earlier studies failed to find any evidence that the Sun emitted such rays, but here Victor Hess reports new experiments showing that it does. As he notes, recent experiments at high altitude in the Swiss Alps found the average intensity of radiation to be higher during the day and lower at night. Further experiments with lead shielding showed that the Sun's light included a component of highly penetrating rays, with intensity equal to about 0.5 percent of the total observed cosmic ray intensity. Hess argues that cosmic rays most probably have a stellar origin, as all other stars probably emit them much as the Sun. The precise nature of these particles remained unknown.

WHILE in former years all observers were agreed that the sun does not contribute any noticeable amount to the total intensity of the cosmic ultra-radiation, the increase in the sensitivity of the apparatus used within recent years, and the increase in the number of observations made at different stations and under different experimental conditions, makes it possible to investigate once more whether the influence of the sun is altogether negligible.

Very accurate and trustworthy registrations of the cosmic radiation have been carried out with Prof. G. Hoffmann's high-pressure ionisation chamber at Muottas Muraigl (2,456 m. above sea-level) in the Engadine. These measurements show, beyond any doubt, that the average intensity of the radiation is somewhat greater in daytime than during the night. G. Hoffmann and F. Lindholm[1] give the average difference between day and night intensities as 0.12 mA., ~0.0125 ions per c.c. per sec. while the apparatus was unscreened from above, and 0.04 mA., ~0.0042 *I* with a lead-screening of 6 cm. and 9 cm. thickness. (The letter "*I*" always denotes "ions per c.c. and sec.".) F. Lindholm,[2] with the same apparatus, found from longer series of observations (8 months) the values in the accompanying table (see Table 6 of his paper).

In Hoffmann and Lindholm's apparatus a compensation current of one milliampere corresponds to an ionisation of 0.104 *I*. Therefore the total intensity of the ultra-radiation with the apparatus unscreened from above was about 2.50 *I* at Muottas Muraigl.

The difference between day and night intensity can be taken, provisionally at least, as the actual intensity of the solar penetrating radiation. One can see at once that at Muottas

宇宙超穿透性辐射起源于恒星的证据

维克托·赫斯

编者按

物理学家们仍在思考宇宙射线的性质。以前的研究未能找到任何证据证明太阳发射了这类射线，如今维克托·赫斯报告了他用新的实验结果说明确实如此。正如他所指出的，在瑞士阿尔卑斯山上的高海拔区进行的一项最新实验发现，辐射的平均强度白天比晚上高。采用铅屏蔽板以后再作的实验表明，太阳光中包含一个穿透力很强的射线成分，其强度约为宇宙射线总观测强度的0.5%。赫斯认为宇宙射线很可能起源于恒星，因为除太阳以外所有其他恒星发射的宇宙射线很可能与太阳发射的一样多。这些粒子的确切性质现在还不清楚。

在过去，所有的观测者一致认为，在宇宙超级辐射的总强度中，太阳没有任何值得注意的贡献。近年来，随着观测仪器灵敏度的不断增强，以及在不同国家、不同实验环境下进行的观测次数不断增多，于是有可能再一次研究由太阳造成的影响是不是可以完全忽略不计。

有人把霍夫曼教授的高压电离室放在瑞士恩加丁地区的穆拉古尔山(海拔 2,456 m)上，由此得到了一些非常准确而且可靠的有关宇宙辐射的数据。这些测量结果毫无疑问地说明白天的平均辐射强度要略高于夜晚。霍夫曼和林霍尔姆[1]给出了昼夜间强度差异的平均值：当仪器上方没有屏蔽时，平均值为 0.12 mA，或～ 0.0125 个离子每立方厘米每秒；当使用 6 cm 和 9 cm 厚的铅板屏蔽时，平均值是 0.04 mA，～0.0042 I (符号“I”通常表示“每立方厘米每秒的离子数”)。林霍尔姆[2]使用同样的仪器进行了更长期的观测（8 个月），所得数据列于附表中（参见他文章中的表 6）。

在霍夫曼和林霍尔姆使用的仪器中，一个 1 mA 的补偿电流相当于 0.104 I 的电离值。由此得出，在穆拉古尔山上由顶部没有铅板屏蔽的仪器测得的超级辐射的总强度大约为 2.50 I。

我们至少可以暂时把昼夜间的强度差视为太阳贯穿辐射的实际强度。于是马上就可以看到在海拔 2,456 m 的穆拉古尔山上，大约有一半这类太阳辐射成分能够穿

Muraigl, 2,456 m. above sea-level, about one-half of this solar radiation component is able to penetrate through 10 cm. of lead. This component is therefore far more penetrating than the gamma rays from radioactive substances. If we assume that all of the above-mentioned 0.011 I is of solar origin, we can compute the absorption coefficient in lead μ_{Pb} (it will suffice to take the case of perpendicular incidence) from the equation $I = I_0 e^{-\mu_{Pb} d}$ taking $I_0 = 0.011$, $I = 0.0058$, and $d = 10$ cm.; thus we obtain $\mu_{Pb} = 0.064$ cm.[1] and the mass absorption coefficient $\left(\frac{\mu}{\rho}\right)_{Pb} = 5.7 \times 10^{-3}$ cm.²/gm.

This value is almost exactly equal to the mass absorption coefficient value of the total cosmic radiation at the same altitude ($(\mu/\rho)_{Pb} = 6.3\times10^{3}$ cm.²/sec. as found by Büttner on the Eiger glacier 2.3 km. above sea-level).[3] If we assume that part of the (0.011 I) difference between day and night values with unscreened apparatus is due to an increase in the average content of radium emanation and its products in the air during daytime, then we should get an even more pronounced hardness of the solar penetrating rays, that is, a smaller value for their mass absorption coefficient. Therefore we are justified in concluding *that the sun emits penetrating rays of at least the same penetrating power as the well-known cosmic ultra-radiation. The total amount of the solar penetrating rays (at 2,456 m. above sea-level) is about one-half percent of the total intensity of the cosmic radiation, as it is seen from the accompanying table*. Of course, one might think it possible to explain the increase in the total radiation during daytime as due to an indirect influence of the sun (that is, an increase in the scattering of the ultra-rays by the heating of the atmosphere during the day). In this case, however, one would expect that this scattered radiation, represented by the difference between the day and night values, would be much softer than the general cosmic radiation; but this is in contradiction to the experimental results analysed above.

Recent observations of R. Steinmaurer[4] on the summit of the Sonnblick (3,100 m. above sea-level) in the summer of 1929, made with three different instruments (two of the Kolhörster double loop-electrometer type and one of the Wulf–Kolhörster type), also show clearly that the total ultra-radiation in daytime is slightly higher than at night; the difference amounts to about 0.7 percent (0.06 I, average difference for the three forms of apparatus mentioned above, the total intensity on the Sonnbick being about 8.7 I with the screening open on the top). The increase of radiation was also observed with apparatus screened with 7 cm. iron all around, but the number of these observations on the Sonnblick is not sufficient for quantitative calculations. It may be mentioned that even in the old observations on the summit of the Obir (2,000 m. above sea-level), made by V. F. Hess and M. Kofler,[5] the solar influence is noticeable (the total intensity of the ultra-radiation plus earth-radiation during the day being 11.11, during the night 11.09 I, in the average for 13 months), although at that time the apparatus were not screened from the earth radiation. The difference of 0.02 I was—at that time—considered as practically amounting to zero.

Observations with apparatus of the Wulf– or Kolhörster type for shorter periods (like those of Kolhörster–v. Salis on the Jungfraujoch, on the Mönch, and of Büttner at other places

过 10 cm 厚的铅板。因此这部分辐射的穿透性大大高于放射性物质发出的 γ 射线。如果我们假设所有上述的 0.011 I 全部起源于太阳，我们就可以根据方程 $I = I_0 e^{-\mu_{Pb} d}$ 计算出铅的吸收系数 μ_{Pb}(只考虑垂直入射的情况已经足够)，代入 $I_0 = 0.011$，$I = 0.0058$ 和 $d = 10$ cm，我们得到 $\mu_{Pb} = 0.064\ cm^{-1}$ 和质量吸收系数 $\left(\frac{\mu}{\rho}\right)_{Pb} = 5.7 \times 10^{-3}\ cm^2/g$。

这个数值几乎精确地等于所有宇宙辐射在这个高度上的质量吸收系数（比特纳在海拔 2.3 km 的艾格尔冰川上的测量值为 $(\mu/\rho)_{Pb} = 6.3 \times 10^{-3}\ cm^2/sec$）。[3] 如果我们假设在没有屏蔽层的仪器上测量到的昼夜间差异（0.011 I）中，有一部分是由于白天空气中镭射气和其产物的平均含量上升引起的，那么我们观察到的太阳贯穿射线会更硬，即它们的质量吸收系数会更小。因此我们认为以下结论是合理的：**太阳发出的贯穿射线的穿透能力至少与著名的宇宙超穿透辐射相当。太阳贯穿射线的总量（在海拔 2,456 m 处）大约占宇宙辐射总强度的 0.5%，如附表所示。**当然，有人可能将白天辐射总量的升高解释为受太阳间接影响所致（即白天被加热的大气增加了对超穿透射线的散射）。然而在这种情况下，因散射造成的辐射——由昼夜间辐射量的差异表示，会比一般的宇宙辐射更软；而这与上面分析的实验结果是矛盾的。

1929 年夏天，斯坦莫勒[4] 在松布利克山峰顶（海拔约 3,100 m）用三种不同仪器（两台柯尔霍斯特型双环静电计和一台伍尔夫–柯尔霍斯特型）的最新观测也明确显示出测量的超级辐射总量白天的数值略高于夜晚；差值大约为 0.7%（用上面提到的三种仪器测量的差值取平均后得到 0.06 I，顶部没有屏蔽的仪器在松布利克山测量的总强度约为 8.7 I。）当仪器四周用 7 cm 厚的铁板屏蔽时仍然可以观测到辐射量的增加，但是在松布利克山上的观测次数太少不足以作出定量计算。人们也许会提到即使从之前赫斯和科夫勒[5] 在奥柏（海拔 2,000 m）山顶的观测数据中也可以看出太阳带来的影响（超级辐射加上地球辐射的总强度在 13 个月中的平均值：白天为 11.11 I，晚上为 11.09 I），尽管那时的仪器没有屏蔽掉地球辐射的影响。0.02 I 的差别在当时几乎可以被看作是零。

至于使用伍尔夫型或柯尔霍斯特型仪器进行的短周期观测（比如冯萨利斯在少女峰和修士峰以及比特纳在阿尔卑斯山其他地方用柯尔霍斯特型仪器所做的观测），