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On the evidence for high energy γ-ray emission from the Orion nebula stemming from COS-B observations

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The E.S.A. COS-B satellite performed a one-month observation pointing in the direction of M42 in Orion, during July–August 1978. An excess of high energy (above 100 MeV) photons is seen in the data, well coinciding with the Orion cloud complex. Features of such an excess are discussed, such as flux value, spectral shape and possible spatial extension of the emission. Brief astrophysical implications are then derived for the physical association of the excess with the Nebula.

At a distance of *ca.* 500 pc and with a mass of the order of $1–2 \times 10^5\ M_{\odot}$, bathed in a cosmic ray flux similar to the local one, the *Orion cloud complex* represented one of the best potential candidates for a '*passive*' source of high energy γ-rays (see Black & Fazio 1973). Marginally covered by the SAS-2 satellite (Thompson *et al.* (1977); for a re-analysis of the data see Wolfendale 1980) the giant complex in Orion (Kutner *et al.* 1977 and references therein) was considered a very promising target for detectability with a one-month observation by the COS-B satellite. Such an observation has now been made, mapping the high energy γ-ray emission from local galactic features, notably of Gould's belt. The satellite was pointed at $\alpha_{1950} = 05\text{h}32$, $\delta_{1950} = -5°\,48'$ ($l = 209.2°$, $b = -19.8°$) from 1978, August 23 to September 29, with a useful time of 1.42×10^6 s, and recorded a total of *ca.* 2500 photons (above 70 MeV). These are shown in figure 1 in the form of a γ-ray contour sky-map (above 70 MeV).

The existence of a structured excess is apparent, thus representing the first clearly *extended* source of celestial γ-rays coinciding with a known localized object (see also Caraveo *et al.* 1980). In fact, the positions of the γ-ray enhancements, roughly centred at $\alpha_{1950} = 05\text{h}44$, $\delta_{1950} = 0°\,0'$, ($l = 205.4°$, $b = -14.4°$) and at $\alpha_{1950} = 05\text{h}30$, $\delta_{1950} = -6°\,30'$ ($l = 210.0°$, $b = -20.6°$) coincide, from a γ-ray astronomy point of view, with the dark clouds L1630 and L1641 (Lynds 1962), i.e. the Orion northern and southern complexes, also shown in figure 1. This coincidence is also apparent in figure 2, where a set of right-ascension profiles integrated over declination are presented. Because of the limited statistics in the peaks in figure 2, and of the uncertainty in the evaluation of the background in the histograms, it is difficult to estimate separately the fluxes from the two clouds. An evaluation of the flux from the whole γ-ray excess yields a value of $(2.0 \pm 0.5) \times 10^{-6}\ \text{ph}\,\text{cm}^{-2}\,\text{s}^{-1}$ in the range $70 < E < 5000$ MeV.

The discovery of the *first extended* γ-ray source and its straightforward identification gives a

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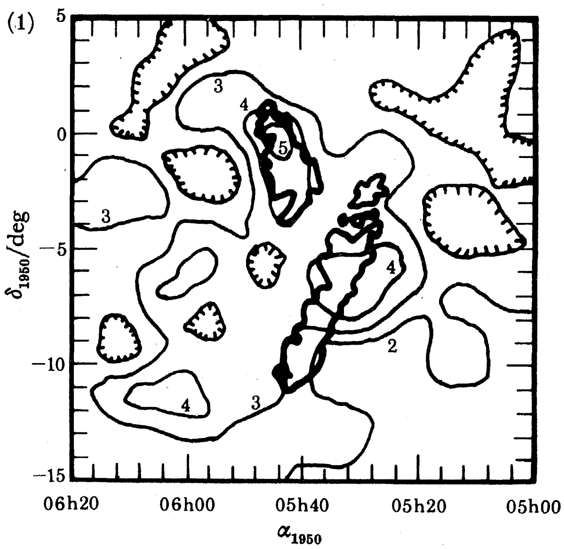

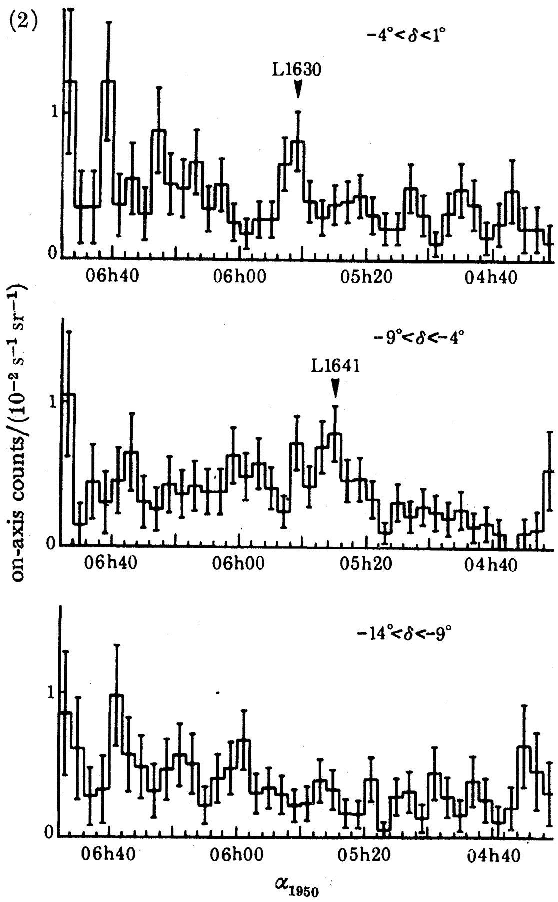

FIGURE 1. Smoothed γ-ray contour map of the Orion region. The contour unit is 2×10^{-3} 'on-axis counts' s^{-1} sr^{-1} (see Mayer-Hasselwander *et al.* 1980). The thick line follows the boundaries of the L1641 and L1630 dark clouds.

FIGURE 2. Right-ascension profiles of the Orion region: 'on-axis counts' for $70 < E < 5000$ MeV. The declination ranges of integration as well as the position of L1630 and L1641 are shown. Statistical errors are indicated.

unique possibility of investigating the physical processes that produce the γ-ray emission in a giant molecular complex. As sketched above, for Orion it is tempting to rely on the simplest point of view in which the total mass of the complex, completely penetrated by cosmic rays, is considered as a *passive* target for high energy cosmic radiation. Moreover, once the elementary production rate, q_γ, is established, one can evaluate the mass of the cloud from the measured γ-ray flux simply, thus avoiding the problems of the CO-line method for the determination of the mass, which is affected by uncertainties ranging between factors of 3 (Blitz 1980) and 10 (Stenholm 1980). In general, the best way of evaluating the emissivity is to correlate the γ-ray fluxes with galactic absorption as a tracer of the total gas column density (for more details see Lebrun & Paul 1979; Lebrun *et al.* 1981). To minimize the effect of possible large-scale variations of q_γ in the local medium, the correlation has been studied over a limited area (about 800 square degrees) encompassing the Orion cloud and yielding a value of

$$q_\gamma\,(>70\,\mathrm{MeV}) = (4.3 \pm 0.6) \times 10^{-25}\,\mathrm{ph\,(H\ atom)^{-1}\,s^{-1}},$$

where the quoted error reflects only the statistical uncertainty in the γ-ray flux. On the assumption that the derived q_γ holds true for the cloud, which is about 30 square degrees in extent, the total mass for the flux and distance given above is $(1.2 \pm 0.4) \times 10^5\,M_\odot$, to be compared with previous radio astronomical estimates of $1.5 \times 10^5\,M_\odot$ (Kutner *et al.* 1977; Blitz 1980) and of $2 \times 10^5\,M_\odot$ (Stark & Blitz 1978).

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