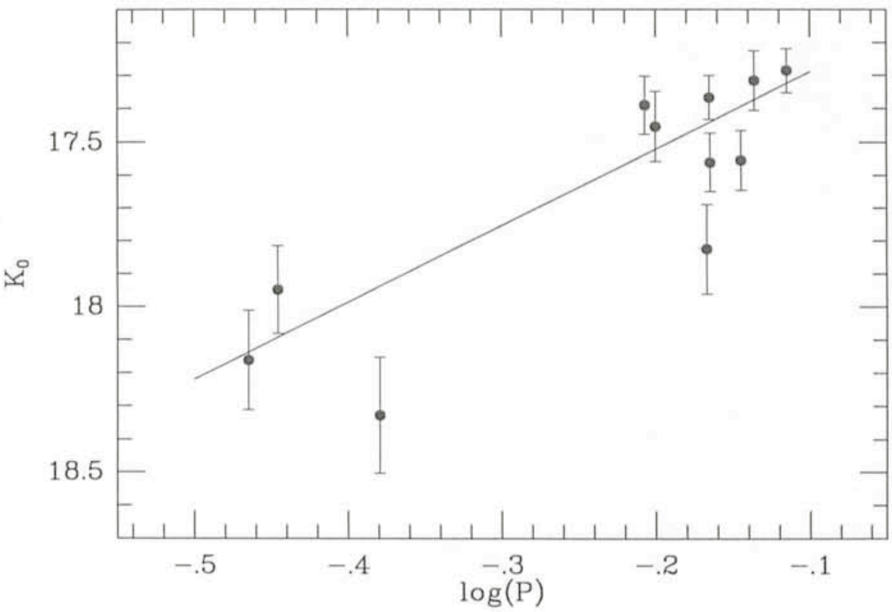

Figure 2: *The Infrared Period-Luminosity relation as derived from the RR Lyrae stars of NGC1841. The line is the best fitting line through the weighted data points.*

This result is in excellent agreement with the relation found for galactic RR Lyrae stars by Jones et al. (1992) using the Baade-Wesselink method, which is

$$\langle M_K \rangle = -2.33(\pm 0.20)\log P - 0.88(\pm 0.06). \qquad (2)$$

While it might be coincidental that the slopes agree so well, the result clearly indicates that the slope $d\langle K \rangle / d \log P$ determined for Galactic RR Lyrae stars can also be applied to low metallicity RR Lyrae stars in the LMC, and the relation can thus be used to determine the distance to such stars.

From the above equations we derive a distance modulus of 17.94 ± 0.15 to NGC1841, where the uncertaintly reflects internal errors only. This value is in excellent agreement with the results of Walker (1990) when adjusted to a common zero point. He derives a value of 18.19 from the $\langle M_V \rangle - [Fe/H]$ relation assuming a value of +0.5 mag for $\langle M_V \rangle$ at [Fe/H] of −2.2 dex. Jones et al. (1992), on the other hand, find a value of +0.67 mag more appropriate based on the same Baade-Wesselink results that provides the basis for Eq. 2. Correcting the modulus of Walker (1990) accordingly, we derive a modulus of 18.02 mag.

To further constrain the slope, we are attempting to obtain more data at different phases to decrease the scatter due to the random phasing of the data points and to improve the S/N for the faintest of the stars. Finally, we intend to measure stars in more LMC clusters to increase the sample size.

For a discussion of the adopted zero points see e.g. Carney et al. (1992) and Cacciari et al. (1992).

NGC1841, being located almost 15 degrees from the bar, is known to be far from the centre of the LMC. Walker (1990) argues that NGC1841 is approximately 0.3 mag closer than the LMC centre and adding in this offset leads to a modulus of 18.24 to the centre of the LMC. This is about 0.3 mag closer than suggested by the most recent Cepheid calibration (see Feast 1991), but in good agreement with other LMC RR Lyrae data (e.g. Walker 1992). A similar difference between distances based on RR Lyrae's and Cepheid's found by Saha et al. (1992) in the Local Group galaxy IC1613, suggest that there is a problem either with the zero point of one or both of the methods or that there are still effects like differences in chemistry which are not taken properly into account in the various methods.

In conclusion we must stress the importance of the big efforts that are currently being put into the better understanding of the various distance calibrators as well as their zero points.

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The Great Annihilator in the Central Region of the Galaxy

I.F. MIRABEL, Service d'Astrophysique, CE-Saclay, France

1. The Sepulchral Silence of the Hypothetical Super-Massive Black Hole

For two decades gamma-ray astronomers observing the galactic centre region with many balloon and satellite-borne instruments have been reporting intermittent radiation from the annihilation of positrons with electrons. Positrons are electrons of positive charge that annihilate when they meet ordinary matter, producing pairs of photons of 511 keV, the rest-mass energy of the annihilated particules.

The sporadic appearance of this type of gamma radiation in the central region of our Galaxy indicated the existence of a compact object (or objects) capable of fabricating enormous quantities of positrons in short periods of time. The poor angular resolution of the detectors used until recently gave wide latitude to the belief that the mysterious compact source of positrons could be a black hole of several million solar masses residing at the dynamic centre of the Galaxy.

However, the French gamma-ray telescope SIGMA on board the Russian satellite GRANAT has recently found[1] that the strongest source of 511 keV gammas is not at the dynamic centre of the Galaxy, but 50 arcminutes away from it (Fig. 1). On October 13–14, 1990, SIGMA detected from this source

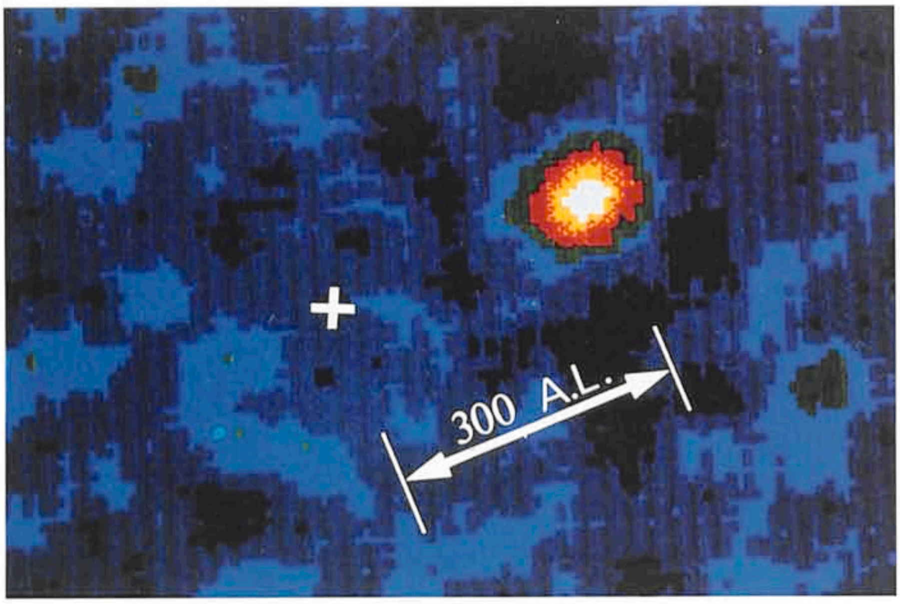

Figure 1: *Image of the Great Annihilator of positrons near the Galactic Centre obtained by the SIGMA telescope on board of GRANAT. Contrary to the expectations, in hard X-rays (40-120 keV) the strongest source is not at the dynamic centre of the Galaxy (white cross), but 50 arcminutes away from it (~ 300 light-years at the distance of the galactic centre). (Photo CEA/ CESR/CNES.)*

a powerful annihilation burst[2], and we then realized that this object is the strongest compact annihilation source known in the Galaxy. Since it can fabricate 10 billion (10^{10}) tons of positrons in just one second, it is now known under the name of the "Great Annihilator".

The Great Annihilator may be a black hole of stellar mass. In its standard state, the X-ray spectrum resembles that of the stellar-mass black-hole candidate Cygnus X-1, both in shape and intrinsic luminosity. Furthermore, dynamic studies of sources detected by SIGMA beyond 100 keV show that they are likely to be binary systems with gravitationally collapsed objects having masses between 3 and a few tens of solar masses.

2. A "Microquasar" Ejecting Positrons Into the Cold Interstellar Medium

To know the nature of this extraordinary source we have carried out ground-based multiwavelength observations coordinated with the observations by SIGMA from space. Due to the high interstellar absorption along the line of sight to the central region of the Galaxy, the optical identification of a binary companion is very difficult[3]. Therefore, we have undertaken a programme of observations at centimetre, millimetre, and infrared wavelengths using the Very Large Array (VLA), the 30-m telescope of the IRAM, and the 2.2-m telescope of ESO.

Our search for a radio counterpart of the compact source of positrons had an unexpected turn[4]. Using the VLA we find inside the error circle of the X-ray and gamma-ray telescopes a compact radio source that varies in a synchronized way with the high energy source. This compact variable source is the radio counterpart of the Great Annihilator. A pair of radio jets whose centre coincides with the variable source was soon discovered[4] (see Fig. 2). These jets, at least three light-years long, are probably synchrotron emission from positron-electron pairs streaming out at high velocities from the source of antimatter.

The broad annihilation line detected by SIGMA from the Great Annihilator must be distinguished from the variable component of the narrow annihilation line observed since two decades from the galactic centre region. The broad line was observed only once, in less than one day. This implies that the annihilation took place in a region smaller than 200 astronomical units. If the observed redshift of 20 % is gravitational, the annihilation took place in a region closer than 10 Schwarzschild radii from the black hole (for a black hole of stellar mass, the Schwarzschild radius is a few tens of km). This annihilation medium must have a size smaller than a few hundred kilometres in radius, temperatures above 10^8 K, and should be essen-

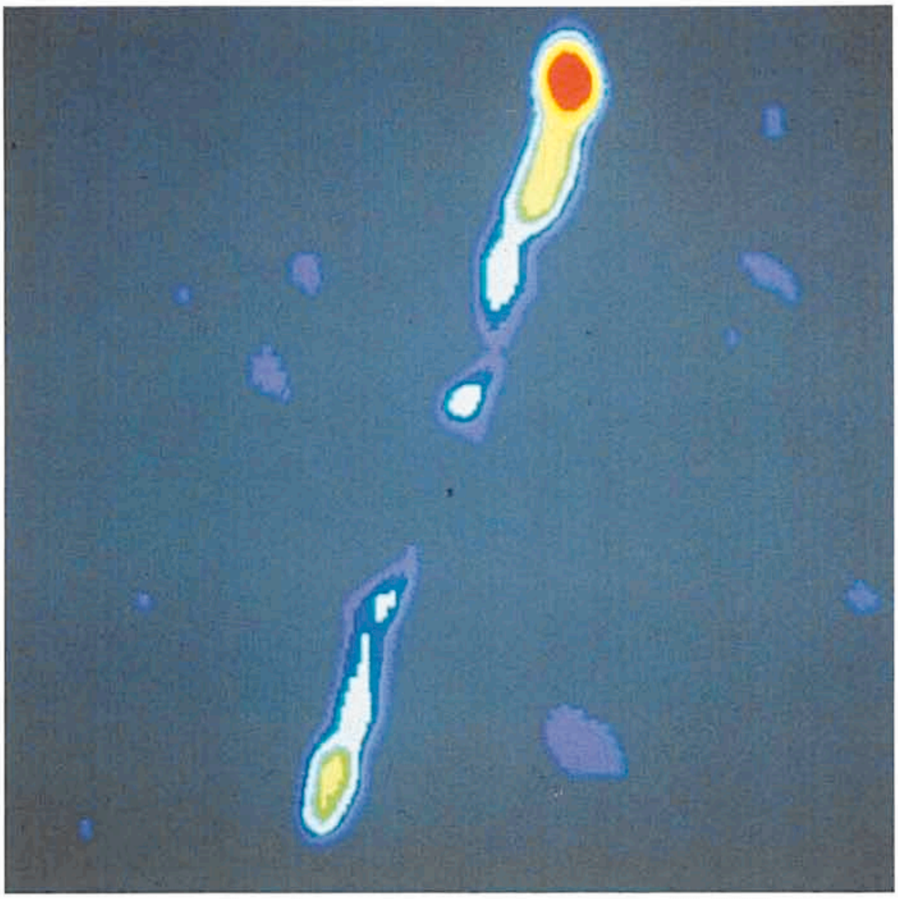

Figure 2: *This 20-centimetre VLA radio image shows jets at least 3 light-years long emerging from the Great Annihilator. The jets seem to be streams of electrons and their antimatter counterparts, positrons.*

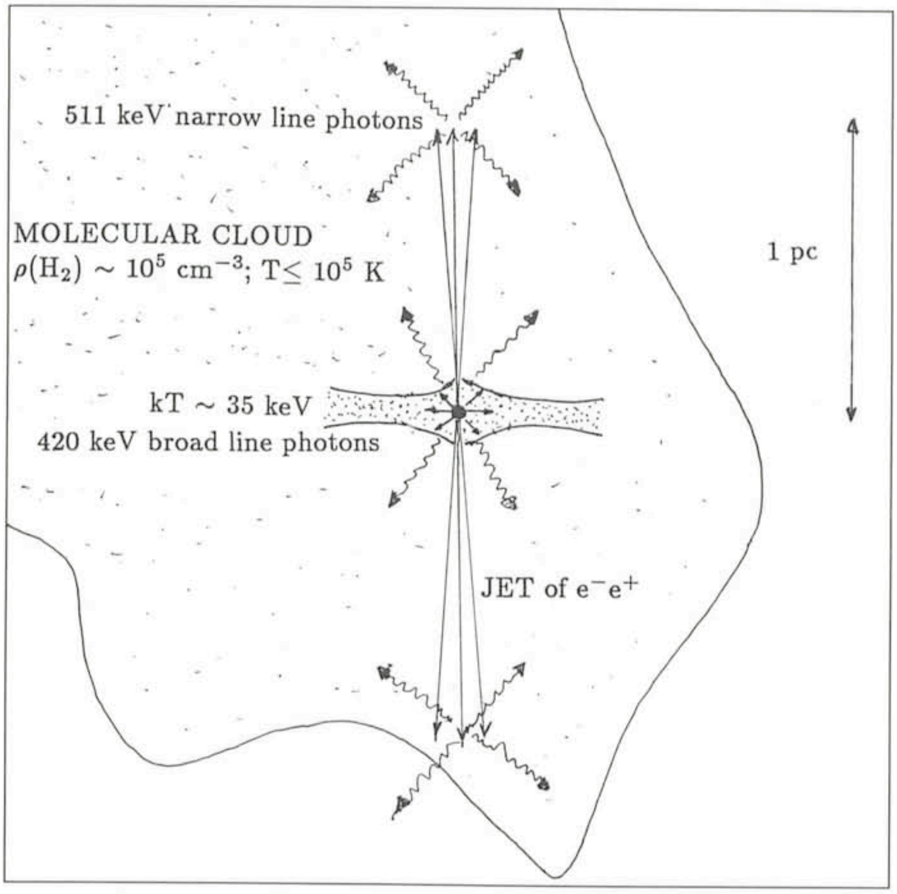

Figure 3: *Theoretical model of the Great Annihilator, possibly a stellar-mass black hole in a molecular cloud. Electron-positron pairs will annihilate sporadically within a few hundred kilometres from the black hole producing the redshifted broad emission line centred at 420 keV observed by SIGMA. Some fraction of the pairs will stream out at high velocities up to distances of ~ 1 pc before they are slowed down in the high density molecular gas, and annihilate giving rise to the 511 keV narrow line.*

tially transparent for the 511 keV annihilation photons.

Although the source of positrons at the origin of the broad line and the variable component of the narrow line may be the same, the annihilation medium of the narrow line must be different from that of the broad line. The redshift upper limit of 10^{-5} and the line width smaller than 5 % indicate that this narrow line is arising in a cold ($\leq 10^5$ K) and high density medium ($n \geq 10^4$ cm^{-3}). These properties are consistent with those of molecular clouds which have temperatures below 100 K, and densities greater than 10^4 cm^{-3}. In this context one may ask if the Great Annihilator could be a black hole in a molecular cloud.

3. A Black Hole Passing Slowly Through a Dense Molecular Cloud?

To answer this question we carried out observations of molecular transitions at millimetre wavelengths with the 30-m telescope of IRAM in the Sierra Nevada, southern Spain. The observations revealed the presence of a molecular cloud in the direction of the Great Annihilator[5]. The radial velocity indicates that this molecular cloud is in the galactic centre region, has a total mass of 50,000 solar masses and a mean density of 10^5 cm^{-3}. The absorption in soft X-rays along the line of sight to the Great Annihilator suggests that the compact source could be inside or near the foreground surface of this cloud. Although the physical association of the gamma-ray source and the molecular cloud has not been demonstrated, the probability of a coincidental superposition is less than 7 %.

To build up a model of the phenomenological diversity associated to the Great Annihilator we use a cartesian approach, going from a simple picture to a more complex one. This simple picture, which at present is full of unanswered questions is shown in Figure 3. Instabilities in the accretion disk around a stellar-mass black hole produce an enhancement of gamma photons, which by γ-γ interactions produce bursts of e^+e^- pairs that will annihilate within a few hundreds of kilometres from the black hole, producing the broad line observed by SIGMA. Some fraction of the e^+e^- pairs will be accelerated by radiation pressure, and collimated by magnetic fields. These pairs streaming away at relativistic velocities will produce the well-aligned synchrotron radio jets observed with the VLA over a few light-years of distance from the central source. The positrons will be slowed down in high density clumps of the molecular cloud with the subsequent annihilation that gives rise to the time variable narrow line.

When it is not fed, a black hole remains silent. Besides its gravitational effects it can reveal its existence as a source of high-energy photons and particles produced at or near an accretion disk built at the expense of matter coming from a binary companion. For instance, Cygnus X-1, one of the best black hole candidates has a blue supergiant companion that feeds the black hole by its strong stellar wind. Other black-hole candidates are fed by low-mass stellar companions, which transfer mass through the Roche lobes to the accretion disk of the black hole.

P.A. Duc from Saclay and I have used IRAC2 on the 2.2-m telescope at La Silla in an attempt to identify a binary companion. We obtained J, H, and K images of the field centred at the position of the VLA compact source, which we know with a precision better than 1″. Despite the high density of optically absorbed stars in the field, Figure 4 shows no infrared counterpart within 1″ of the radio counterpart down to mag K = 17. This is comparable to the result obtained by Djorgovski et al.[7] at Palomar. For an optical absorption of 50 mag along the line of sight to the galactic centre, this infrared magnitude limit implies that the Great Annihilator is not accompanied by a massive star, as is the black hole in Cygnus X-1. Conservative calculations show that no massive star with optical luminosity brighter than $M_V = -3$ mag is associated with the high energy source.

Since it is difficult to explain the light curve of the Great Annihilator observed by SIGMA[1] in terms of feeding from a low-mass companion, we envisage the possibility that the compact source is fed directly from the interstellar cloud by a classic mechanism first proposed by Bondi and Hoyle[8]. We have shown[5] that a compact object of stellar mass slowly moving through a dense molecular cloud can accrete more than 10^{-8} solar masses per year, namely, the equivalent of the accretion rate from the stellar wind of a massive companion.

In the context of this hypothesis one may ask why only a single powerful source of high-energy emission and annihilation occurs within the inner few degrees of the Galaxy, where molecular gas is more abundant than anywhere else in the Galaxy, and where there is no reason to expect that massive stellar remnants are rare. According to our hypothesis, the unusual properties of the Great Annihilator are the result of two conditions, each of which has a small probability of being satisfied: first, that the object is located within a dense cloud, and second, that it has a relatively small velocity with respect to that cloud. Our calculations show that only one among the ~40,000 massive remnants within 200 pc from the centre of the Galaxy would satisfy the conditions required to produce a substantial accretion luminosity without a binary companion. Therefore, it is not surprising that despite the large amount of compact objects in the central region of the Galaxy, there is only one Great Annihilator.

Although this is a possible scenario from a theoretical point of view, we have not demonstrated that it also corresponds to reality. Therefore, it still remains an open question how the accretion disk of the black hole is actually fed.

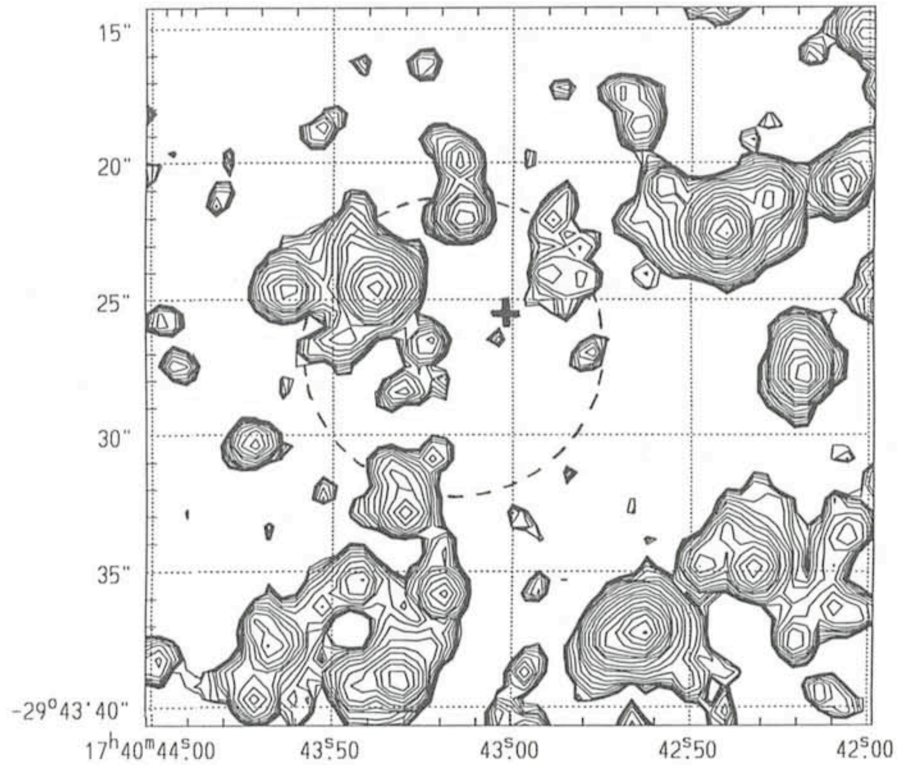

Figure 4: *K band image of the field in the direction of the Great Annihilator obtained with IRAC2 on the 2.2-m in June 1992. The ROSAT HRI X-ray error circle[6], and the cross corresponding to the compact radio counterpart of the high energy source[4] are indicated. Within 1" of the VLA counterpart there is no infrared source down to mag K = 17. This implies that there is no massive star associated to the compact source more luminous than $M_V = -3$.*

4. A Second Microquasar in the Central Region of the Galaxy

After the Great Annihilator, the second strongest persistent gamma-ray source in the galactic centre region is the source GRS1758-258[1], which is located at galactic coordinates $l = 4.51°$; $b = -1.36°$. We have recently identified the compact radio counterpart of this gamma-ray source[9]. Infrared imaging with IRAC2 on the 2.2-m by P.A. Duc and the author shows that the field is less populated than that of the Great Annihilator. However, as for the Great Annihilator, we did not detect any K band counterpart to a limiting magnitude of 17.

The recent discovery[10] of equally symmetric radio jets emerging from the second strongest persistent gamma-ray source in the galactic centre region suggests that positron-electron pair jets may be common phenomena associated with high energy sources. Our observations suggest that this class of objects represents a scaled-down version of active galactic nuclei, which appear as "microquasar" stellar remnants in high density environments.

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ANNOUNCEMENT

ESO/OHP WORKSHOP ON DWARF GALAXIES

A joint ESO/OHP Workshop on Dwarf Galaxies will be held from 6 to 9 September 1993, at the Observatoire de Haute-Provence (OHP) in France.

Topics of the workshop:
- Searches for dwarf galaxies
- Morphological classification
- Luminosity function
- Spatial distribution
- Detailed kinematical and dynamical studies
- Photometry and HR diagram
- Spectral synthesis
- Evolution and origin

Contact Address: Georges Meylan, European Southern Observatory, Karl-Schwarzschild-Straße 2, D-W8046 Garching bei München, Germany, e-mail (Internet): gmeylan@eso.org