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The Newsletter of Galactic Center Research

Edited by Robin Herrnstein, Cornelia Lang, Joseph Lazio, Sera Markoff, Rainer Schödel & Loránt Sjouwerman

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INTEGRAL Gamma-Ray View of the Galactic Center

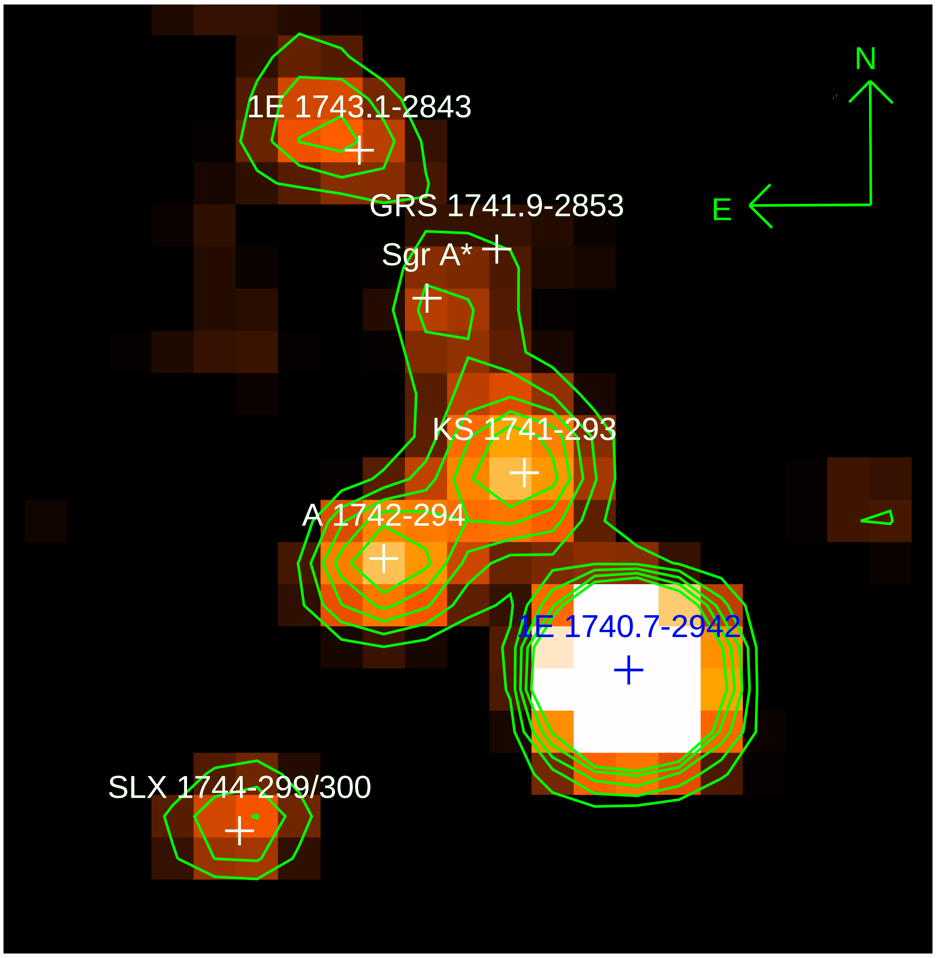

Figure 4 **b** from Ubertini's invited article: The high energy emission (40-100 keV) observed by the INTEGRAL Observatory in a region of 2 $\times$ 2 degrees toward the Galactic Center. The article starts on page 4 of this issue.

Table of Contents

In the News

Cornelia Lang

Welcome to the third GCNEWS of 2004. Since the last GCNEWS, we've seen a number of new results on the larger-scale interstellar medium in the GC arena as well as some results from the gamma-ray part of the spectrum (see abstracts below for more information). The summer observing season has come to a close and we hope that you have all had success at the telescopes!

As always, please feel free to contact any of us with GC newsworthy items or future article ideas. We also remind our readers to *please* submit their abstracts to GCNEWS. As you know, GCNEWS promises rapid delivery of your results to fellow GC researchers. While *astro-ph* is a valuable resource, GCNEWS directly targets those readers with an acknowledged interest in GC science.

In this Volume

In this volume, we are excited to report on a number of upcoming conferences, including several which are in the very early planning stages for 2006.

We are pleased to have this issue's invited review focused on recent results on the Galactic Center from the very high energy end of the spectrum. Pietro Ubertini, who is the Principal Investigator on the IBIS instrument aboard the INTEGRAL Observatory, has provided us with a nice overview of the observations of the central region of our Galaxy in the gamma ray part of the spectrum over the past 30 years. INTEGRAL has made a strong committment to studying the Galactic Center by devoting significant time to this target and has already made some exciting discoveries.

A hefty number of GC abstracts have come in since July and as always, we encourage you to continue to submit your latest results. Our next issue of GCNEWS will be early in 2005 after the winter American Astronomical Society meeting—hope to see many of you there!

Upcoming GC Meetings

The Paradoxes of Massive Black Holes: April 14-16 2005

The Kavli Institute for Theoretical Physics (KITP) at UC Santa Barbara is planning a three day conference on "The Paradoxes of Massive Black Holes: A Case Study in the Milky Way" during the period of April 14-16, 2005. See http://www.kitp.ucsb.edu/activities/conferences for updates regarding the conference. The conference will be focused on the twin puzzles of (1) star formation and the young stellar population in the central parsec of the Galactic Center, and (2) the "luminous" source Sagittarius A* associated with the massive black hole in the Galactic Center. The goal of the meeting is to bring together scientists with expertise in the Galactic Center, star formation and stellar dynamics, and accretion disks and jets to discuss the exciting recent results on the Galactic Center and their broader implications. We expect a very exciting conference, with adequate time for discussions and debate of the forefront issues in the field. There will also be ample opportunity to present posters with current results. Any questions regarding the meeting can be addressed to Andrea Ghez (ghez@astro.ucla.edu), Sera Markoff (sera@space.mit.edu), or Eliot Quataert (eliot@astron.berkeley.edu).

Planning for the Next GC Conference: April 2006 in Germany

We have started planning for the next Galactic Center conference. It is still very early in the planning stage, but so far we would like to call to your attention that:

- The meeting will be held at the Physik Zentrum in Bad Honnef (near Bonn, Germany) in the beautiful Rhineland.
- The dates are scheduled for the 17 to 22 of April 2006.
- The number of participants will be limited to 100-120.
- This time we are also considering widening the focus of the conference somewhat in order to include nearby normal galactic nuclei for comparison with our own GC.

Please stay tuned for further news and expect a more formal announcement in Spring 2005.

IAU 2006: Thinking about a Joint Discussion

We have also started thinking about organizing a Joint Discussion (JD) at the next General Assembly of the IAU to be held in Prague in the Czech Republic sometime during 14-26 August of 2006. The focus of this one day JD would also be to broaden our scope from our own Galactic nuclear region to the nuclei of other nearby, similar galaxies. So far we have thought about a combination of talks on the GC and similar low-luminosity active galactic nuclei. We welcome any thoughts or suggestions you may have.

INTEGRAL Gamma-Ray View of the Galactic Center

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1. Background and Introduction

1.1 Early High Energy Observations of our Galactic Center

In the last GCNEWS issue, S. Doeleman & G. Bower nicely illustrated that the increasing capability of Very Long Baseline Interferometry (VLBI) will soon allow images to be taken very close to the region at which photons can no longer escape from the super massive black hole (SMBH), Sgr A*. We have clearly come a long way in our search to understand this object. As early as the 1960s, it was suggested that the central core of our Galaxy was a central hot engine, from the view point of energy release. This scenario became clear from the first X-ray all sky maps. Figure 1 (left) shows the 1968 X-ray sky, obtained with a number of short rocket flights, and clearly demonstrates the clustering of discovered sources toward the plane and the central region of the Galaxy.

The extreme variability in time of the handful of X-ray sources discovered at that time and the ratio of the luminosity $L_X/L_{optical}$ of ~1000 was immediately interpreted to be a powerful new observational tool. A clue to determining the dimension of the high energy emitting regions is achieved by measuring the time scale of fast transient events that were associated with physical processes showing matter accreting into a extremely high gravitational field, i.e. close to the Schwarzschild radius of the black hole or in the vicinity of the hard surface of a neutron star.

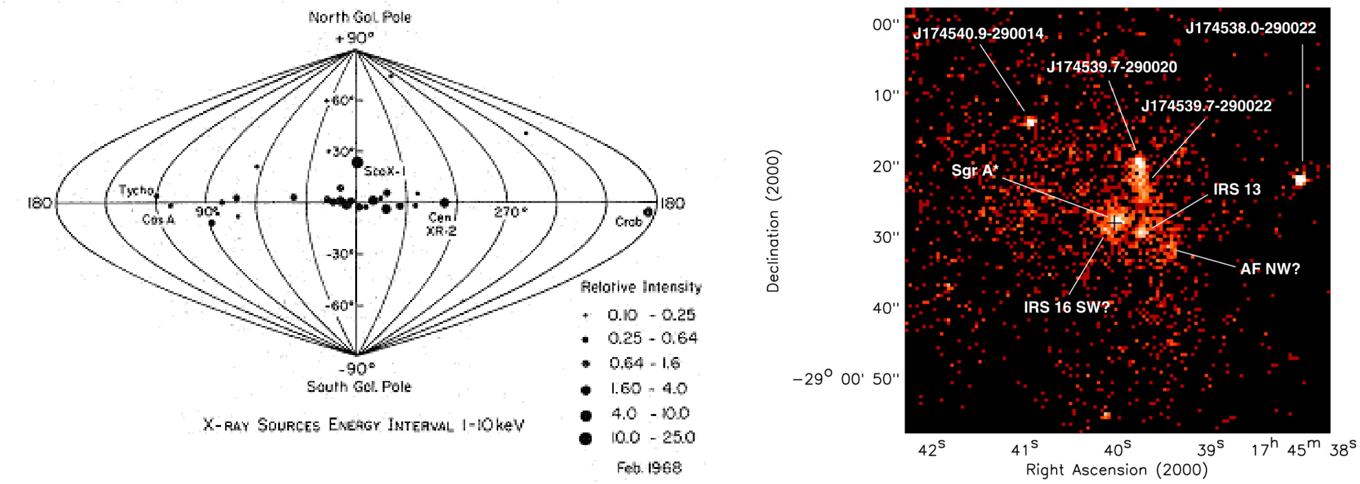

Figure 1 Left: The map of the X-ray sky as available in February 1968. It is clear that there is a clustering of the powerful X-ray emitters in the central region of the Galaxy. Right: A recent *Chandra* image of the GC region in the 0.5-7 keV energy range with a size of one arcmin squared (Baganoff et al. 2003).

The astonishing X-ray and γ-ray skies were depicted by a number of balloon and rocket payloads launched in the 1960s. The first X-ray satellite, UHURU, launched in late 1970, discovered more than 300 X-ray sources. Furthermore, diffuse γ-ray emission from the plane and the central part of the Galaxy was detected by SAS 2 (NASA) and COS-B (ESA), launched during November 1972 and August 1975 respectively. COS-B also revealed high energy emission from a number of pulsars in the MeV domain.

The presence of strong, variable emission from the dynamical centre of the Galaxy, together with the diffuse emission discovered in γ-rays were considered the major clues for the existence of a massive-peculiar object located there, as predicted by Lynden Bell and Rees in 1971. The discovery by Balick and Brown (1974; also see GCNEWS

Vol. 18) of a sub-arcsec compact radio source three years later was the proof of the peculiarity of the GC. Since then, the poor angular resolution of X-ray and γ-ray telescopes has hampered the unambiguous detection of high energy emission from Sgr A* for almost 30 years. A detection of short time variability at high energies from the central degree of the Galaxy had been identified in early high energy satellites (in the 1970s), however it has been difficult to assign this variability to Sgr A* itself.

The quest for a high energy sign of vitality was continued using a coded mask experiment on board Spacelab 2 (1985), sensitive in the hard X-ray range (2.5-30 keV), with the detection of a source ~1 arcmin from the centre (Skinner et al. 1987): the result was puzzling because it was clearly not radiation coming from Sgr A* but rather one of the active binaries in the crowded Galactic Centre region. At even higher energy none of the satellites of the 1990s had the sufficient angular resolution and sensitivity to be able to understand the lack of γ-ray emission from this region. In fact, the OSSE experiment on board the Compton Gamma Ray Observatory provided high sensitivity, but was not able to do imaging studies. SIGMA, the French-Russian high energy imager on board the GRANAT satellite, in spite of the ~15 arcminute imaging capability above 35 keV, did not have the required sensitivity to image the Sgr A* region. SIGMA spent as much as 9 million seconds on the GC in the time frame 1990-1997 and derived only an upper limit for γ-ray emission from the SMBH vicinity (Goldwurm et al. 1994, Goldoni et al. 1999).

1.2 The Recent High Energy Galactic Center

Finally, the first X-ray detection from the compact radio source region was achieved by the *Chandra* X-Ray Observatory in 1999 (Baganoff et al. 2003; Figure 1 (right)) followed by the detection of short flaring activity demonstrating the high energy emitting region was extremely close to the SMBH (Goldwurm et al., 2003). Similarly, Sgr A* was recently discovered to flare frequently in the near-IR (Genzel et al. 2003; Ghez et al. 2004). This implies that both the near-IR and X-ray emission arise from a region of only 10-15 light minutes across, i.e. the dimension of our solar system. At high energies, the lack of the expected strong, variable emission from SgrA* has always been mysterious: stellar mass black holes (Cygnus X-1 is the prototype) or the central BH in active galactic nuclei (AGN) typically show high luminosity and strong γ-ray emission, mainly due to Comptonisation of low energy photons (0.2-1 keV) up-scattered by the high energy electrons of the hot plasma surrounding the collapsed object. So, why is Sgr A* extremely sub-luminous even with the expected accretion rate of the order of few 10^{-6} M$\odot$ yr^{-1} (Melia & Falke, 2001)?

2. The INTEGRAL Observatory

INTEGRAL is an astrophysical γ-ray observatory with unprecedented sensitivity and angular resolution that was launched from Baikonour (Kazakhstan) in 2002 October (Figure 2). INTEGRAL is devoted to observing the γ-ray universe in the energy range from 15 keV to 10 MeV with substantial monitoring capability in the X-ray range (3 to 30 keV) and also in the optical V-band at 550 nm (Winkler 2003). It is an international mission led by ESA with main payload contribution from Italy, France and Germany, several other European countries, and the USA.

The two γ-ray instruments are the spectrometer (SPI) and the imager (IBIS). SPI is a high resolution, cooled germanium based coded mask spectrometer with unprecedented sensitivity to diffuse emission over a very wide field of view (~25° FWHM) and optimized for the high resolution γ-ray line spectroscopy in the energy range 20 keV–8 MeV (Vedrenne et al. 2003). IBIS (Ubertini et al. 2003) is a large-area, coded aperture mask telescope based on two layers of 16,384 Cadmium Telluride detectors (Lebrun et al. 2003) and 4,096 Caesium Iodide detectors (Labanti et al. 2003). This configuration provides angular resolution of ~12 arcmin, with wide spectral response (15 keV to 10 MeV) and high resolution timing (60 s) and spectroscopy (6% at 100 keV). In view of the impossibility of focusing high energy X-rays and soft γ-rays, the three high energy instruments are operated with a coded mask device to provide good imaging capability over a wide field of view. The coded mask technology and pixel size are different for the X-ray monitor and for the two γ-ray instruments. The coded mask technique allows one to obtain a large sky image (of the order of 1000 squared degree) coupled with high spatial resolution, which will independently provide the position, spectra and light curve of each γ-ray source detected.

INTEGRAL, compared with earlier high energy observatories, such as BeppoSAX, RXTE, GRANAT or the COMPTON observatories, features almost an order of magnitude improved performances in spectroscopy and imaging (Winkler 2003). IBIS can achieve simultaneously an unprecedented sensitivity, 10 times better than SIGMA, with

Figure 2 A pictorial view of the INTEGRAL Observatory in flight: the gold tube is the main spectrometer structure (on the right). The IBIS coded mask (top left) and the imaging detector (middle left) are also visible.

12 arcmin angular resolution and a ~1000 squared degree field of view: all the γ-ray sources active in the pointed region with a flux exceeding a milliCrab ($\sim 3 \times 10^{-11}$erg/cm^{2}s) can be located with an accuracy of the order of one arcmin in a day (Figure 3).

3. INTEGRAL Observations of the Galactic Center

At the end of February 2003, INTEGRAL started one of its key programmes planned to guarantee high scientific return for the mission and the hardware teams. This programme was entitled *The Galactic Centre Deep Exposure* and involved observations of this region carried out for about ~2.5 Ms, deeply imaging the Sgr A* region for more than 1.1 Ms. After 30 years of unsuccessful attempts to detect high energy emission from the nuclear region of our Galaxy, IBIS has detected γ-rays from 6 known high energy sources plus a new one (IGR J1745.6−2901) which coincides with the radio position of Sgr A* to within 0.9 arcmin.

Figure 4 shows the 2×2 square degrees image of the Galactic Centre constructed by adding ~600 independent IBIS/ISGRI pointings. The two images show integrated energies over the range of (a; left) 20-40 keV and (b; right) 40-100 keV, illustrating for the first time the details of this region with a sensitivity threshold of the order of a milliCrab. The most luminous of the detected sources is a black hole candidate (BHC) 1E1740.7−2942, also known to be a galactic microquasar, due to its superluminal plasmoid emission (Mirabel et al. 1992). Three of the other

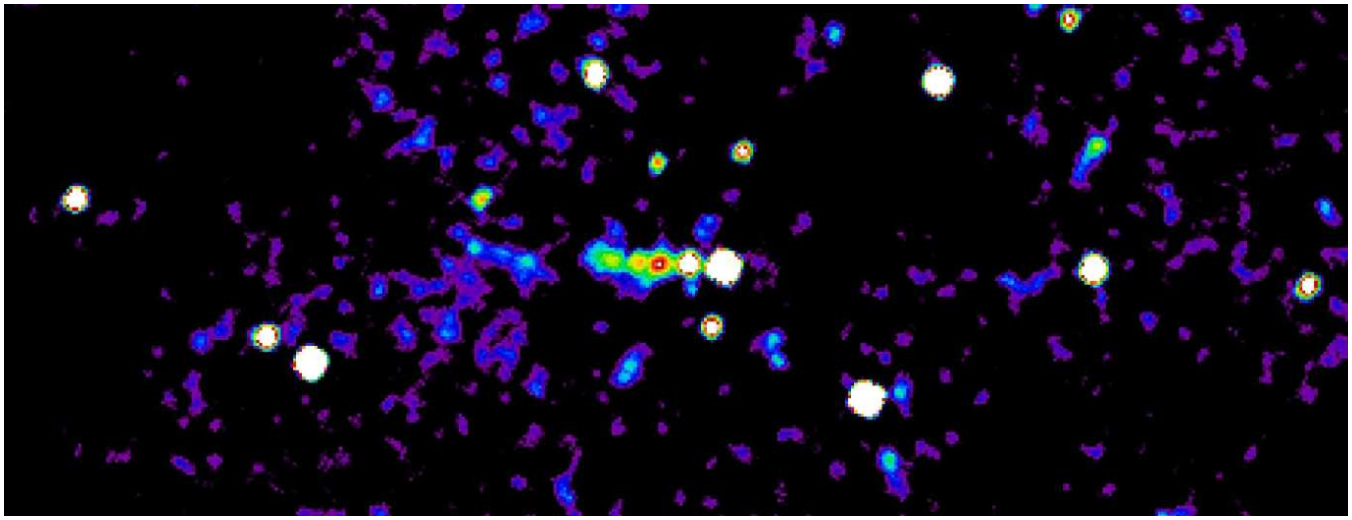

Figure 3 The high energy emission (20-100 keV) observed by the INTEGRAL Observatory along the Galactic plane toward the Sgr A* direction. The image shows a region of approximately 13 × 5 degrees centered on the Galactic Center. The presence of several sources emitting above 20 keV is clear. Figure 4(a) and Figure 4(b) below are a close up view of the 2×2 square degrees centered on Sgr A*

γ-ray sources are known, weakly-magnetised neutron stars, A1742−294, KS1741−293 and SLX1744−299. They are all part of low mass X-ray binary systems (LMXB) emitting X-ray bursts lasting from ten to few hundred seconds. These bursts have been discovered to be thermonuclear flashes of hydrogen and helium as the result of matter accreted from the low mass, non-evolved companion on the hard crust of the NS surface and have spectral emission extended up to several tens of keV. When the temperature and pressure reach the ignition values, the short flash occurs (Lewin et al. 1993) transforming the gravitational energy in X-rays and γ-rays. SLX1744-300 is another LMXB, separated ∼3 arcmin from SLX1744−299. The sixth γ-ray source is 1E1743.1−2843, whose nature is still unknown.

From the map of energy in the 20-40 keV range, a source (∼9 sigma excess) is detected in the vicinity of Sgr A*, conincident with the radio source. The newly detected source (IGR J1745.6−2901) shows some elongation in the north-west direction, which is considered to be a contribution from the known BHC GRS 1741.9−2853. At higher energies (40-100 keV) the Sgr A* flux is weaker and is detected at ∼5 sigma, but, as expected, the contribution from the nearby BHC source is decreasing. The total flux integrated over the entire energy range is about 3.8×10^{-11} erg/cm^{2}s, i.e. corresponding to a few times 10^{-3} the flux of the Crab. This value clearly confirms the under-luminous behaviour of the SMBH thought to be associated with Sgr A*. This also confirms the peculiar behaviour of our nucleus, when compared with stellar-mass binary BHCs or SMBHs in extragalactic AGNs.

New models to explain, at least in a first approximation, the X-ray and γ-ray behaviour of the non-efficient accretion of the GC (Melia & Falcke 2001) may now need to be refined in view of the INTEGRAL results. The details of the IBIS detection of γ-ray radiation from Sgr A* and the Galactic Centre region are too long to be outlined here and are discussed in depth in Belanger et al. (2003). It is clear that a part or most of the detected radiation could be due to one or more of the active binary objects in the vicinity of Sgr A* in view of the limited, even if unprecedented, INTEGRAL/IBIS accuracy. In any case, the capability of IBIS to pin point the arrival direction of new γ-ray photons and its unprecedented sensitivity have permitted for the first time to show high energy emission from the vicinity of the SMBH or, perhaps from the inner part of its accretion disk. After a 30 year quest, the time variability of Sgr A* could be again a clue to demonstrate the origin of high energy radiation. In fact, the strong near-IR flares observed by Genzel et al. in May 2003 may be coming from a region close to the Sgr A* event horizon. This seems to be a direct signature of radiation coming from the SMBH, which may give us a chance to observe simultaneous X-ray and γ-ray fast variability in a planned XMM and INTEGRAL coordinated observation. In the future, the new generation of X-ray and γ-ray instruments and observatories will only improve our understanding of the region near Sgr A*.

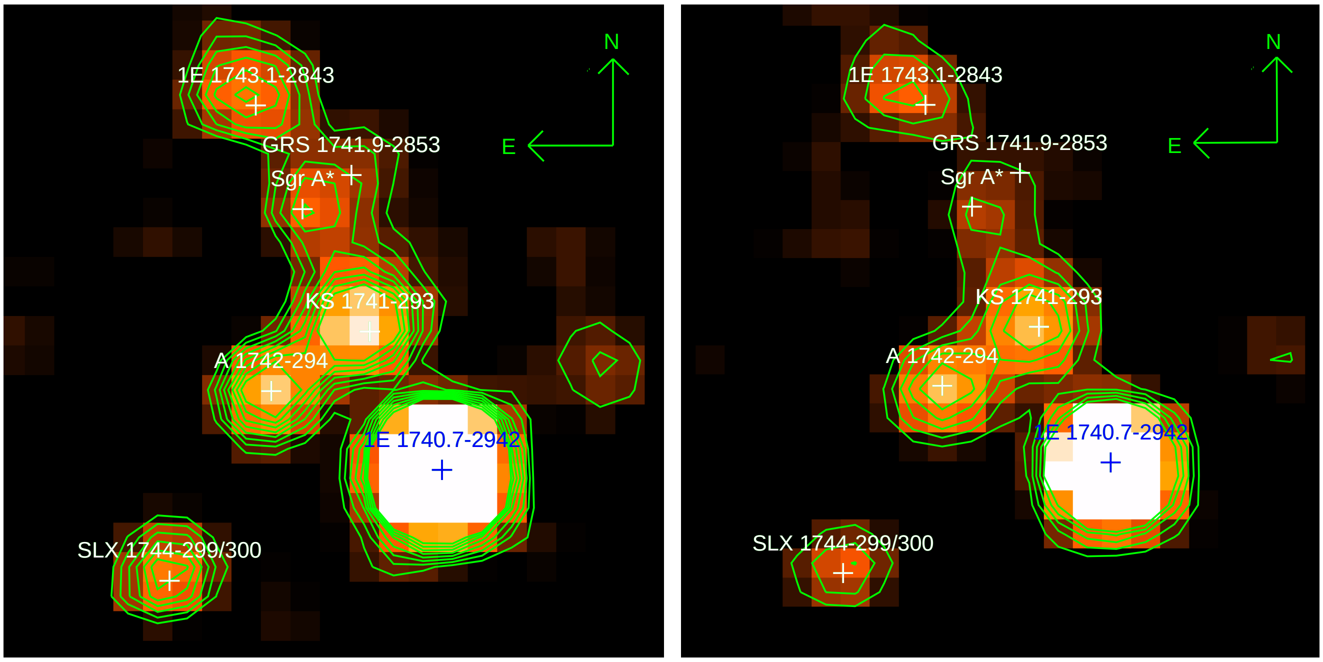

Figure 4 The IBIS/ISGRI images of the inner Galactic Center region in two energy ranges: left (a) 20-40 keV; right (b) 40-100 keV. Each celestial pixel is 5 arcmin and the total picture is 2×2 square degrees.

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Abstracts

ISO observations of the Galactic center Interstellar Medium: neutral gas and dust

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The 500 central pc of the Galaxy (hereafter GC) exhibit a widespread gas component with a kinetic temperature of 100-200 K. The bulk of this gas is not associated to the well-known thermal radio continuum or far infrared sources like Sgr A or Sgr B. How this gas is heated has been a longstanding problem. With the aim of studying the thermal balance of the neutral gas and dust in the GC, we have observed 18 molecular clouds located at projected distances far from thermal continuum sources with the Infrared Space Observatory (ISO). In this paper we present observations of several fine structure lines ([OI] 63 and 146 μm, [CII] 158 μm, [SiII] 35 μm, [SI] 25 μm, and [FeII] 26 μm), which are the main coolants of the gas with kinetic temperatures of several hundred K. We also present the full continuum spectra of the dust between 40 and 190 μm. All the clouds exhibit a cold dust component with a temperature of $\sim$ 15 K. A warmer dust component is also required to fit the spectra. The temperature of this dust component changes between 27 and 42 K from source to source. We have compared the gas and the dust emission with the predictions from J-type and C-type shocks and photodissociation region (PDRs) models. We conclude that the dust and the fine structure lines observations are best explained by a PDR with a density of 10^3 cm^{-3} and an incident far-ultraviolet field 10^3 times higher than the local interstellar radiation field. The fine structure line emission arises in PDRs in the interface between a diffuse ionized gas component and the dense molecular clouds. The [CII] 158 μm and [SiII] 35 μm lines also have an important contribution from the ionized gas component. PDRs can naturally explain the discrepancy between the gas and the dust temperatures. However, these PDRs can only account for 10-30% of the total H_2 column density with a temperature of $\sim$ 150 K. We discuss other possible heating mechanisms for the rest the warm molecular gas, such as non-stationary PDRs, X-ray Dominated Regions (XDRs) or the dissipation of supersonic turbulence.

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Eprint: astro-ph/0407479

Electron Acceleration around the Supermassive Black Hole at the Galactic Center

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The recent detection of variable infrared emission from Sagittarius A*, combined with its previously observed flare activity in X-rays, provides compelling evidence that at least a portion of this object's emission is produced by nonthermal electrons. The polarization and variability of Sgr A*'s emission depend strongly on the observed wavelength, indicating distinct physical processes. We show here that acceleration of electrons by plasma wave turbulence in hot gases near the black hole's event horizon, though with several theoretical uncertainties, can reasonably account both for Sgr A*'s mm and shorter wavelength emission in the quiescent state, and for the infrared and X-ray flares, induced either via an enhancement of the mass accretion rate onto the black hole or by reorganization of magnetic fields coupled to the accretion gas. High-energy electrons diffusing away from the acceleration site toward larger radii might account for Sgr A*'s emission at longer wavelengths. The acceleration model produces prominent

IR flares accompanying X-ray bursts. Future coordinated multi-wavelength observations will be able to test this model and constrain its parameters.

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Eprint: astro-ph/0403487

On the Origin of the Wide HI Absorption Line Toward Sgr A*

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We have imaged a region of ∼ 5' extent surrounding Sgr A* in the HI 21 cm-line absorption using the Very Large Array. A Gaussian decomposition of the optical depth spectra at positions within $\sim 2'$ (∼ 5 pc at 8.5 kpc) of Sgr A* detects a wide line underlying the many narrow absorption lines. The wide line has a mean peak optical depth of 0.32 ± 0.12 centered at a mean velocity of $V_{lsr} = -4 \pm 15$ km s^{-1}. The mean full width at half maximum is 119 ± 42 km s^{-1}. Such a wide line is absent in the spectra at positions beyond ∼ 2' from Sgr A*. The position-velocity diagrams in optical depth reveal that the wide line originates in various components of the circumnuclear disk (radius ∼ 1.3') surrounding Sgr A*. These components contribute to the optical depth of the wide line in different velocity ranges. The position-velocity diagrams do not reveal any diffuse feature which could be attributed to a large number of HI clouds along the line of sight to Sgr A*. Consequently, the wide line has no implications either to a global population of shocked HI clouds in the Galaxy or to the energetics of the interstellar medium as was earlier thought.

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The Stellar Initial Mass Function in the Galactic Center

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Massive stars define the upper limits of the star formation process, dominate the energetics of their local environs, and significantly affect the chemical evolution of galaxies. Their role in starburst galaxies and the early Universe is likely to be important, but we still do not know the maximum mass that a star can possess, i.e."the upper mass cutoff." I will discuss results from a program to measure the upper mass cutoff and IMF slope in the Galactic Center. The results suggest that the IMF in the Galactic center may deviate significantly from the Salpeter value, and that there may be an upper mass cutoff to the initial mass function of $\sim 150\ M_{\odot}$.

Ref.: IMF@50 conference proceedings
Email: figer@stsci.edu
http://www-int.stsci.edu/~figer/private/papers/IMF50/astro-ph_0409415.pdf

ISO observations of the Galactic center Interstellar Medium: ionized gas

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We present fine structure and recombination lines observations of the ionized gas toward a sample of 18 sources located within 300 pc of the center of the Galaxy (hereafter Galactic center, GC). The sources were selected as molecular clouds located far from thermal continuum sources. The fine structure lines from [NII] and [SIII] have been detected in 16 sources. In 10 sources we have even detected the [OIII] 88 μm line. Several techniques have been used to determine lower and upper limits to the extinction toward each source to correct the observed line fluxes. The derived electron densities of the ionized gas vary from ~ 100 to ≤ 30 cm^{-3}. For some sources we were able to derive N, S and Ne abundances. We found that they are similar to those measured in the HII regions in the 5-kpc ring and in the nuclei of starburst galaxies. The fine structure lines ratios measured for all the sources can be explained by photo-ionization with an effective temperature of the ionizing radiation of 32000-37000 K and an ionization parameter, U, of $-1 > \log U > -3$. The highest excitation is found in the Radio Arc region but it does not decrease smoothly with distance. There must be more ionizing sources distributed over the Galactic center than the known clusters of massive stars. Most of the clouds are located far (up to 45 pc for M-0.96+0.13) from the prominent continuum complexes (Sgr C, B ...). However, it is possible that the clouds are ionized by escaped photons from those complexes. The comparison of the effective temperatures of the ionizing radiation to the measured Lyman continuum photons emission rate imply that the clouds are indeed ionized by distant sources. The excitation ratios, effective temperature and ionization parameter measured in the GC are similar to those found in some low excitation starburst galaxies. The [NeIII]/[NeII] line ratios measured in the GC sources are consistent with the results of the Thornely et al. (2000) model for a short burst of massive star formation less than 8 Myr ago. We have also found that the [NeII] 13 μm to far-infrared continuum ratio measured for the GC sources is similar to that of external galaxies, supporting the idea by Sturm et al. (2002) that the far-infrared continuum in active galaxies is dominated by dust heated by stellar radiation rather than by the AGN.

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Eprint: astro-ph/0409334

The Proper Motion of Sgr A*: II. The Mass of Sgr A*

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We report measurements with the VLBA of the position of Sgr A* with respect to two extragalactic radio sources over a period of eight years. The apparent proper motion of Sgr A* relative to J1745–283 is 6.379 ± 0.024 mas y^{-1} along a position angle of 209.60 ± 0.18 degrees, almost entirely in the plane of the Galaxy. The effects of the orbit of the Sun around the Galactic center can account for this motion, and the residual proper motion of Sgr A* perpendicular to the plane of the Galaxy is -0.4 ± 0.9 km s^{-1}. A maximum-likelihood analysis of the motion expected for a massive object within the observed Galactic center stellar cluster indicates that Sgr A* contains more than about 10% of the $\approx 4 \times 10^6$ $M_\odot$ deduced from stellar orbits. The intrinsic size of Sgr A*, as measured by several investigators, is less than 1 AU, and the implied mass density of $\sim 10^{22}$ $M_\odot \mathrm{pc}^{-3}$ is within about three orders of magnitude of a comparable super-massive black hole within its Schwarzschild radius. Our observations provide the first direct evidence that a compact radiative source at the center of a galaxy contains of order 10^6 $M_\odot$ and provides overwhelming evidence that it is in the form of a super-massive black hole. Finally, the existence of "intermediate mass" black holes more massive than $\sim 10^4$ $M_\odot$ between roughly 10^3 and 10^5 AU from Sgr A* are excluded.

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Eprint: astro-ph/0408107

Hard X-ray view of the past activity of Sgr A* in a natural Compton mirror

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We report the association of the recently discovered hard X-ray source IGR J17475−2822 with the giant molecular cloud Sgr B2 in the Galactic Center region. The broad band (3–200 keV) spectrum of the source constructed from data of different observatories strongly supports the idea that the X-ray emission of Sgr B2 is Compton scattered and reprocessed radiation emitted in the past by the Sgr A* source. We conclude that 300–400 years ago Sgr A* was a low luminosity ($L \approx 1.5 \times 10^{39}\,\mathrm{erg\,s^{-1}}$ at 2–200 keV) AGN with a characteristic hard X-ray spectrum (photon index $\Gamma \approx 1.8$). We estimate the mass and iron abundance of the Sgr B2 scattering gas at $2 \times 10^6 M_\odot (r/10\,\mathrm{pc})^2$ and 1.9 solar, respectively (where r is the radius of the cloud).

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Dense Ionized and Neutral Gas Surrounding Sgr A*

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We present high resolution H41α hydrogen recombination line observations of the 1.2$'$ (3 pc) region surrounding Sagittarius A* (Sgr A*) at 92 GHz using the Millimeter Array at the Owens Valley Radio Observatory (OVRO) with an angular resolution of $7'' \times 3''$ and velocity resolution of 13 km s^{-1}. New observations of H31α, H35α, H41α and H44α lines were obtained using the NRAO 12-m telescope, and their relative line strengths are interpreted in terms of various possible emission mechanisms. These NRAO 12-m measurements are the most extensive recombination line survey of this region to date. These OVRO data also represent the highest angular resolution and the highest sensitivity observations of Sgr A* West in hydrogen recombination line and continuum emission at the millimeter (mm) wavelengths. Observations of HCO$^+$($J = 1 \rightarrow 0$) transition at 89 GHz are obtained simultaneously with a 40% improved angular resolution and 4-15 times improved sensitivity over the previously published results, and the distribution and kinematics of the dense molecular gas in the circumnuclear disk (CND) are mapped and compared with those of the ionized gas. The line brightness ratios of the hydrogen recombination lines are consistent with purely spontaneous emission from $T_e \sim 7000$ K gas with $n_e \sim 2 \times 10^4$ cm^{-3} near LTE condition. A virial analysis suggests that the most prominent molecular gas clumps in the CND have mean densities of order 10^7 cm^{-3}, sufficient to withstand the tidal shear in the Galactic Center region. Therefore, these clumps may survive over several dynamical times, and the CND may be a dynamically stable structure. We estimate a total gas mass of about $3 \times 10^5 M_\odot$ for the CND. Our combined analysis of the new high resolution H41α and HCO$^+$ images and our kinematic model demonstrates a widely spread physical and dynamical link between the molecular gas in the CND and the ionized gas, including along the eastern rim of the CND where a gap was previously suggested.

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The Nature of the Molecular Environment within 5 pc of the Galactic Center

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We present a detailed study of molecular gas in the central 10 pc of the Galaxy through spectral line observations of four rotation inversion transitions of NH_3 made with the Very Large Array. Updated line widths and NH_3(1,1) opacities are presented, and temperatures, column densities, and masses are derived for the major molecular features. We examine the impact of Sgr A East on molecular material at the Galactic center and find that there is no evidence that the expansion of this shell has moved a significant amount of the 50 km s^{-1} giant molecular cloud. The western streamer, however, shows strong indications that it is composed of material swept-up by the expansion of Sgr A East. Using the mass and kinematics of the western streamer, we calculate an energy of $E_{SN} = (2-9) \times 10^{51}$ ergs for the progenitor explosion and conclude that Sgr A East was most likely produced by a single supernova. The temperature structure of molecular gas in the central $\sim$ 20 pc is also analyzed in detail. We find that molecular gas has a "two-temperature" structure similar to that measured by Huttemeister et al. (1993a) on larger scales. The largest observed line ratios, however, cannot be understood in terms of a two-temperature model, and most likely result from absorption of NH_3(3,3) emission by cool surface layers of clouds. By comparing the observed NH_3 (6,6)-to-(3,3) line ratios, we disentangle three distinct molecular features within a projected distance of 2 pc from Sgr A*. Gas associated with the highest line ratios shows kinematic signatures of both rotation and expansion. The southern streamer shows no significant velocity gradients and does not appear to be directly associated with either the circumnuclear disk or the nucleus. The paper concludes with a discussion of the line-of-sight arrangement of the main features in the central 10 pc.

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The AGASA/SUGAR Anisotropies and TeV Gamma Rays from the Galactic Center: A Possible Signature of Extremely High-energy Neutrons

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Recent analysis of data sets from two extensive air shower cosmic ray detectors shows tantalizing evidence of an anisotropic overabundance of cosmic rays towards the Galactic Center (GC) that "turns on" around 10^{18} eV. We demonstrate that the anisotropy could be due to neutrons created at the Galactic Center through charge-exchange in proton-proton collisions, where the incident, high energy protons obey an $\sim E^{-2}$ power law associated with acceleration at a strong shock. We show that the normalization supplied by the gamma-ray signal from EGRET GC source 3EG J1746−2851—ascribed to p-p–induced neutral pion decay at GeV energies—ogether with a very reasonable spectral index of 2.2, predicts a neutron flux at $\sim 10^{18}$ eV fully consistent with the extremely high energy cosmic ray data. Likewise, the normalization supplied by the very recent GC data from the HESS air-Cerenkov telescope at TeV energies is almost equally-well compatible with the $\sim 10^{18}$ eV cosmic ray data. Interestingly, however, the EGRET and HESS data appear to be themselves incompatible. We consider the implications of this discrepancy. We discuss why the Galactic Center environment can allow diffusive shock acceleration at strong shocks up to energies approaching the ankle in the cosmic ray spectrum. Finally, we argue that the shock acceleration may be occuring in the shell of Sagittarius A East, an unusual supernova remnant located very close to the Galactic Center. If this connection between the anisotropy and Sagittarius A East could be firmly established it would be the first direct evidence for a particular Galactic source of cosmic rays up to energies near the ankle.

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The Nature of the Variable Galactic Center Source IRS16SW

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We report measurements of the light curve of the variable Galactic Center source IRS16SW. The light curve is not consistent with an eclipsing binary or any other obvious variable star. The source may be an example of a high mass variable predicted theoretically but not observed previously.

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The INTEGRAL View of the Galactic Nucleus

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We present the preliminary results of the observational campaign performed in 2003 to study the Galactic nucleus with INTEGRAL. The mosaicked images obtained with the IBIS/ISGRI coded aperture instrument in the energy range above 20 keV, give a yet unseen view of the high-energy sources of this region in hard X- and gamma-rays, with an angular resolution of $12'$. We report on the discovery of a source, IGR J17456-2901, compatible with the instrument's point spread function and coincident

with the Galactic nucleus Sgr A*to within 0.9′. The source is visible up to 60-80 keV with a 20–100 keV luminosity at 8 kpc of 3×10^{35} erg s^{-1}. Although we cannot unequivocally associate the new INTEGRAL source to the Galactic nucleus, this is the first report of significant hard X-ray emission from within the inner 10′ of the Galaxy and a contribution from the galactic center supermassive black hole itself cannot be excluded. Here we discuss the results obtained and the perspectives for future observations of the Galactic Nucleus with INTEGRAL and other observatories.

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High energy gamma rays from the massive black hole in the galactic center

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Accreting black holes (BHs) are believed to be sites of possible particle acceleration with favorable conditions also for effective gamma-ray production. However, because of photon-photon pair production, only low energy (MeV) gamma-rays can escape these compact objects with typically very large compactness parameter, $\kappa = \frac{L}{L_{Edd}} \frac{R_g}{R} \geq 0.01$, given that in most cases the accretion disks within 10 Schwarzschild radii R_g radiate with a power exceeding 10 percent of the Eddington luminosity, L_{Edd}. Therefore the high energy gamma-ray emission of these objects (both of stellar mass and super-massive BHs) is generally suppressed, and consequently the unique information on possible particle acceleration processes near the event horizon of the BH is essentially lost. Fortunately this is not the case for the super-massive BH located at the dynamical center of our Galaxy (Sgr A*), which thanks to its extraordinary low bolometric luminosity ($\leq 10^{-8} L_{Edd}$) is transparent for gamma-rays up to very high energies, $E \sim 10\ TeV$. We discuss different scenarios of gamma-ray production in Sgr A*, and show that for a reasonable set of parameters one can expect detectable gamma-ray fluxes of both hadronic and electronic origin. Some of these scenarios are applicable not only for the TeV gamma-ray emission recently reported from the direction of Galactic Center, but may have broader implications relevant to highly variable nonthermal emission of Sgr A* in radio, IR and X-ray bands.

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Announcements

First announcement for the MODEST-5c Master Class: THE ART OF COMPUTATIONAL N-BODY DYNAMICS

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University of Amsterdam

This is the first announcement for a 6-day summer school on the art of computational N-body dynamics, which will be held from July 24 to July 30, 2005 in Amsterdam, the Netherlands. Lectures are given in English at the Astronomical Institute 'Anton Pannekoek' and at the Section Computational Science of the University of Amsterdam, Kruislaan 403, 1098SJ Amsterdam. For details see: `http://carol.science.uva.nl/~spz/act/modest5c/`

Topic of the school:
The proposed educational program will be presented at the graduate student level in the specialization of gravitational N-body dynamics. After successfully finishing the course, the student will be able to read and understand scientific papers on high-precision stellar dynamics and be able to start research in this field.

Who can apply:
Advanced master students (a letter of their supervisor is required), PhD students and young post doctoral researchers starting up in the field.

Main aim:
The aim of this school is to educate the participants in the art of computational N-body dynamics through a hands-on approach, which includes mastering numerical techniques and algorithms for solving second order differential equations; in particular Newtons' equation of gravity. Applications will be in gravitational dynamics, which includes planetary dynamics, star cluster evolution, galaxy formation and cosmology.

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