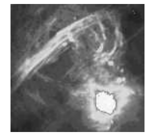
GCNEWS



The Newsletter of Galactic Center Research

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

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2006: The Year of the GC Meetings

Figure 1 *Spitzer* multi-wavelength view of the GC *Image credit: S. Stolovy*

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In the News

Cornelia Lang & Joseph Lazio

Once again we have a full issue with 32 new GC abstracts included in this month's newsletter. Headlining this issue is the recently released *Spitzer* images of the GC.

In this issue we have two meeting reports, one of them contributed by **Masaaki Sakano**. We welcome meeting or workshop reports and encourage organizers (or participants!) of meetings or workshops to provide brief summaries so that those not able to attend might still be able to keep abreast of developments.

Also in this issue is the up-to-date information on the GC-related meetings occurring in this "Year of the GC Meetings." We hope that you have registered, and we look forward to seeing you at at least one of them!

Meeting Summaries

American Astronomical Society The 207th meeting of the American Astronomical Society (January 8–12) was also the largest in the society's history (approximately 3100 attendees; possibly the largest gathering of astronomers ever!). There were two well-attended sessions on the Galactic center, with the recent Spitzer images a noticeable draw for many people. We describe briefly those papers with a GC component at the AAS meeting, with apologies to anybody whose work we might have missed. We give the AAS paper number in parentheses at the end of each summary.

Sgr A* was the target of observations over a wide range of wavelengths:

- Bushouse et al. used the Hubble Space Telescope for a near-IR monitoring campaign (103.02, "A Multi-Wavelength Study of Sgr A*: Near-IR Variability").
- Hornstein et al. used the recently commissioned laser-guide star system at the Keck Observatory to observe Sgr A* in the near-IR (78.13, "Infrared Colors of Sgr A* From HKLM Adaptive Optics Observations").
- Roberts et al. conducted radio monitoring observations with multiple instruments over more than an order of magnitude in wavelength (103.03, "A Multi-Wavelength Study of Sgr A*: Radio Continuum Variability").
- Yusef-Zadeh et al. summarized a series of observations from radio to the high-energy in an effort to arrive at a single, comprehensive explanation for the emission from Sgr A* (103.04, "A Multi-Wavelength Study of Sgr A*: The Correlation of X-ray, Near-IR and Sub-millimeter Emitting Flares").

Stars in the GC came in for their share of observations as well:

- Berukoff & Hansen used numerical simulations in an effort to explain the presence of the young stars in the central cluster (181.02, "Cluster Core Dynamics at the Galactic Center").
- Haislip & Youdin use numerical simulations to see whether the S stars could have formed in a disk, then be scattered into their current orbits (181.14, "A Disk Origin for S-Stars in the Galactic Center?").
- Hewitt et al. reported the possible discovery of a site of forming massive stars (181.01, "The Sites of Massive Star Formation Toward the Galactic Center Region Using Methanol Masers").
- Hong et al. considered point-source X-ray emitters, many of which are stars in binaries (181.04, "X-ray Point Sources in Galactic Center Region Fields").
- Howard et al. may have found a pulsar wind nebula (181.12, "Chandra Observations of the Cometary X-Ray Feature at the Galactic Center").
- Lu et al. used the recently commissioned laser-guide star system at the Keck Observatory to track the motions of various stars in the central cluster (98.06, "Constraints on Orbits and Origins of Young Stars in the Central Parsec of the Galaxy").
- Mauerhan et al. found a number of candidate young massive stars in a near-IR survey (181.13, "A Photometric Search for Young Massive Stars in the Galactic Center").
- Mikles et al. describe a new compact binary found toward the Galactic center (6.03, "Galactic Center X-ray Binary Candidate Screams for Attention").

The first release of (spectacular) *Spitzer* images merits a category unto itself:

- "A Mid-Infrared Survey of the Inner 2 × 1.5 Degrees of the Galaxy with Spitzer/IRAC" (181.05, Stolovy et al.)
- "Spitzer/IRAC Mid-Infrared Colors of the ISM in the Central 200 pc of the Galaxy" (181.06, Arendt et al.)
- "Comparison of Spitzer/IRAC Galactic Center Mid-IR Survey Results with X-ray and Radio Emission Due to High-Energy Processes in the Central 100 Parsecs" (181.07, Gezari et al.)
- "Point Sources and Source Subtracted Images in a Spitzer/IRAC Survey of the Galactic Center (181.08, Ramirez et al.)
- "Massive Star Formation in the Galactic Center as Revealed by Spitzer/IRAC Observations (181.09, Cotera et al.)

The larger environment of the GC was considered from a variety of approaches:

- Boldyrev & Yusef-Zadeh suggested a new mechanism for the generation of the magnetic nonthermal filaments (103.06, "Turbulent Origin of the Galactic-Center Magnetic Field: Nonthermal Radio Filaments").
- Law presented his dissertation work on the GC Lobe (103.05, "A Study of the Galactic Center Lobe").
- Venturing slightly further away, Martin et al. conducted CO observations of two molecular clouds (181.11, "AST/RO survey of the Galactic Center: Clumps 1 & 2 in ^{13}CO(2-1), CO(4-3), and [C I]").
- Morris et al. found a curious feature which they attribute to a propagating magnetic wave (103.01, "The Double Helix Nebula: A Torsional Wave Propagating Along the Galactic Center Magnetic Field?").
- Zhao et al. conducted a multi-wavelength survey of the GC (181.03, "ChaMPlane Optical Survey in the Galactic Center Region").

Instruments that either are or will be improving our view of the GC include

- FLAMINGOS-2, a near-infrared wide-field imager and multi-object spectrograph for the Gemini telescopes (Eikenberry et al., 181.10, "The FLAMINGOS-2 Galactic Center Survey");
- The Square Kilometer Array (Cordes et al., 137.04, "Key Science with the Square Kilometer Array: Strong-field Tests of Gravity using Pulsars and Black Holes"); and
- The Sub-millimeter Array (Marrone, 85.07, "SMA Studies of the Galactic Center Region").

The Galactic Center: Molecular Clouds to High Energy Phenomena We hear from **Masaaki Sakano** that a one-day workshop was held at the University of Nagoya, Japan on 2005 December 5. The aim of the workshop was to bring together new, multi-wavelength research on the Galactic center that is being conducted in Japan. There were 14 oral presentations.

- Oka reported on CO (J = 3-2) and (1-0) observations, in which a high ratio (3-2/1-0) of approximately 0.9 was found. In contrast, the ratio in the disk is approximately 0.5. Very high (3-2/1-0) ratios of approximately 1.5 are found toward some of the CO spots out to a Galactic longitude of 0.8°. ("The Large Scale CO 3-2 Observations in the Galactic Center by ASTE")
- Tsuboi reported on the observations of Nobeyama Millimeter Array which have shown that the molecular clouds at +50 km s^{-1} are interacting with SNR Sgr A East on their far side. ("The Interaction between Molecular Clouds and SNR Sgr A East")
- Yamamoto presented the the large scale distribution of molecular clouds toward the Galactic center taken by NANTEN telescope. ("Giant Molecular Clouds toward the Galactic Center")
- Kudo presented the comparison between 2MASS sources and molecular clouds derived by NANTEN observations. ("Search for the Molecular Clouds associated with 2MASS Clusters in the Galactic Center")
- Handa reported on SiO (J = 1-0 v = 0, J = 2-1 v = 0) and $H^{13}CO^+$(J = 1-0) observations toward the molecular cloud G0.11−0.11, which show that the column density of the molecular cloud is of order of 10^{23} cm^{-2} and its size is approximately 0.06 pc. The A_V of the cloud is roughly 640–740 mag, and he also described one of the darkest MSX features within the cloud. ("Molecular Cloud G0.11−0.11: Indication of Very High Column Density")
- Miyazaki and Sudo presented a monitoring program of Sgr A*, at 100 and 140 GHz using Nobeyama Millimeter Array and with 4 cm continuum by e-VLBI and by ATCA. ("Flux Variation of Sgr A* in mm Band" and "Optical Network VLBI Observations in Sgr A*")

- Kohno presented the possibility of an X-ray dominated region in the Galactic center. ("Is There XDR in the Galactic center? The Point of View from Nearby AGNs")

- Oyama described detailed observations toward the infrared sources associated with a maser source in the Galactic center, taken by VLBA, which indicate the presence of a compact dark mass object whose mass is of order 4×10^5 $M_\odot$. ("The Proper Motion of Stars in Very Nearby Galactic Center")

- Nishiyama reported on deep J, H, and Ks band observations with IRFS/SIRIUS which show that our Galaxy has a double bar from the distribution of the red clumps. In addition, the [Fe/H] distribution estimated from the slope of the red giant branch has no gradient in the region $0^\circ < |\ell| < 7^\circ$ and $1 < |b| < 3^\circ$. ("Near Infrared Survey in the Galactic Center by IRSF/SIRIUS")

- Inui and Murakami showed results of the X-ray Suzaku telescope, launched last July, from its observations of the Radio Arc, Sgr A, Sgr B2, and Sgr C. They noted that the 6.4 keV Fe neutral line is extended outside of the giant molecular clouds. ("The Map of the Reflection X-ray in Molecular Clouds Sgr B2" and "Fe Observations in X-ray in the Galactic Center")

- Ebisuzaki discussed formation mechanisms of a super massive black hole by a coalescence of intermediate mass black holes. ("The Settling of Clusters near the Galactic Center and Intermediate Mass Black Hole")

- Also presenting was A. Yasuda, "The Physical State of Interstellar Medium in the Galactic Center."

Upcoming GC Meetings

Galactic Center Workshop 2006

From the Center of the Milky Way to Nearby Low-Luminosity Galactic Nuclei

18-22 April 2006, Bad Honnef, Germany

The Galactic Center Workshop 2006 will be devoted to the presentation and discussion of the most recent observational and theoretical results on the center of the Milky Way and on other low-luminosity galactic nuclei in the local neighborhood. It will continue the tradition of the previous Galactic Center (GC) workshops, 1998 in Tucson, Arizona, and 2002 in Kona, Hawaii. While the main emphasis of the workshop will be clearly set on the center of the Milky Way, as a new feature in GC 2006, there will be a widening of the perspective to include other nearby low-luminosity galactic nuclei as well. This will serve to apply the detailed knowledge that has been gathered so far on the center of our own Galaxy to other systems as well as to place the center of the Milky Way into the broader context of quiescent/low-luminosity galactic nuclei. The latter will be especially important for topics such as accretion and emission mechanisms of highly under-luminous central black holes or the role and mechanisms of massive star formation in galactic nuclei.

The full scientific program is now available from the Web site, http://www.ph1.uni-koeln.de/GC06/ . Sessions include

- Large Scale Structures in the GC: ISM and Magnetic Fields
- Large Scale Structures in the GC/Surveys
- Star Formation in the Center of the Milky Way
- The Nuclear Stellar Cluster of the Milky Way
- The Nuclei of Nearby Galaxies
- Observations of Sagittarius A*
- Sagittarius A*: Observations and Theory

Mapping the Galaxy and Nearby Galaxies

26-30 June 2006, Ishigaki Island, Okinawa, Japan

Abstract deadline: March 1 (!!)
The symposium will focus on "mapping" the interstellar media and other components in galactic disks, bulges, halos, and central regions of galaxies. Thanks to recent progress in observations using radio interferometers and optical/infrared telescopes in ground and space, our knowledge on structures of our Galaxy and nearby galaxies has been growing for the last decade. Yet we do not fully understand the physics behind the observational results, and a number of questions still remain : What is the origin of spiral structure?; How should the global star formation rate be determined?; What causes the differences between our Galaxy and other nearby galaxies?; What differentiates galaxies with starburst/AGN activity from normal galaxies?

The current set of sessions is

1. "Basic Components of the Galaxy and Spiral Galaxies"

2. "The Galactic Center and Central Region of Galaxies"

3. "Nearby Galaxies"

4. "Galactic Evolution and Environment"

This symposium is also planned in celebration of Professor Yoshiaki Sofue's 63th birthday and his retirement from the University of Tokyo. Although Prof. Sofue has worked mainly in the field of radio astronomy, the subjects in this conference reflect the wide range of research in which he has been active in over the past four decades.

For more information, see http://www.ioa.s.u-tokyo.ac.jp/galaxy2006/

Physics and Astrophysics of Supermassive Black-Holes

9-14 July 2006, Santa Fe, New Mexico

In the past, they were recognized as the most destructive force in nature. Now, following a cascade of astonishing discoveries, supermassive black holes have undergone a dramatic shift in paradigm. Astronomers are finding out that these objects may have been critical to the formation of structure in the early universe, spawning bursts of star formation, planets, and even life itself. They may have contributed as much as half of all the radiation produced after the Big Bang, and at least 300 million of them may now be lurking through the vast expanses of the observable cosmos. The most accessible among them appears to be lurking at the Center of our own Galaxy.

For more information, see http://qso.lanl.gov/meetings/meet2006/index.html

The 26th General Assembly of the International Astronomical Union

14-25 August 2006, Prague, Czech Republic
http://www.astronomy2006.com/

This summer's IAU meeting will see a number of discussions on the Galactic Center.
Invited Discourse 4 will take place at 18:15 on Tuesday, August 22. Dr. Reinhard Genzel will deliver the keynote address, "The Power of New Experimental Techniques in Astronomy: Zooming in on the Black Hole in the Center of the Milky Way."
Symposium 238, "Black Holes: from Stars to Galaxies – across the Range of Masses" runs from August 21 to 25 and will have a session on the Galactic Center

The IAU Division VII: The Galactic System, whose current president is Dr. Patricia Whitelock (South African Astronomical Observatory), is considering making a working group on the Galactic Center and Nearby Normal Nuclei. To this end, they are sponsoring a one-day meeting on these topics at the IAU on Monday, August 21. The current schedule for this Division VII session is

1. HESS results
2. Radio Shadow of Sgr A*
3. Theory of Accretion & Flares
4. Star Clusters and Star Formation in the GC
5. The Young Star Disks in the Central pc
6. Origin of Young Stars in Central pc
7. Overview of GC

The *Spitzer* View of the Galactic Center

On the cover of this issue is one of the first *Spitzer* images of the GC, unveiled by Stolovy et al. at the recent American Astronomical Society meeting. Using the IRAC instrument, they conducted a survey of the central $2^\circ \times 1.5^\circ$ (280×210 pc) of the Galaxy at 3.6, 4.5, 5.8, and 8.0 μm. These images have an angular resolution of $2''$, corresponding to 0.08 pc at the GC, making them the highest spatial resolution and sensitivity large-scale map made to date of the GC at mid-infrared wavelengths.

While analysis of these images is on-going, several aspects are already clear. Much of the dust and the absorption is in highly filamentary structure in the interstellar medium. At the longer wavelengths, much of the interstellar emission is dominated by PAH emission from small grains in star-forming regions. Comparisons with other wavelengths may provide indications of the relative locations of many of these features.

Stay tuned for many additional results from these fascinating images.

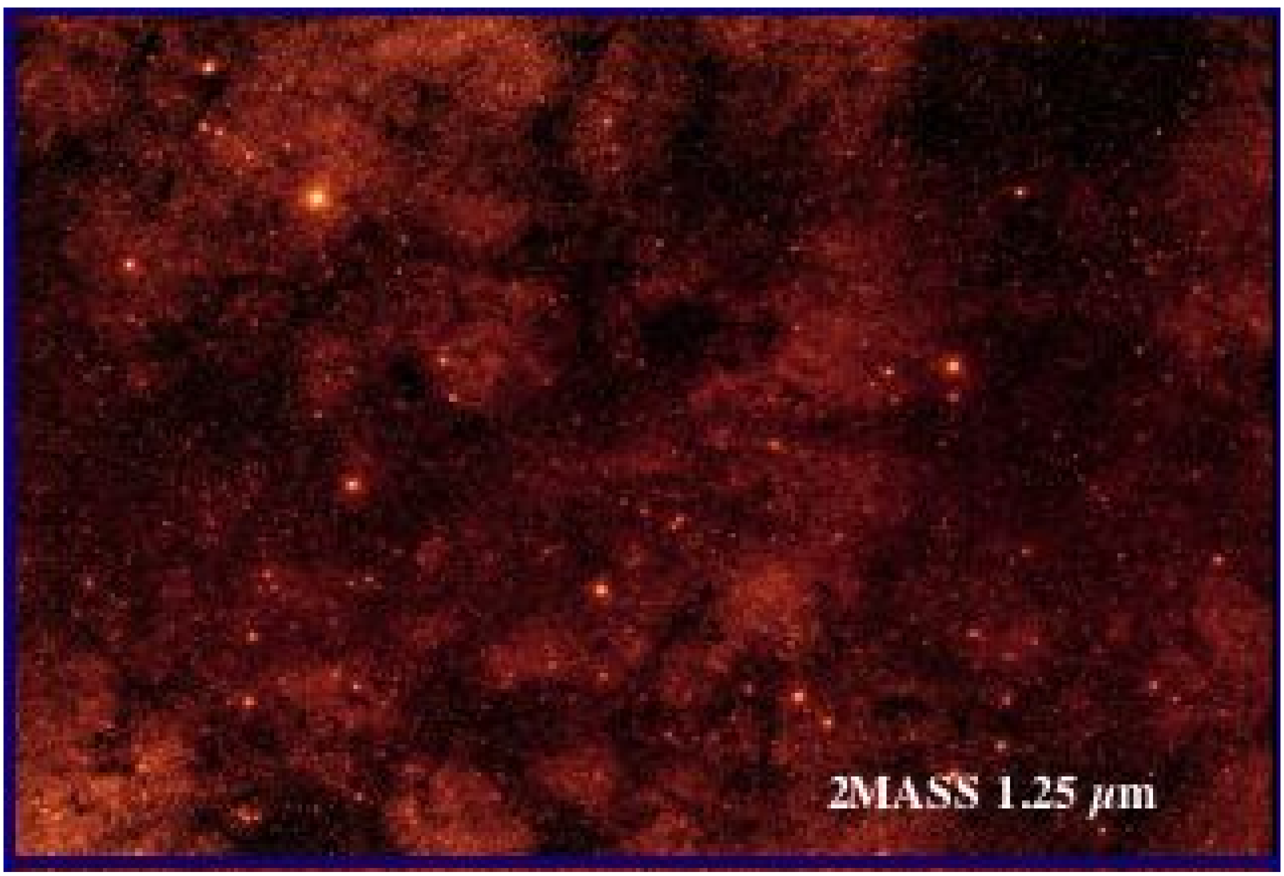
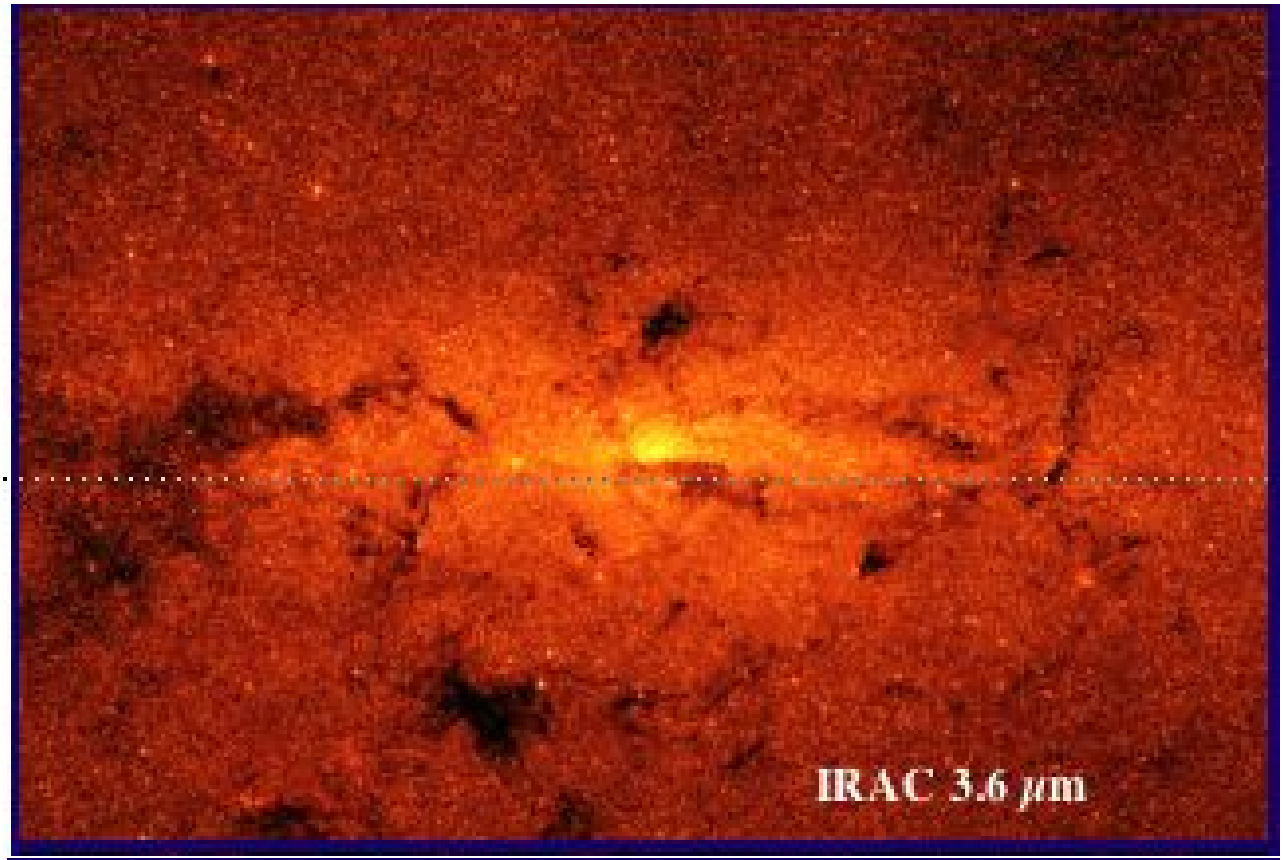
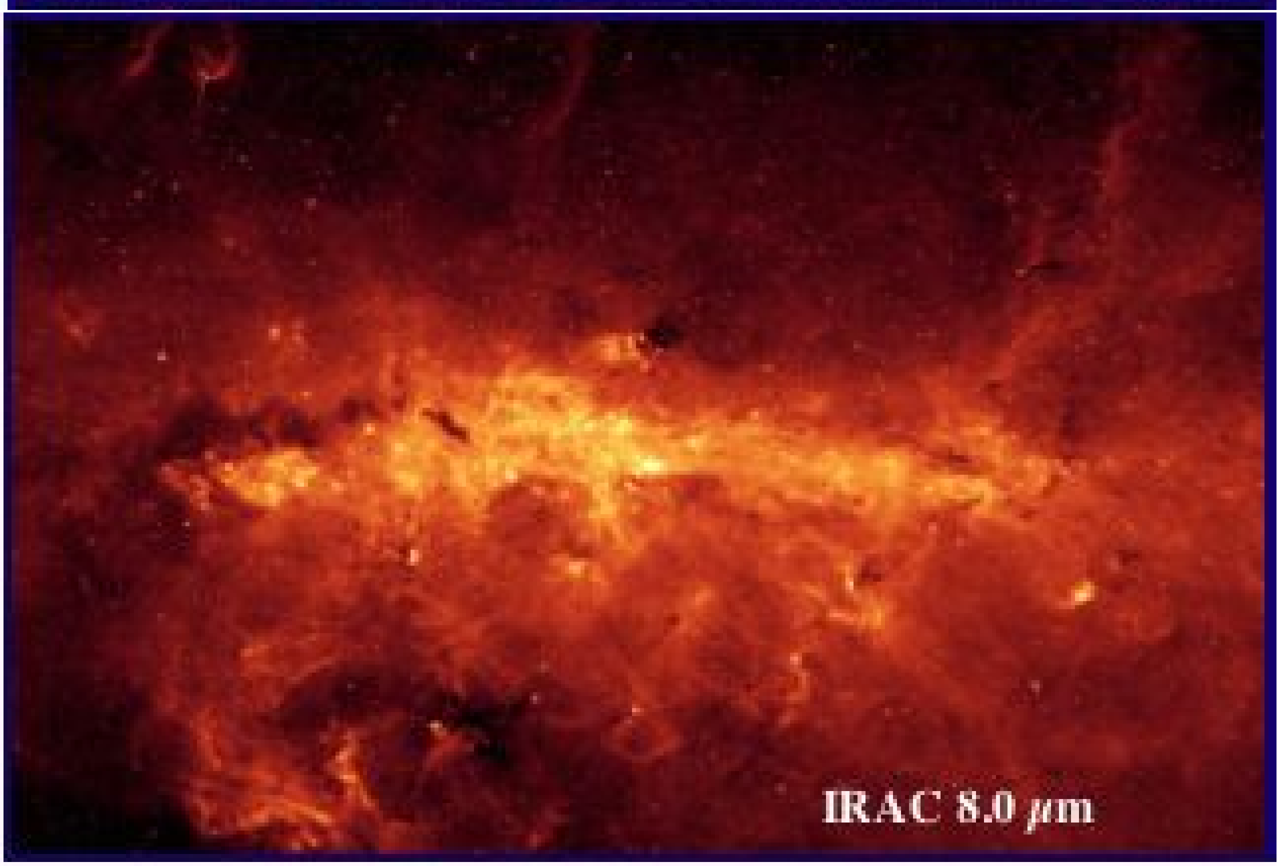


Figure 1 These three images (two on the next page) show the same field of view at wavelengths ranging from 1.25 μm (2MASS) to 8.0 μm (IRAC). They illustrate dramatically the need for longer IR wavelength studies to penetrate the severe interstellar extinction toward the GC. The IRAC 3.6 μm image is dominated by red giants and AGB stars. The diffuse ISM structures in the IRAC 8.0 μm image are dominated by emission from small dust grains (PAHs) in star forming regions.


IRAC 3.6 μm


IRAC 8.0 μm

Abstracts

Stellar Orbit Constraints on Neutralino Annihilation at the Galactic Center

Jeter Hall, Paolo Gondolo

Dark matter annihilation has been proposed to explain the TeV gamma rays observed from the Galactic Center. We study constraints on this hypothesis coming from the mass profile around the Galactic Center measured by observing stellar dynamics. We show that for current particle models, the constraints on the dark matter density profile from measurements of mass by infrared observations are comparable to the constraints from the measurements of the TeV source extension.

Ref.:
Email: jeter@physics.utah.edu
Eprint: astro-ph/0602400

Capture of a Red Giant by the Black Hole Sgr A* as a Possible Origin for the TeV Gamma-Rays from the Galactic Center

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Non-thermal TeV γ-ray emission within multi-pc scale has been observed from the center region of our Galaxy. We argue that these γ-rays are the result of a transient activity of the massive black hole Sgr A* which resides at the Galactic center. About thousands of years ago, the black hole may have experienced an active phase by capturing a red giant star and forming an accretion disk, temporarily behaving like an active galactic nuclear. A powerful jet, which contains plenty of high speed protons, was launched during the process. These runaway protons interact with the dense ambient medium, producing TeV γ-ray emission through the π°-decay process. We show that the total energy deposited in this way is large enough to account for observations. The diffusion length of protons is also consistent with the observed size of the TeV source.

Ref.: ApJ, Apr. 2006, in press
Email: ly@bao.ac.cn

Obtaining cosmic ray propagation parameters from diffuse VHE gamma-ray emission from the Galactic center ridge

I. Büsching, O. C. de Jager, J. Snyman

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The recent discovery of diffuse, VHE γ radiation from the Galactic center ridge by the H.E.S.S. telescope allow for the first time the direct determination of parameters of galactic cosmic ray propagation models. In this paper we show that the diffuse γ radiation near the Galactic center may be explained by the interaction of VHE cosmic ray (CR) protons with the interstellar gas located in several giant molecular clouds leading to a measurement of the cosmic ray diffusion coefficient for the Galactic center region of $\kappa = 1.3$ kpc^2 Myr^{-1} for a mean proton energy of ~ 3 TeV, if we assume that the CR protons originated from a supernova event (Sgr A East), which took off about 10 kyr ago. This value of κ is ~ 5 to 10 times smaller than the locally measured value.

Ref.: ApJ, submitted astro-ph/0602193
Email: fskib@puk.ac.za
Eprint: astro-ph/0602193

A Multi-Wavelength Study of Sgr A*: The Role of Near-IR Flares in Production of X-ray, Soft gamma-ray and Sub-millimeter Emission

F. Yusef-Zadeh, H. Bushouse, C. D. Dowell, M. Wardle, D. Roberts, C. Heinke, G. C. Bower, B. Vila Vilaro, S. Shapiro, A. Goldwurm, G. Belanger

Although Sgr A* is known to be variable in radio, millimeter, near-IR and X-rays, the correlation of the variability across its spectrum has not been fully studied. Here we describe highlights of the results of two observing campaigns in 2004 to investigate the correlation of flare activity in different wavelength regimes, using a total of nine ground and space-based telescopes. We report the detection of several new near-IR flares during the campaign based on

HST observations. The level of near-IR flare activity can be as low as $\sim$ 0.15 mJy at 1.6 μm and continuous up to $\sim$40% of the total observing time, thus placing better limits than ground-based near-IR observations. Using the NICMOS instrument on the *HST*, the *XMM-Newton* and *Caltech Submillimeter* observatories, we also detect simultaneous bright X-ray and near-IR flare in which we observe for the first time correlated substructures as well as simultaneous submillimeter and near-IR flaring. X-ray emission is arising from the population of near-IR-synchrotron-emitting relativistic particles which scatter submillimeter seed photons within the inner 10 Schwarzschild radii (R_{sch}) of Sgr A* up to X-ray energies. In addition, using the inverse Compton scattering picture, we explain the high energy 20-120 keV emission from the direction toward Sgr A*, and the lack of one-to-one X-ray counterparts to near-IR flares, by the variation of the magnetic field and the spectral index distributions of this population of nonthermal particles. In this picture, the evidence for the variability of submillimeter emission during a near-IR flare is produced by the low-energy component of the population of particles emitting synchrotron near-IR emission. Based on the measurements of the duration of flares in near-IR and submillimeter wavelengths, we argue that the cooling could be due to adiabatic expansion with the implication that flare activity may drive an outflow.

Ref.: ApJ (in press)
Email: zadeh@northwestern.edu
Eprint: astro-ph/0510787

Thermal SiO and $H^{13}CO^+$ Line Observations of the Dense Molecular Cloud G0.11−0.11 in the Galactic Center Region

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We obtained the first view in $H^{13}CO^+$ $J = 1-0$ and a high-resolution map in thermal SiO lines of G0.11−0.11, which is a molecular cloud situated between the Galactic Center radio arc and Sgr A. From a comparison with previous line observations, we found that the $H^{13}CO^+$ $J = 1-0$ line is optically thin, whereas the thermal SiO lines are optically thick. The line intensity in $H^{13}CO^+$ $J = 1-0$ shows that the cloud has a large column density, up to $N(H_2) = (6\text{–}7) \times 10^{23}$ cm^{-2}, which corresponds to about 640–740 mag in A_V or 10–12 mag in $A_{25\mu m}$. The estimated column density is the largest known of any even in the Galactic center region. We conclude from the intensity ratio of SiO $J = 1-0$ to CS $J = 1-0$ that emitting gas is highly inhomogeneous for SiO abundance on a scale smaller than the beam width $\sim 35''$.

Ref.: ApJ, 636, 261
Email: handa@ioa.s.u-tokyo.ac.jp
Eprint: astro-ph/0510565

QPOs in microquasars and Sgr A*: measuring the black hole spin

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In all four microquasars which show double peak kHz QPOs, the ratio of the two frequencies is 3:2. This strongly supports the suggestion that twin peak kHz QPOs are due to a resonance between some modes of accretion disk oscillations. Here, we stress that fits to observations of the hypothetical resonances between vertical and radial epicyclic frequencies (particularly of the parametric resonance) give an accurate estimate of the spin for the three microquasars with known mass. Measurement of double peak QPOs frequencies in the Galaxy centre seems also to be consistent with the 3:2 ratio established by previous observations in microquasars, however the Sgr A* data are rather difficult for the same exact analysis. If confirmed, the 3:2 ratio of double peak QPOs in Sgr A* would be of a fundamental importance for the black hole accretion theory and the precise measurement could help to solve the question of QPOs nature.

Ref.: Astron. Nachr., 9 (2005) 856–860
Email: terek@volny.cz

Eprint: astro-ph/0510669
http://xxx.lanl.gov/ps/astro-ph/0510669

A Successful Targeted Search for Hypervelocity Stars

Warren R. Brown, Margaret J. Geller, Scott J. Kenyon, Michael J. Kurtz

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Hypervelocity stars (HVSs) travel with velocities so extreme that dynamical ejection from a massive black hole is their only suggested origin. Following the discovery of the first HVS by Brown and collaborators, we have undertaken a dedicated survey for more HVSs in the Galactic halo and present here the resulting discovery of two new HVSs: SDSS J091301.0+305120 and SDSS J091759.5+672238, traveling with Galactic rest-frame velocities at least $+558 \pm 12$ and $+638 \pm 12$ km s^{-1}, respectively. Assuming the HVSs are B8 main sequence stars, they are at distances $\sim$75 and $\sim$55 kpc, respectively, and have travel times from the Galactic Center consistent with their lifetimes. The existence of two B8 HVSs in our 1900 deg^2 survey, combined with the Yu & Tremaine HVS rate estimates, is consistent with HVSs drawn from a standard initial mass function but inconsistent with HVS drawn from a truncated mass function like the one in the top-heavy Arches cluster. The travel times of the five currently known HVSs provide no evidence for a burst of HVSs from a major in-fall event at the Galactic Center in the last $\sim$160 Myr.

Ref.: ApJ Letters, Jan 2006, submitted
Email: wbrown@cfa.harvard.edu
Eprint: astro-ph/0601580

A Chandra Catalog of X-ray Sources in the Central 150 pc of the Galaxy

M. P. Muno, F. E. Bauer, R. M. Bandyopadhyay, Q. D. Wang

We present the catalog of X-ray sources detected in a shallow Chandra survey of the inner 2°×0.8° of the Galaxy, and in two deeper observations of the Radio Arches and Sgr B2. The catalog contains 1352 objects that are highly-absorbed ($N_H \gtrsim 4 \times 10^{22}$ cm^{-2}) and are therefore likely to lie near the Galactic center ($D \approx 8$ kpc), and 549 less-absorbed sources that lie within $\lesssim$6 kc of Earth. Based on the inferred luminosities of the X-ray sources and the expected numbers of various classes of objects, we suggest that the sources with $L_X \lesssim 10^{33}$ erg s^{-1} that comprise ≈90% of the catalog are cataclysmic variables, and that the ≈100 brighter objects are accreting neutron stars and black holes, young isolated pulsars, and Wolf-Rayet and O stars in colliding-wind binaries. We find that the spatial distribution of X-ray sources matches that of the old stellar population observed in the infrared, which supports our suggestion that most of the X-ray sources are old cataclysmic variables. However, we find that there is an apparent excess of ≈10 bright sources in the Radio Arches region. That region is already known to be the site of recent star formation, so we suggest that the bright sources in this region are young high-mass X-ray binaries, pulsars, or WR/O star binaries. We briefly discuss some astrophysical questions that this catalog can be used to address.

Ref.: ApJ submitted
Email: mmuno@astro.UCLA.EDU
Eprint: astro-ph/0601627

Isolated, Massive Supergiants near the Galactic Center

M. P. Muno, G. C. Bower, A. J. Burgasser, F. K. Baganoff, M. R. Morris, W. N. Brandt

We have carried out a pilot project to assess the feasibility of using radio, infrared, and X-ray emission to identify young, massive stars located between 1 and 25 pc from the Galactic center. We first compared catalogs compiled from the Very Large Array, the *Chandra X-ray Observatory*, and 2MASS. We identified two massive, young stars: the previously-identified star that is associated with the radio HII region H2, and a newly-identified star that we refer to as CXOGC J174516.1-290315. The infrared spectra of both stars exhibit very strong Brackett-γ and He I lines, and resemble those of massive supergiants that have evolved off of the main sequence, but not yet reached the Wolf-Rayet phase. We estimate that each star has a bolometric luminosity $\gtrsim 10^6 L_\odot$. These two stars are also associated with bright mid-infrared sources from the *Midcourse Space Experiment* survey, although the origin of this emission is uncertain. Likewise, the detection of these two sources in X-rays is surprising, because stars at similar evolutionary states are not uniformly bright X-ray sources. Therefore, we suggest that both stars are in binary systems that contain either OB stars whose winds collide with those of the luminous supergiants, or compact objects that

are accreting from the winds of the supergiants. We also identify X-ray emission from a nitrogen-type Wolf-Rayet star and place upper limits on the X-ray luminosities of three more evolved, massive stars that previously have been identified between 1 and 25 pc from Sgr A*. Finally, we briefly discuss the implications that future searches for young stars will have for our understanding of the recent history of star formation near the Galactic center.

Ref.: ApJ, 638, 183, 2006 in press
Email: mmuno@ucla.edu
Eprint: astro-ph/0509617

The Fate of Former Companions to Hypervelocity Stars Originating at the Galactic Center

Idan Ginsburg & Abraham Loeb

The hypervelocity star SDSS J090745.0+024507 in the halo of the Milky Way Galaxy most likely originated from the breakup of a binary star system by the central black hole, Sgr A*. We examine the fate of former binary companions to similar hypervelocity stars (HVSs) by simulating 600 different binary orbits around Sgr A* with a direct N-body integration code. For some orbital parameters, the binary breakup process leads to HVSs with ejection velocities that are almost an order of magnitude larger than the velocity observed for SDSS J090745.0+024507. The former companion stars populate highly eccentric orbits which resemble the observed orbits for some of the stars nearest to Sgr A*.

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Resonant relaxation near a massive black hole: the stellar distribution and gravitational wave sources

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Resonant relaxation (RR) of orbital angular momenta occurs near massive black holes (MBHs) where the stellar orbits are nearly Keplerian and so do not precess significantly. The resulting coherent torques efficiently change the magnitude of the angular momenta and rotate the orbital inclination in all directions. As a result, many of the tightly bound stars very near the MBH are rapidly destroyed by falling into the MBH on low-angular momentum orbits, while the orbits of the remaining stars are efficiently randomized. We solve numerically the Fokker-Planck equation in energy for the steady state distribution of a single mass population with a RR sink term. We find that the steady state current of stars, which sustains the accelerated drainage close to the MBH, can be $\leq$ than 10 times larger than that due to non-coherent 2-body relaxation alone. RR mostly affects tightly bound stars, and so it increases only moderately the total tidal disruption rate, which is dominated by stars originating from less bound orbits farther away. We show that the event rate of gravitational wave (GW) emission from inspiraling stars, originating much closer to the MBH, is dominated by RR dynamics. The GW event rate depends on the uncertain efficiency of RR. The efficiency indicated by the few available simulations implies rates ≤ 10 times higher than those predicted by 2-body relaxation, which would improve the prospects of detecting such events by future GW detectors, such as LISA. However, a higher, but still plausible RR efficiency can lead to the drainage of all tightly bound stars and strong suppression of GW events from inspiraling stars. We apply our results to the Galactic MBH, and show that the observed dynamical properties of stars there are consistent with RR.

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Warm Water Vapor around Sagittarius B2

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In the region of Sgr B2 there are several condensations heated externally by nearby hot stars. Therefore H_2O far–IR lines are expected to probe only an external low–density and high temperature section of these condensations, whereas millimeter-wave lines can penetrate deeper into them where the density is higher and T_k lower. We have conducted a study combining H_2O lines in both spectral regions. First, Infrared Space Observatory observations of several H_2O thermal lines seen in absorption toward Sgr B2(M) at a spectral resolution of

$\sim$35 km s^{-1} have been analyzed. Second, an IRAM–30m telescope map of the para–H_2O $3_{13} - 2_{20}$ line at 183.31 GHz, seen in emission, has also been obtained and analyzed. The H_2O lines seen in absorption are optically thick and are formed in the outermost gas of the condensations in front of the far–IR continuum sources. They probe a maximum visual extinction of $\sim$5 to 10 mag. Radiative transfer models indicate that these lines are quite insensitive to temperature and gas density, and that IR photons from the dust play a dominant role in the excitation of the involved H_2O rotational levels. In order to get the physical conditions of the absorbing gas we have also analyzed the CO emission toward Sgr B2(M). We conclude, based on the observed CO J=7–6 line at 806.65 GHz with the *Caltech Submillimeter Observatory*, and the lack of emission from the far–IR CO lines, that the gas density has to be lower than $\sim 10^4$ cm^{-3}. Using the values obtained for the kinetic temperature and gas density from OH, CO, and other molecular species, we derive a water column density of $(9 \pm 3) \times 10^{16}$ cm^{-2} in the absorbing gas. Hence, the water vapor abundance in this region, $\chi(H_2O)$, is $\simeq$(1-2)$\times 10^{-5}$. The relatively low H_2O/OH abundance ratio in the region, $\simeq$2-4, is a signature of UV photon dominated surface layers traced by far–IR observations. As a consequence the temperature of the absorbing gas is high, $T_K \simeq$300-500 K, which allows very efficient neutral–neutral reactions producing H_2O and OH. On the other hand, the 183.31 GHz data provide a much better spatial and spectral resolution than the far-IR ISO data. This maser line allows to trace water deeper into the cloud, i.e., the inner, denser ($n(H_2) \geq 10^5$–10^6 cm^{-3}) and colder ($T_k \sim 40$ K) gas. The emission is very strong toward the cores. The derived water vapor abundance for this component is a few$\times 10^{-7}$. There is also moderate extended emission around Sgr B2 main condensations, a fact that supports the water vapor abundance derived from far–IR H_2O lines for the outer gas.

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Dark Matter and the CACTUS Gamma-Ray Excess from Draco

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The CACTUS atmospheric Cherenkov telescope collaboration recently reported a gamma-ray excess from the Draco dwarf spheroidal galaxy. Draco features a very low gas content and a large mass-to-light ratio, suggesting as a possible explanation annihilation of weakly interacting massive particles (WIMPs) in the Draco dark-matter halo. We show that with improved angular resolution, future measurements can determine whether the halo is cored or cuspy, as well as its scale radius. We find the relevant WIMP masses and annihilation cross sections and show that supersymmetric models can account for the required gamma-ray flux. We compute for these supersymmetric models the resulting Draco gamma-ray flux in the GLAST energy range and the rates for direct neutralino detection and for the flux of neutrinos from neutralino annihilation in the Sun. We also discuss the possibility that the bulk of the signal detected by CACTUS comes from direct WIMP annihilation to two photons and point out that a decaying-dark-matter scenario for Draco is not compatible with the gamma-ray flux from the Galactic center and in the diffuse gamma-ray background.

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Clockwise Stellar Disk and the Dark Mass in the Galactic Center

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Two disks of young stars have recently been discovered in the Galactic Center. The disks are rotating in the gravitational field of the central black hole at radii $r \sim 0.1$–0.3 pc and thus open a new opportunity to measure the central mass. We find that the observed motion of stars in the clockwise disk implies $M = (4.3 \pm 0.5) \times 10^6 M_\odot$ for the fiducial distance to the Galactic Center $R_0 = 8$ kpc and derive the scaling of M with R_0. As a tool for our estimate we use orbital roulette, a recently developed method. The method reconstructs the three-dimensional orbits of the disk stars and checks the randomness of their orbital phases. The clockwise-disk stars are found to have modest orbital eccentricities.

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Interstellar Extinction Law in the J, H, and K_S Bands toward the Galactic Center

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We have determined the ratios of total to selective extinction in the near-infrared bands (J, H, K_S) toward the Galactic center from the observations of the region $|l| < 2.0°$ and $0.5° < |b| < 1.0°$ with the IRSF telescope and the SIRIUS camera. Using the positions of red clump stars in color-magnitude diagrams as a tracer of the extinction and reddening, we determine the average of the ratios of total to selective extinction to be $A_{K_S}/E_{H-K_S} = 1.44 \pm 0.01$, $A_{K_S}/E_{J-K_S} = 0.494 \pm 0.006$, and $A_H/E_{J-H} = 1.42 \pm 0.02$, which are significantly smaller than those obtained in previous studies. ¿From these ratios, we estimate that $A_J : A_H : A_{K_S} = 1 : 0.573 \pm 0.009 : 0.331 \pm 0.004$ and $E_{J-H}/E_{H-K_S} = 1.72 \pm 0.04$, and we find that the power law $A_\lambda proportional to \lambda^{-1.99 \pm 0.02}$ is a good approximation over these wavelengths. Moreover, we find a small variation in A_{K_S}/E_{H-K_S} across our survey. This suggests that the infrared extinction law changes from one line of sight to another, and the so-called "universality" does not necessarily hold in the infrared wavelengths.

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Email: shogo@z.phys.nagoya-u.ac.jp
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The Arches Cluster - Evidence for a Truncated Mass Function?

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We have analyzed high-resolution, adaptive optics (AO) HK observations of the Arches cluster obtained with NAOS/CONICA. With a spatial resolution of 84 mas, the cluster center is uniquely resolved. From these data the present-day mass function (MF) of Arches is derived down to $\sim 4\,M_\odot$. The integrated MF as well as the core and 2^{nd} annulus MFs are consistent with a turn-over at $6-7\,M_\odot$. This turn-over indicates severe depletion of intermediate and low-mass stars in the Arches cluster, possibly caused by its evolution in the Galactic Center environment. The Arches MF represents the first resolved observation of a starburst cluster exhibiting a low-mass truncated MF. This finding has severe implications for stellar population synthesis modelling of extragalactic starbursts, the derivation of integrated properties such as the total mass of star clusters in dense environments, the survival of low-mass remnants from starburst populations, and chemical enrichment during starburst phases.

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G359.95−0.04: An Energetic Pulsar Candidate Near Sgr A*

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We report the discovery of a prominent nonthermal X-ray feature located near the Galactic center that we identify as an energetic pulsar wind nebula. This feature, G359.95−0.04, lies 1 lyr north of Sgr A* (in projection), is comet-like in shape, and has a power law spectrum that steepens with increasing distance from the putative pulsar. The distinct spectral and spatial X-ray characteristics of the feature are similar to those belonging the rare class of ram-pressure confined pulsar wind nebulae. The luminosity of the nebula at the distance of Sgr A*, consistent with the inferred X-ray absorptions, is $L_x \sim 1 \times 10^{34}$ ergs s^{-1} in the 2–10 keV energy band. The cometary tail extends back to a region centered at the massive stellar complex IRS 13 and surrounded by enhanced diffuse X-ray emission, which may represent an associated supernova remnant. Furthermore, the inverse Compton scattering of the strong ambient radiation by the nebula consistently explains the observed TeV emission from the Galactic center. We also briefly discuss plausible connections of G359.95−0.04 to other high-energy sources in the region, such as the young stellar complex IRS 13 and SNR Sgr A East.

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A size of ∼1 AU for the radio source Sgr A* at the centre of the Milky Way

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Although it is widely accepted that most galaxies have supermassive black holes (SMBHs) at their centers[1−3], concrete proof has proved elusive. Sagittarius A* (Sgr A*)[4], an extremely compact radio source at the center of our Galaxy, is the best candidate for proof[5−7], because it is the closest. Previous Very Long Baseline Interferometry (VLBI) observations (at 7mm) have detected that Sgr A* is ∼ 2 astronomical unit (AU) in size[8], but this is still larger than the "shadow" (a remarkably dim inner region encircled by a bright ring) arising from general relativistic effects near the event horizon[9]. Moreover, the measured size is wavelength dependent[10]. Here we report a radio image of Sgr A* at a wavelength of 3.5mm, demonstrating that its size is ∼1 AU. When combined with the lower limit on its mass[11], the lower limit on the mass density is 6.5×10^{21} Msun pc^{-3}, which provides the most stringent evidence to date that Sgr A* is an SMBH. The power-law relationship between wavelength and intrinsic size (size ∝ wavelength$^{1.09}$), explicitly rules out explanations other than those emission models with stratified structure, which predict a smaller emitting region observed at a shorter radio wavelength.

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Dynamical Cusp Regeneration

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After being destroyed by a binary supermassive black hole, a stellar density cusp can regrow at the center of a galaxy via energy exchange between stars moving in the gravitational field of the single, coalesced hole. We illustrate this process via high-accuracy N-body simulations. Regeneration requires roughly one relaxation time and the new cusp extends to a distance of roughly one-fifth the black hole's influence radius, with density $\rho \sim r^{-7/4}$; the mass in the cusp is of order 10% the mass of the black hole. Growth of the cusp is preceded by a stage in which the stellar velocity dispersion evolves toward isotropy and away from the tangentially-anisotropic state induced by the binary. We show that density profiles similar to those observed at the center of the Milky Way and M32 can regenerate themselves in several Gyr following infall of a second black hole; the presence of density cusps at the centers of these galaxies can therefore not be used to infer that no merger has occurred. We argue that $\rho \sim r^{-7/4}$ density cusps are ubiquitous in stellar spheroids fainter than $M_V \approx -18.5$ that contain supermassive black holes, but the cusps have not been detected outside of the Local Group since their angular sizes are less than $\sim 0.1''$. We show that the presence of a cusp implies a lower limit of $\sim 10^{-4}$ yr^{-1} on the rate of stellar tidal disruptions, and discuss the consequences of the cusps for gravitational lensing and the distribution of dark matter on sub-parsec scales.

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Turbulent Origin of the Galactic-Center Magnetic Field: Nonthermal Radio Filaments

Stanislav Boldyrev and Farhad Yusef-Zadeh

A great deal of study has been carried out over the last twenty years on the origin of the magnetic activity in the Galactic center. One of the most popular hypotheses assumes milli-Gauss magnetic field with poloidal geometry, pervading the inner few hundred parsecs of the Galactic-center region. However, there is a growing observational evidence for the large-scale distribution of a much weaker field of B less than or equal than 10 micro G in this region. Here, we propose that the Galactic-center magnetic field originates from turbulent activity that is known to be extreme in the central hundred parsecs. In this picture the spatial distribution of the magnetic field energy is highly intermittent, and the regions of strong field have filamentary structures. We propose that the observed nonthermal radio filaments appear in (or, possibly, may be identified with) such strongly magnetized regions. At the same time, the large-scale diffuse magnetic field is weak. Both results of our model can explain the magnetic field

measurements of the the Galactic-center region. In addition, we discuss the role of ionized outflow from stellar clusters in producing the long magnetized filaments perpendicular to the Galactic plane.

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GCIRS34W: An irregular variable in the Galactic Centre

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We report the results of time-resolved photometric and spectroscopic near-infrared observations of the Ofpe/WN9 star and LBV candidate GCIRS34W in the Galactic Centre star cluster. Diffraction limited resolution photometric observations obtained in H- and K-bands show a strong, non-periodic variability on time scales from months to years in both bands, accompanied by variations of the stellar colour. Three K-band spectra obtained in 1996, 2003, and 2004 with integral field spectrometers are identical within their accuracies and exclude significant spectroscopic variability. The most probable explanation of the stellar photometric variability is obscuration by circumstellar material ejected by the star. The approximated position of GCIRS34W in an HR diagram is located between O supergiants and LBVs, suggesting that this star is a transitional object between these two phases of stellar evolution.

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The ecology of star clusters and intermediate mass black holes in the Galactic bulge

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We simulate the inner 100pc of the Milky-Way Galaxy to study the formation and evolution of the population of star clusters and intermediate mass black holes. For this study we perform extensive direct N-body simulations of the star clusters which reside in the bulge, and of the inner few tenth of parsecs of the super massive black hole in the Galactic center. In our N-body simulations the dynamical friction of the star cluster in the tidal field of the bulge are taken into account via (semi)analytic solutions. The N-body calculations are used to calibrate a (semi)analytic model of the formation and evolution of the bulge. We find that about 10% of the clusters born within 100pc of the Galactic center undergo core collapse during their inward migration and form intermediate-mass black holes (IMBHs) via runaway stellar merging. After the clusters dissolve, these IMBHs continue their inward drift, carrying a few of the most massive stars with them. We predict that region within about 10 parsec of the SMBH is populated by about 50IMBHs of some 1000Msun. Several of these are expected to be accompanied still by some of the most massive stars from the star cluster. We also find that within a few milliparsec of the SMBH there is a steady population of several IMBHs. This population drives the merger rate between IMBHs and the SMBH at a rate of about one per 10Myr, sufficient to build the accumulate majority of mass of the SMBH. Mergers of IMBHs with SMBHs throughout the universe are detectable by LISA, at a rate of about two per week.

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The Flare Activity of Sgr A*; New Coordinated mm to X-Ray Observations

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We report new simultaneous near-infrared/submillimeter/X-ray observations of the SgrA* counterpart associated with the massive 3–4 $\times 10^6$ solar mass black hole at the Galactic Center. The main aim is to investigate the physical processes responsible for the variable emission from Sgr A*. The observations have been carried out using the NACO adaptive optics (AO) instrument at the European Southern Observatory's Very Large Telescope and the ACIS-I instrument aboard the Chandra X-ray

Observatory as well as the Submillimeter Array SMA on Mauna Kea, Hawaii, and the Very Large Array in New Mexico. We detected one moderately bright flare event in the X-ray domain and 5 events at infrared wavelengths.

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Observation of Gamma Rays from the Galactic Center with the MAGIC Telescope

J. Albert and another 130 authors

Recently, the Galactic Center has been reported to be a source of very high energy (VHE) γ-rays by the VERITAS, CANGAROO and HESS experiments. The energy spectra as measured by these experiments show substantial differences. In this *Letter* we present MAGIC observations of the Galactic Center, resulting in the detection of a differential γ-ray flux consistent with a steady, hard-slope power law, described as $dN_\gamma/(dAdtdE) = (2.9\pm0.6)\times10^{-12}(E/TeV)^{-2.2\pm0.2}\ cm^{-2}s^{-1}TeV^{-1}$. The γ-ray source is centered at (Ra, Dec)=($17^h45^m20^s$, -29°2′). This result confirms the previous measurements by the HESS experiment and indicates a steady source of TeV γ-rays. We briefly describe the observational technique used, the procedure implemented for the data analysis, and discuss the results in the perspective of different models proposed for the acceleration of the VHE γ-rays.

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The Double Helix Nebula: a magnetic torsional wave propagating out of the Galactic centre

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Radioastronomical studies have indicated that the magnetic field in the central few hundred parsecs of our Milky Way Galaxy has a dipolar geometry and a strength substantially larger than elsewhere in the Galaxy, with estimates ranging up to a milligauss. A strong, large- scale magnetic field can affect the Galactic orbits of molecular clouds by exerting a drag on them, it can inhibit star formation, and it can guide a wind of cosmic rays away from the central region, so a characterization of the magnetic field at the Galactic center is important for understanding much of the activity there. Here, we report Spitzer Space Telescope observations of an unprecedented infrared nebula having the morphology of an intertwined double helix. This feature is located about 100 pc from the Galaxy's dynamical centre toward positive Galactic latitude, and its axis is oriented perpendicular to the Galactic plane. The observed segment is about 25 pc in length, and contains about 1.25 full turns of each of the two continuous, helically wound strands. We interpret this feature as a torsional Alfvn wave propagating vertically away from the Galactic disk, driven by rotation of the magnetized circumnuclear gas disk. As such, it offers a new morphological probe of the Galactic center magnetic field. The direct connection between the circumnuclear disk and the double helix is ambiguous, but the MSX images show a possible meandering channel that warrants further investigation.

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Millisecond pulsar population in the Galactic center and high energy contributions

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We propose that there possibly exists a population of millisecond pulsars in the Galactic center region. Millisecond pulsars (MSPs) could emit GeV gamma-rays through synchrotron-curvature radiation as predicted by outer gap models. In the same time, the compact wind nebulae around millisecond pulsars can emit X-rays though synchrotron radiation and TeV photons through inverse Compton processes. Besides, millisecond pulsar winds provide good candidates for the electron-positrons sources in the Galactic center. Therefore, we suggest that the millisecond pulsar population could contribute to the weak unidentified Chandra X-ray sources, the diffuse gamma-rays detected by EGRET, electron-positron annihilation lines and TeV photons detected by HESS toward the Galactic center.

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Eprint: astro-ph/0510461

Understanding the Radio Variability of Sgr A*

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We determine the characteristics of the 7 mm to 20 cm wavelength radio variability in Sgr A* on time scales from days to three decades. The amplitude of the intensity modulation is between 30 and 39% at all wavelengths. Analysis of uniformly sampled data with proper accounting of the sampling errors associated with the lightcurves shows that Sgr A* exhibits no 57- or 106-day quasi-periodic oscillations, contrary to previous claims. The cause of the variability is investigated by examining a number of plausible scintillation models, enabling those variations which could be attributed to interstellar scintillation to be isolated from those that must be intrinsic to the source. Thin-screen scattering models do not account for the variability amplitude on most time scales. However, models in which the scattering region is extended out to a radius of 50–500 pc from the Galactic center account well for the broad characteristics of the variability on > 4-day time scales. The $\sim 10\%$ variability on < 4-day time scales at 0.7–3 cm appears to be intrinsic to the source. The degree of scintillation variability expected at millimeter wavelengths depends sensitively on the intrinsic source size; the variations, if due to scintillation, would require an intrinsic source size smaller than that expected.

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http://www.aoc.nrao.edu/%7Ejmacquar/SgrA.pdf

High Spectral Resolution Observations of the Massive Stars in the Galactic Center

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We present high-resolution near-infrared spectra, obtained with the NIRSPEC spectrograph on the W. M. Keck II Telescope, of a collection of hot, massive stars within the central 25 arcseconds of the Galactic center. We have identified a total of twenty-one emission-line stars, seven of which are new radial velocity detections with five of those being classified as He I emission-line stars for the first time. These stars fall into two categories based on their spectral properties: 1) those with narrow $\lambda\lambda$ 2.112, 2.113 μm He I doublet absorption lines, and 2) those with broad 2.058 μm He I emission lines. These data have the highest spectral resolution ever obtained for these sources and, as a result, both components of the absorption doublet are separately resolved for the first time. We use these spectral features to measure radial velocities. The majority of the measured radial velocities have relative errors of 20 km s^{-1}, smaller than those previously obtained with proper-motion or radial velocity measurements for similar stellar samples in the Galactic center. The radial velocities estimated from the He I absorption doublet are more robust than those previously estimated from the 2.058 μm emission line, since they do not suffer from confusion due to emission from the surrounding ISM. Using this velocity information, we agree with previous stellar velocity studies that the stars are orbiting in a somewhat coherent manner but are not as defined into a disk or disks as previously thought. Finally, multi-epoch radial velocity measurements for IRS 16NE show a change in its velocity presumably due to an unseen stellar companion.

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Interferometric Measurements of Variable 340 GHz Linear Polarization in Sgr A*

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Using the Submillimeter Array, we have made the first high angular resolution measurements of the linear polarization of Sagittarius A* at submillimeter wavelengths, and the first detection of intra-day variability in its linear polarization. We detected linear polarization at 340 GHz (880 um) at several epochs. At the typical resolution of $1''.4\times2''.2$, the expected contamination from the surrounding (partially polarized) dust emission is negligible. We found that both the polarization fraction and position angle are variable, with the polarization fraction dropping from 8.5% to 2.3% over three days. This is the first significant measurement of variability in the linear polarization fraction in this source. We also found variability in the polarization and total intensity within single nights, although the relationship between the two is not clear from these data. The simultaneous 332 and 342 GHz position angles are the same, setting a one-sigma rotation measure (RM) upper limit of 7×10^5 rad/m^2. From position angle variations and comparison of "quiescent" position angles observed here and at 230 GHz we infer that the RM is a few$\times10^5$ rad/m^2, a factor of a few below our direct detection limit. A generalized model of the RM produced in the accretion flow suggests that the accretion rate at small radii must be low, below $10^{-6} - 10^{-7}$ M$_\odot$ yr^{-1} depending on the radial density and temperature profiles, but in all cases below the gas capture rate inferred from X-ray observations.

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The Nature of the Faint Chandra X-ray Sources in the Galactic Centre

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Recent Chandra observations have revealed a large population of faint X-ray point sources in the Galactic Centre. The observed population consists of $\sim$ 2000 faint sources in the luminosity range $\sim 10^{31}$–10^{33} erg s^{-1}. The majority of these sources (70%) are described by hard spectra, while the rest are rather soft. The nature of these sources still remains unknown. Belczynski & Taam (2004) demonstrated that X-ray binaries with neutron star or black hole accretors may account for most of the soft sources, but are not numerous enough in order to account for the observed number and X-ray properties of faint hard sources. Both wind-fed systems and quiescent Roche lobe overflow transients were tested as potential source candidates. Muno et al. (2004) proposed that intermediate polars (subclass of magnetic cataclysmic variables) may be able to explain the faint hard population. Since an observational test of this hypothesis is not currently feasible due to *(i)* the large extinction toward the Galactic Centre, and *(ii)* low luminosity of intermediate polar donors (K-M dwarfs), we propose a theoretical test. A full population synthesis calculation of the Galactic Centre region has been carried out. Our results indicate that the numbers and X-ray luminosities of intermediate polars are consistent with the observed faint hard Galactic Centre population. We discuss the properties of the intermediate polar population, and suggest future tests for the hypothesis. For example, the derived slope of the X-ray luminosity function from our synthetic population of $\sim$ 0.8 could be compared with the observed slope, once one has been obtained from observations.

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The Observed Galactic Annihilation Line: Possible Signature of Accreting Small Mass Black Holes in the Galactic Center

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Various balloon and satellite observatories have revealed what appears to be an extended source of 0.511 MeV annihilation radiation with flux of $\sim 10^{-3}$ photons cm^{-2} s^{-1} centered on the Galactic Center. Positrons from radioactive products of stellar explosions can account for a significant fraction of the emission. We discuss an additional source for this emission: namely e^+e^- pairs produced when X-rays generated from the $\sim 2.6\times10^6$ M$_\odot$ solar mass Galactic Center Black Hole interact with $\sim$ 10 MeV temperature blackbody emission from 10^{17} g black holes within 10^{14}-10^{15} cm of the center. The number of such Small Mass Black Holes (SMMBHs) can

account for the production of the 10^{42} positrons s^{-1} that produces the observed annihilation in the inner Galaxy when transport effects are taken into account. We consider the possibility for confirming the presence of these SMMBHs in the Galactic Center region with future generations of gamma-ray instruments if a blackbody like emission of 10 MeV temperature would be detected by them. Small Mass Black Hole can be a potential candidate for dark (invisible) matter halo.

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Variations in the spectral slope of Sgr A* during a NIR flare

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We have observed a bright flare of Sgr A* in the near infrared with the adaptive optics assisted integral field spectrometer SINFONI. The observed spectrum is featureless and can be described by a power law. We show for the first time that the spectral index is correlated with the instantaneous flux and that both flux and spectral index experience significant changes within less than one hour. We argue that the near infrared flares from Sgr A* are due to synchrotron emission of transiently heated electrons, the emission being affected by orbital dynamics and synchrotron cooling, both acting on timescales of ~ 20 min. The synchrotron cooling process may account for the observed variation in spectral index, which in turn requires a magnetic field ~ 30 G, consistent with the equipartition field in a hot accretion flow with an accretion rate of $\sim 10^{-8}$ $M_\odot$ yr^{-1}.

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A Possible Rossby Wave Instability Origin for the Flares in Sagittarius A*

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In recent years, near-IR and X-ray flares have been detected from the Galaxy's central radio point source, Sagittarius A* (Sgr A*), believed to be a $\sim 3 \times 10^6$ $M_\odot$ supermassive black hole. In some cases, the transient emission appears to be modulated with a (quasi-)period of ~ 17–20 min. The implied $\sim 3\,r_S$ size of the emitter (where $r_S \sim 2GM/c^2$ is the Schwarzschild radius) points to an instability—possibly induced by accretion—near the Marginally Stable Orbit (MSO) of a slowly spinning object. But Sgr A* is not accreting via a large, "standard" disk; instead, the low density environment surrounding it apparently feeds the black hole with low angular momentum clumps of plasma that circularize within ~ 10–$300\,r_S$ and merge onto a compact, hot disk. In this *Letter*, we follow the evolution of the disk following such an event, and show that a Rossby wave instability, particularly in its magnetohydrodynamic form, grows rapidly and produces a period of enhanced accretion lasting several hours. Both the amplitude of this response, and its duration, match the observed flare characteristics rather well.

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