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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Summer 2006 GC News

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In the News

Cornelia Lang & Loránt Sjouwerman

It's been a productive spring and early summer for many GC researchers as evidenced by the 35 new GC abstracts! Thanks to all authors for getting your abstracts in for periodic e-newsflashes. We will get back to having a regular science feature article in the Fall 2006 issue of GCNEWS.

In the current issue we have a meeting summary from the GC06 Workshop held in late April in Bad Honnef, Germany, written by Rainer Schödel. This meeting was well-attended and provided lively discussions on many exciting GC topics! The spectacular location (and in-haus bier stube) helped to facilitate such discussions. A number of presentations on the theory of massive star formation and on nearby low-luminosity active galactic nuclei added breadth to the program. We continue to 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 related to GC science.

Finally, we include the full program for the Special Science Session at the IAU Division VII (Galactic) Meeting on Monday, August 21st. This session will hopefully provide the basis for forming a working group on the Galactic Center and nearby normal nuclei. We hope if you are planning to attend the IAU you will go to this session and encourage your colleagues (especially from other sub-fields) to join you to find out about the latest GC findings.

Meeting Summaries

1 Galactic Center Workshop 2006

Rainer Schödel (Universität zu Köln)

The Galactic Center Workshop 2006 took place in the *Physikzentrum* of the *Deutsche Physikalische Gesellschaft* in Bad Honnef, Germany, on 18-22 April 2006. Information on the conference such as the list of participants, scheduled talks, and displayed posters can be found on the web site *http://www.ph1.uni-koeln.de/GC06/*. Conference photos are available online as well. Here we provide a short summary, highlighting some of the most prominent topics and open questions.

1.1 ISM and Magnetic fields

Speakers: M. Morris, T. LaRosa, M. Tsuboi, Y. Fukui, S. Lee, J. Staguhn. M. Montero-Castano, N. Rodriguez-Fernandez

GC magnetic field: The fundamental question discussed with respect to the large-scale magnetic field in the GC is whether it traces a large scale field or local magnetic field density enhancements. Is there a pervasive field of milli-Gauss strength present or is the field predominantly weak ($10 - 100\,\mu$G), with localized filamentary maxima having $B \sim 1\,$mG? The double helix nebula identified on Spitzer images provides possible evidence for large scale magnetic fields that may be twisted by orbital motion of the ISM around the GC.

Molecular/atomic gas in the GC: One of the open questions is the nature of the heating mechanism of the GC molecular gas that is significantly warmer than the molecular gas in the rest of the Galaxy. What is the exact relation of the molecular gas to the magnetic field? How, and where do massive clusters such as Quintuplet and Arches form? What is the mechanism for the $m = 1$ offset? There is new evidence from mm observations for an interaction between the Sgr A East SN remnant shell and the $50\,\mathrm{km\,s^{-1}}$ molecular cloud. Additional evidence comes from observations of the IR H_2-line.

The circumnuclear disk/ring (CND): There is still considerable debate concerning the mass of the CND and lower masses seem more likely now (about $10^4 - 10^5\,\mathrm{M}_\odot$). The question of the density and mass of the clumps in the CND is also intimately related with the possibility of star formation in the CND. The CND may be the prototype of dusty tori in (LL)AGN. The clumpy nature is in contrast to the rather homogeneous rings assumed in the originally proposed AGN models.

1.2 Large scale structures and surveys

Speakers: A. Goldwurm, K. Koyama, R. Warwick, J. Lazio, D. Wang, S. Park, M. Sakano, J. Hinton, A. Cotera, S. Stolovy

Diffuse 8 keV emission: What is the origin of the 8 keV diffuse emission in the central ~40 pc? A reasonable solution appears to be that the emission comes from unresolved cataclysmic variables. This is among other supported by the fact that the profile of the diffuse 8 keV emission is the same as that of the stellar cluster derived from IR observations.

X-ray line emission from GC molecular clouds: The Suzaku X-ray maps provide an excellent new source of data. They allow to use line ratios to derive T_e. Focus of the debate is whether the emission from the clouds is related to increased activity of Sgr A* a few hundred years ago.

Spitzer IRAC survey: A highlight of the conference was the presentation of the detailed, large scale IRAC survey images from the Spitzer space telescope. They will be an important mine in the years to come to address issues such as star formation, the large scale structure of the central bulge, or the properties of dusty clouds.

1.3 Star formation at the center of the Milky Way

Speakers: C. Clarke, T. Paumard, S. Nayakshin, A. Stolte, F. Najarro, S. Kim

The formation and properties of the young stars in the central half-parsec of the Milky Way was an issue that received much attention at the conference. The young stars in the GC are found to be a few million years old and to be located in one, possibly two disks/rings. While the existence of the clockwise rotating disk appears to be well established, the evidence for the existence of the second (counter-clockwise rotating) disk is still debated. It may be possible to explain the observations with just one system of young stars. There is evidence that the IMF of the young stars is top-heavy. In combination with the observation that the density profile of the disks displays a steep fall-off from the center, the currently favored – but not undisputed – scenario is that the young stars formed in an accretion disk in possibly relatively short time ($10^4 - 10^5$ yr). Should this scenario be true this would lead, however, to the problem that if most of the material in the accretion disk is used for star formation then how do quasars get their fuel? Also it appears not clear yet whether the accretion disk scenario can explain the relatively high eccentricities of the orbits of some of the young stars.

1.4 The nuclear star cluster of the Milky Way

Speakers: T. Alexander, M. Freitag, R. Schödel, T. Ott, F. Martins, J.-U. Pott, J. Lu, S. Trippe, Y. Levin, H. Perets

The central topics in this session were above all the effects of mass segregation and the puzzle of the origin of the young, massive main sequence stars in the immediate environment of Sgr A* (the "S-stars"). Detailed theoretical models predict significant effects of mass segregation in the GC cluster. It is expected that of the order 20,000 stellar mass BHs have accumulated in the central parsec over the lifetime of the galaxy. The radial density profiles of stars of different magnitudes provide indeed some observational evidence for mass segregation. The S-stars appear to have the properties of normal main sequence stars. Thus scenarios appear less likely in which the S-stars are actually exotic objects or older stars rejuvenated through some unknown mechanism. If the S-stars formed simultaneously with the other young stars in the central half-parsec, then there must exist a mechanism that scatters these stars efficiently into tight orbits around Sgr A*. Several mechanisms appear viable, but all are confronted with challenges in terms of producing the right numbers. A promising mechanism may be resonant relaxation of orbits around the BH.

1.5 The nuclei of nearby galaxies

Speakers: C. Hopman, R. T Jihad, L. Tacconi, L. Sjouwerman, A. Brunthaler, S. Markoff, T. Beckert, T. Krichbaum, A. Doi, M. Filho

A new feature of the 2006 workshop compared to earlier GC workshops was expanding the focus of attention to include nearby low-luminosity galactic nuclei. Results from high-resolution mm-observations of nearby LLAGN indicate that gas at distances greater than 100 pc does not appear to be transported further inward and feed the AGNs. The LLAGN in M31 and M81 are the next stepping stones away from Sgr A* toward higher luminosities and larger distances. They are the nearest logical links in the chain toward AGNs and quasars and are now in the focus of observations from X-rays to the radio regime. Coordinated multi-wavelength campaigns have proved to be highly useful tools for understanding Sgr A*. Such a campaign was directed to M81* in spring/summer 2005. First results were presented at the conference. Successive campaigns are in preparation.

1.6 Observations and theory of Sgr A*

Speakers: D. Marrone, A. Miyazaki, G. Bower, Z.-Q. Shen, M. Miyoshi, T. An, A. Eckart, S. Hornstein, A. Krabbe, S. Gillessen, G. Belanger, F. Yuan, J. Cuadra, A. Broderick, W. Duschl, P. Biermann

Observations of long-term changes in the turnover frequency of Sgr A* at long wavelengths indicate a variable mass flux of the stellar winds captured by the MBH, which could modulate the opacity of the local absorbing medium.

The most recent constraints on the size of Sgr A* from VLBI at a wavelength of 3 mm are 15±4 Schwarzschild radii. In these measurements the extrapolation of the scattering law toward short wavelengths is of paramount importance.There is still some discussion which power-law is the exact one to describe the scattering law.

Both RIAF (radiatively inefficient accretion flow) and jet models as well as their combination are consistent with the size limits on Sgr A*.

Observations of the flux from Sgr A* at X-ray, IR and mm wavelengths are particularly directed toward observing its variability. Variability time scales provide information on the properties of the accretion flow and –at the shortest frequencies – possibly on the angular momentum of the black hole. At mm wavelengths the amplitude of the variability is about 10% to 20%, with significant power – but no confirmed periodicity – at time scales of hours. First observations of the variable polarization of the mm-flux from Sgr A* have provided some hints at circular motion of the plasma.

Polarized NIR radiation has been observed for the first time from Sgr A* in 2005, providing clear evidence for the non-thermal nature of the NIR flares. Also, in agreement with earlier observations, there are indications of a variability with a $\sim$20 min period in the NIR polarization measurements. At X-rays, a thorough analysis of a bright flare observed with XMM shows a periodicity at 22 ± 2 min. However, quasi-periodic behavior is only observed in some – not all – NIR and X-ray flares. There exists still debate as to the significance of the quasi-periodic oscillations, their relation to QPOs observed in microquasars, and their interpretation.

Disagreement between observers has also been found concerning the exact relation between NIR and X-ray flares, i.e. whether all X-ray flares occur simultaneous to a NIR flare. Also, different observers have obtained differing slopes of the spectra of the NIR flares. The cause is so far unclear.

1.7 Proceedings

The proceedings of the Galactic Center Workshop 2006 will be published in the *Journal of Physics: ConferenceSeries* by Institute of Physics Publishing online and in hardcopy. Publishing of the online proceedings is foreseen for early autumn 2006.

1.8 Next GC Workshop

Planning for the next Galactic Center workshop has begun with a preliminary date of Spring/Summer 2009, possibly in China.

1.9 Sponsors

The Galactic Center Workshop 2006 was sponsored in part by the *Deutsche Forschungsgemeinschaft* (DFG) via the Sonderforschungsbereich (SFB) grant 494 and by the I.Physikalisches Institut der Universität zu Köln.

Upcoming GC Meetings

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 from 9 am to 5:30 pm in Club B Room.

The current schedule for this Division VII session is

1. 0900: The Supermassive Black Hole at the GC – Mark Morris
2. 0930: Radio Imaging of SgrA* – Avery Broderick
3. 1000: Recent near-IR/X-ray measurements & the first time-resolved AO near-IR polarization measurements – Andreas Eckhart
4. 1020: Coffee
5. 1050: The SgrB2 region in H13CO+ and SiO Lines – Masato Tsuboi
6. 1110: The Galactic Centre region as seen by H.E.S.S.– Loic Rolland
7. 1130: Theory of accretion and flares – Sera Markoff
8. 1400: The young stellar disks in the central parsec –Thibaut Paumard
9. 1430: The origin of young stars in the central parsec – Simon Portegies Zwart
10. 1500: The *Spitzer* mid-infrared survey of the inner 2 x 1.5 degrees of the galaxy – Howard Smith

Abstracts

Folded Fields as the Source of Extreme Radio–Wave Scattering in the Galactic Center

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A strong case has been made that radio waves from sources within about half a degree of the Galactic Center undergo extreme diffractive scattering. However, problems arise when standard ("Kolmogorov") models of electron density fluctuations are employed to interpret the observations of scattering in conjunction with those of free–free radio emission. Specifically, the outer scale of a Kolmogorov spectrum of electron density fluctuations is constrained to be so small that it is difficult to identify an appropriate astronomical setting. Moreover, an unacceptably high turbulent heating rate results if the outer scale of the velocity field coincides with that of the density fluctuations. We propose an alternative model based on folded magnetic field structures that have been reported in numerical simulations of small–scale dynamos. Nearly isothermal density variations across thin current sheets suffice to account for the scattering. There is no problem of excess turbulent heating because the outer scale for the velocity fluctuations is much larger than the widths of the current sheets. We speculate that interstellar magnetic fields could possess geometries that reflect their origins: fields maintained by the galactic dynamo could have large correlation lengths, whereas those stirred by local energetic events might exhibit folded structures.

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Email: ssridhar@rri.res.in
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The Two Young Star Disks in the Central Parsec of the Galaxy: Properties, Dynamics and Formation

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We report the definite spectroscopic identification of $\simeq$ 40 OB supergiants, giants and main sequence stars in the central parsec of the Galaxy. Detection of their absorption lines have become possible with the high spatial and spectral resolution and sensitivity of the adaptive optics integral field spectrometer SPIFFI/SINFONI on the ESO VLT. Several of these OB stars appear to be helium and nitrogen rich. Almost all of the $\simeq$ 80 massive stars now known in the central parsec (central arcsecond excluded) reside in one of two somewhat thick ($< |h|/R > \simeq 0.14$) rotating disks. These stellar disks have fairly sharp inner edges ($R \simeq 1''$) and surface density profiles that scale as R^{-2}. We do not detect any OB stars outside the central 0.5 pc. The majority of the stars in the clockwise system appear to be on almost circular orbits, whereas most of those in the 'counter-clockwise' disk appear to be on eccentric orbits. Based on its stellar surface density distribution and dynamics we propose that IRS 13E is an extremely dense cluster ($\rho_{core} > 3\times10^8 M_\odot$ pc^{-3}), which has formed in the counter-clockwise disk. The stellar contents of both systems are remarkably similar, indicating a common age of $\simeq 6 \pm 2$ Myr. The K-band luminosity function of the massive stars suggests a top-heavy mass function and limits the total stellar mass contained in both disks to $\simeq 1.5 \times 10^4 M_\odot$. Our data strongly favor in situ star formation from dense gas accretion disks for the two stellar disks. This conclusion is very clear for the clockwise disk and highly plausible for the counter-clockwise system.

Ref.: ApJ, 2006, in press
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Eprint: astro-ph/0601268

Understanding the Stellar Initial Mass Function

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The essential features of the stellar Initial Mass Function are, rather generally, (1) a peak at mass of a few tenths of a solar mass, and (2) a power-law tail toward higher masses that is similar to the original Salpeter function. Recent work suggests that the IMF peak reflects a preferred scale of fragmentation associated with the transition from a cooling phase of collapse at low densities to a nearly isothermal phase at higher densities, where the gas becomes thermally coupled to the dust. The Salpeter power law is plausibly produced, at least in part, by scale-free accretion processes that build up massive stars in dense environments. The young stars at the Galactic Center appear to have unusually high masses, possibly because of a high minimum mass resulting from the high opacity of the dense star-forming gas.

Ref.: Revista Mexicana de Astronomia y Astrofisica,
Email: richard.larson@yale.edu
http://www.astro.yale.edu/larson/papers/Pucon05.pdf

Stochastic Acceleration in the Galactic Center HESS Source

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Stochastic acceleration of charged particles interacting resonantly with a turbulent magnetic field in a small accretion torus appears to be the likely mechanism responsible for much of Sagittarius A*'s mm and shorter wavelength spectrum. The longer wavelength radiation is produced at larger radii by electrons either diffusing from smaller scales or accelerated *in situ*. An important prediction of this model is the ejection of a significant flux of relativistic protons from a magnetic-field-dominated acceleration site into the wind-shocked medium surrounding the black hole. Recently, several air Čerenkov telescopes, notably HESS, have detected TeV emission from within $1'$ of the Galactic Center, with characteristics hinting at a pp-induced pion decay process for the γ-ray emission. Given (i) that we now know the size of this acceleration region, where Sagittarius A*'s 7-mm wavelength emission originates, and (ii) that we can now map the wind-injected ISM within ~ 3 pc of the nucleus using the diffuse X- rays detected with *Chandra*, it is feasible to test the idea that protons accelerated within ~ 20 Schwarzschild radii of the black hole produce the TeV emission farther out. We show that the diffusion length of these particles away from their source guarantees a majority of TeV protons scattering at least once within ~ 3 pc of Sagittarius A*, and we demonstrate that the proton power ($\sim 10^{37}$ ergs s^{-1}) produced in concert with the 7-mm radio emission matches the TeV luminosity well. The particle cascade generated by the pp scatterings produces GeV γ-rays from π^0 decays, and bremsstrahlung, inverse Compton, and synchrotron emission at longer wavelengths from secondary particles. We compare these with current measurements and demonstrate that GLAST will detect this source during its one-year all-sky survey. This model explains why the TeV source is unresolved, yet does not vary on a time scale of a year or less, and it also accounts for the high-energy emission while retaining consistency with Sgr A*'s well- studied cm and mm characteristics.

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Testing the Stochastic Acceleration Model for Flares in Sagittarius A*

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The near-IR and X-ray flares in Sagittarius A* are believed to be produced by relativistic electrons via synchrotron and synchrotron self-Comptonization (SSC), respectively. These electrons are likely energized by turbulent plasma waves through second order Fermi acceleration that, in combination with the radiative cooling processes, produces a relativistic Maxwellian distribution in the steady state. This model has four principal parameters, namely the magnetic field B, the electron density n, their "temperature" $\gamma_c m_e c^2$, and the size of the flare region R. In the context of stochastic acceleration by plasma waves, the quantities $R n^{1/2} B$ and $\gamma_c R n$ should remain nearly constant in time. Therefore, simultaneous spectroscopic observations in the NIR and X-ray bands can readily test the model, which, if proven to be valid, may be used to determine the evolution of the plasma properties during an eruptive event with spectroscopic observations in either band or simultaneous flux density measurements in both bands. The formulation we develop here may also be applicable to other sources radiating via thermal synchrotron and SSC processes.

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Email: liusm@lanl.gov
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Sgr A* as probe of the theory of supermassive compact objects without event horizon

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In the present paper some consequences of the hypothesis that the supermassive compact object in the Galaxy centre relates to a class of objects without event horizon are examined. The possibility of the existence of such objects was substantiated by the author earlier. It is shown that accretion of a surrounding gas can cause nuclear combustion in the surface layer which, as a result of comptonization of the superincumbent hotter layer, may give a contribution to the observed Sgr A* radiation in the range 10^{15}-10^{20} Hz. It is found a contribution of the possible proper magnetic moment of the object to the observed synchrotron radiation on the basis of Boltzmann's equation for photons which takes into account the influence of gravity to their motion and frequency. We arrive at the conclusion that the hypothesis of the existence in the Galaxy centre of the object with such extraordinary gravitational properties at least does not contradict observations.

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Email: verozub@t-online.de
Eprint: astro-ph/0601662

Complex small-scale structure in the infrared extinction towards the Galactic Centre

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A high level of complex structure, or "granularity", has been observed in the distribution of infrared-obscuring material towards the Galactic Centre (GC), with a characteristic scale of $5'' - 15''$, corresponding to $0.2 - 0.6$ pc at a GC distance of 8.5 kpc. This structure has been observed in ISAAC images which have a resolution of $\sim 0.6''$, significantly higher than that of previous studies of the GC. We have discovered granularity throughout the GC survey region, which covers an area of $1.6^\circ \times 0.8^\circ$ in longitude and latitude respectively (300 pc $\times$ 120 pc at 8.5 kpc) centred on Sgr A*. This granularity is variable over the whole region, with some areas exhibiting highly structured extinction in one or more wavebands and other areas displaying no structure and a uniform stellar distribution in all wavebands. The granularity does not appear to correspond to longitude, latitude or radial distance from Sgr A*. We find that regions exhibiting high granularity are strongly associated with high stellar reddening.

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Email: ajgosling@gmail.com
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Stellar remnants in galactic nuclei: mass segregation

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The study of how stars distribute themselves around a massive black hole (MBH) in the center of a galaxy is an important prerequisite for the understanding of many galactic-center processes. These include the observed overabundance of point X-ray sources at the Galactic center, the prediction of rates and characteristics of tidal disruptions of extended stars by the MBH and of inspirals of compact stars into the MBH, the latter being events of high importance for the future space borne gravitational wave interferometer LISA. In relatively small galactic nuclei, hosting MBHs with masses in the range $10^5 - 10^7\ M_\odot$, the single most important dynamical process is 2-body relaxation. It induces the formation of a steep density cusp around the MBH and strong mass segregation, as more massive stars lose energy to lighter ones and drift to the central regions. Using a spherical stellar dynamical Monte-Carlo code, we simulate the long-term relaxational evolution of galactic nucleus models with a spectrum of stellar masses. Our focus is the concentration of stellar black holes to the immediate vicinity of the MBH. We quantify this mass segregation for a variety of galactic nucleus models and discuss its astrophysical implications. Special attention is given to models developed to match the conditions in the Milky Way nucleus; we examine the presence of compact objects in connection to recent high-resolution X-ray observations.

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Eprint: astro-ph/0603280

Challenges in Detecting Gamma-Rays From Dark Matter Annihilations in the Galactic Center

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Atmospheric Cerenkov Telescopes, including HESS and MAGIC, have detected a spectrum of gamma-rays from the galactic center region which extends from ∼200 GeV or lower, to at least ∼10 TeV. Although the source of this radiation is not yet known, the spectrum appears to behave as a simple power-law, which is not the expectation for gamma-rays generated through the annihilation of dark matter particles. If instead we conclude that the source of these gamma-rays is astrophysical in origin, this spectrum will constitute a background for future dark matter searches using gamma-rays from this region. In this paper we study how this background will affect the prospects for experiments such as GLAST to detect dark matter in the galactic center. We find that only a narrow range of dark matter annihilation rates are potentially observable by GLAST given this newly discovered background and considering current constraints from EGRET and HESS. We also find that a detection of line emission, while not completely ruled out, is only possible for a very narrow range of dark matter models and halo profiles.

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Eprint: astro-ph/0603540

Annihilation Emission from the Galactic Black Hole

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Both diffuse high energy gamma-rays and an extended electron-positron annihilation line emission have been observed in the Galactic Center (GC) region. Although X-ray observations indicate that the galactic black hole Sgr A* is inactive now, we suggest that Sgr A* can become active when a captured star is tidally disrupted and matter is accreted into the black hole. As a consequence the galactic black hole could be a powerful source of relativistic protons. We are able to explain the current observed diffuse gamma-rays and the very detailed 511 keV annihilation line of secondary positrons by $p-p$ collisions of such protons, with appropriate injection times and energy. Relativistic protons could have been injected into the ambient material if the black hole captured a $50M_\odot$ star at several tens million years ago. An alternative possibility is that the black hole continues to capture stars with $\sim 1M_\odot$ every hundred thousand years. Secondary positrons produced by $p-p$ collisions at energies $\gtrsim 30$ MeV are cooled down to thermal energies by Coulomb collisions, and annihilate in the warm neutral and ionized phases of the interstellar medium with temperatures about several eV, because the annihilation cross-section reaches its maximum at these temperatures. It takes about ten million years for the positrons to cool down to thermal temperatures so they can diffuse into a very large extended region around the Galactic center. A much more recent star capture may be also able to account for recent TeV observations within 10 pc of the galactic center as well as for the unidentified GeV gamma-ray sources found by EGRET at GC. The spectral difference between the GeV flux and the TeV flux could be explained naturally in this model as well.

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Email: anisia@bohr.physics.hku.hk
Eprint: astro-ph/0603659

Testing RIAF model for Sgr A* using the size measurements

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Recent radio observations by the VLBA at 7 and 3.5 mm produced the high-resolution images of the compact radio source located at the center of our Galaxy—Sgr A*, and detected its wavelength-dependent intrinsic sizes at the two wavelengths. This provides us with a good chance of testing previously-proposed theoretical models for Sgr A*. In this *Letter*, we calculate the size based on the radiatively inefficient accretion flow (RIAF) model proposed by Yuan, Quataert & Narayan (2003). We find that the predicted sizes after taking into account the scattering of the interstellar electrons are consistent with the observations. We further predict an image of Sgr A* at 1.3 mm which can be tested by future observations.

Ref.: ApJL, 2006 in press
Email: fyuan@shao.ac.cn
Eprint: astro-ph/0603683
http://www.shao.ac.cn/fyuan

Particle Re-Acceleration in Colliding Winds Systems? Radio, X-ray, and γ-ray Emission Models of WR 140

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We present calculations of the spatial and spectral distribution of the radio, X-ray and γ-ray emission from shock accelerated electrons in the wind-collision region (WCR) of WR 140. Our calculations are for orbital phase 0.837 when the observed radio emission is close to maximum. Using the observed thermal X-ray emission at this phase in conjunction with the radio emission to constrain the mass-loss rates, we find that the O-star mass-loss rate is consistent with the reduced estimates for O4–5 supergiants by (Fullerton:2005), and the wind momentum ratio, $\eta = 0.02$. The observed low frequency turnover at $\sim$ 3 GHz in the radio emission is due to free-free absorption, since models based on the Razin effect have an unacceptably large fraction of energy in non-thermal particles. A key result is the index of the non-thermal electron energy distribution is flatter than the canonical value for diffusive shock acceleration (DSA), namely $p < 2$. It is argued that this requires re-acceleration of non-thermal particles in multiple wind-embedded shocks, which are then injected as seed particles for further acceleration at the global shocks bounding the WCR. There are some tantalizing hints that shock modification occurs in these systems. For example, the estimated amount of energy placed into non-thermal particles is high enough that non-linear effects should be important, and changes in the degree of shock modification with orbital phase may account for the asymmetry of the radio lightcurve and the smaller than expected variation in the X-ray lightcurve. Shock modification also results in softer X-ray emission from the post-shock plasma due to a reduction in the velocity jump across the subshock. While this is also consistent with observations, the long timescale for energy transfer between the post-shock ions and electrons may be the dominant cause. Tighter constraints on p and the nature of the shocks in WR 140 will be obtained from future observations at MeV and GeV energies, for which we generally predict lower fluxes than previous work. Since the high stellar photon fluxes prevent the acceleration of electrons beyond $\gamma > 10^5 - 10^6$, TeV emission from CWB systems will provide unambiguous evidence of pion-decay emission from accelerated ions. We finish by commenting on the emission and physics of the multiple wind collisions in dense stellar clusters, paying particular attention to the Galactic Centre.

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Recent star formation in the inner Galactic Bulge seen by ISOGAL

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The stellar populations in the central region of the Galaxy are poorly known because of the high visual extinction and very great source density in this direction. To use recent infrared surveys for studying the dusty stellar objects in this region. We analyse the content of a $\sim$ 20×20 arcmin^2 field centred at $(l, b) = (-0.27d, -0.06d)$ observed at 7 and 15 micron as part of the ISOGAL survey. These ISO observations are more than an order of magnitude better in sensitivity and spatial resolution than the IRAS observations. The sources are cross-associated with other catalogues to identify various types of objects. We then derive criteria to distinguish young objects from post-main sequence stars. We find that a sample of about 50 young stellar objects and ultra-compact HII regions emerges, out of a population of evolved AGB stars. We demonstrate that the sources colours and spatial extents, as they appear in the ISOGAL catalogue, possibly complemented with MSX photometry at 21 micron, can be used to determine whether the ISOGAL sources brighter than 300 mJy at 15 micron (or [15]<4.5 mag) are young objects or late-type evolved stars.

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Hot Accretion With Conduction: Spontaneous Thermal Outflows

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Motivated by the low-collisionality of gas accreted onto black holes in Sgr A* and other nearby galactic nuclei, we study a family of 2D advective accretion solutions with thermal conduction. While we only impose global inflow, the accretion flow spontaneously develops bipolar outflows. The role of conduction is key in providing the extra degree of freedom (latitudinal energy transport)

necessary to launch these rotating thermal outflows. The sign of the Bernoulli constant does not discriminate between inflowing and outflowing regions. Our parameter survey covers mass outflow rates from $\sim$ 0 to 13% of the net inflow rate, outflow velocities from $\sim$ 0 to 11% of the local Keplerian velocity and outflow opening angles from $\sim$ 0 to 60 degs. As the magnitude of conduction is increased, outflows can adopt a conical geometry, pure inflow solutions emerge, and the limit of 2D non-rotating Bondi-like solutions is eventually reached. These results confirm that radiatively-inefficient, hot accretion flows have a hydrodynamical propensity to generate bipolar thermal outflows.

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A Viscous Heating Mechanism for the Hot Plasma in the Galactic Center Region

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In addition to lines originating in a soft phase at $\sim$ 0.8 keV and to cold molecular clouds, the X-ray spectra from the Galactic center region also exhibit properties similar to those of a diffuse, thin, very hot plasma at 8 keV on a scale of hundreds of parsecs. This phase is surprising for more than one reason. First, such a hot plasma should not be bound to the Galactic plane and the power needed to sustain the escaping matter would be higher then any known source. Second, there is no known mechanism able to heat the plasma to more than a few keV. Recently we have suggested that, hydrogen having escaped, the hot plasma could be a helium plasma, heavy enough to be gravitationally confined. In this case, the required power is much more reasonable. We present here a possible heating mechanism which taps the gravitational energy of the molecular clouds. We note that the 8 keV plasma is highly viscous and we show how viscous friction of molecular clouds flowing within the hot phase can dissipate energy in the gas and heat it. We detail the MHD wake of a spherical cloud by considering the different MHD waves the cloud can excite. We find that most of the energy is dissipated by the damping of Alfvénic perturbations in two possible manners, namely by non-linear effects and by a large scale curvature of the field lines. We find that the total dissipation rate depends on the field strength. For fields B $\lesssim 200\mu$G both mechanisms produce power comparable to or higher than the radiative losses; for strong fields B $\gtrsim$ 1 mG, only the curvature damping can balance the X-ray emission and requires a radius of curvature $R_c \leq 100$ pc; whereas for intermediate fields, the total dissipation is more than one order of magnitude smaller, requiring a higher accretion rate. We note that the plasma parameters may be optimal to make the dissipation most efficient, suggesting a self-regulation mechanism. The loss of kinetic and gravitational energy also causes accretion of the clouds and may have significant action on the gas dynamics in this region between the large scale, bar dominated flow and the central accretion to the massive black hole.

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The pattern of accretion flow onto Sgr A*

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The material accreting onto Sgr A* most probably comes from the nearby stars. We analyze the pattern of this flow at distances of a fraction of a parsec and we argue that the net angular momentum of this material is low but non-negligible, and the initially supersonic disk accretion changes into subsonic flow with constant angular momentum. Next we estimate the flow parameters at a distance R_{BHL} from the black hole and we argue that for the plausible parameter range the accretion flow is non-stationary. The inflow becomes supersonic at distance of $\sim 10^4 R_g$ but the solution does not continue below the horizon and the material piles up forming a torus, or a ring, at a distance of a few up to tens of Schwarzchild radii. Such a torus is known to be unstable and may explain strong variability of the flow in Sgr A*. Our considerations show that the temporary formation of such a torus seems to be unavoidable. Our best fitting model predicts a rather large accretion rate of around $4 \cdot 10^{-6}$ $M_{\odot}/yr$ directly on Sgr A*. We argue that magnetic fields in the flow are tangled and this allows our model to overcome the disagreement with the Faraday rotation limits.

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Near-IR Spectroscopy of OH/IR stars in the Galactic Centre

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Galactic Centre (GC) OH/IR stars can be, based on the expansion velocities of their circumstellar shells, divided into two groups which are kinematically different and therefore are believed to have evolved from different stellar populations. To study the metallicity distribution of the OH/IR stars population in the GC on basis of a theoretical relation between EW(Na), EW(Ca) and EW(CO) and the metallicity.For 70 OH/IR stars in the GC, we obtained near-IR spectra. The equivalent line widths of NaI and CaI, 12CO(2,0) and the curvature of the spectrum around 1.6 μm due to water absorption are determined. The near-IR spectrum of OH/IR stars is influenced by several physical processes. OH/IR stars are variable stars suffering high mass-loss rates. The dust that is formed around the stars strongly influences the near-IR spectra and reduces the equivalent line widths of NaI and CaI. A similar effect is caused by the water content in the outer atmosphere of the OH/IR star. Because of these effects, it is not possible with our low resolution near-infrared spectroscopy to determine the metallicities of these stars.

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Relativistic periastron precession and frame dragging of stellar orbits in the central arcsecond of our Galaxy

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The geodesic equations of general relativity that describe motion of a test particle in Kerr spacetime are solved exactly including the contribution from the cosmological constant. By applying the exact solution for the precession of the point of closest approach for the orbit of the test particle around the Kerr field, we calculate the relativistic effect of periapsis advance for the observed orbits of S-stars in the central arcsecond of our galaxy, assuming that the galactic centre is a Kerr black hole, for various values of the Kerr parameter including those supported by recent observations. The observation of the predicted effects can provide an important test of the theory of general relativity at the strong field regime. In addition, we derive the exact solution of timelike non-spherical polar and non-polar orbits. Exact expressions for the periastron (periapsis) advance and frame dragging (Lense-Thirring) effect for a test particle in a polar, non-spherical orbit in the Kerr gravitational field are derived and applied for practical calculations around the galactic centre. We subsequently derive an analytical expression for the periapsis precession for the equatorial non-circular orbit of a test particle around a rotating mass whose surrounding curved spacetime geometry is described by the Kerr-de Sitter field.

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Diffraction Limited Imaging Spectroscopy of the SgrA* Region using OSIRIS, a new Keck Instrument

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We present diffraction limited spectroscopic observations of an infrared flare associated with the radio source SgrA*. These are the first results obtained with OSIRIS, the new facility infrared imaging spectrograph for the Keck Observatory operated with the laser guide star adaptive optics system. After subtracting the spectrum of precursor emission at the location of Sgr A*, we find the flare has a spectral index ($F(\nu) \propto \nu^{\alpha}$) of $\alpha = -2.6 \pm 0.9$. If we do not subtract the precursor light, then our spectral index is consistent with earlier observations by Ghez et al. (2005). All observations published so far suggest that the spectral index is a function of the flare's K-band flux.

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Exploring High-Velocity NH3(6,6) Emission at the Center of our Galaxy

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Using the NH3 (6,6) transition, which samples dense ($\sim 10^5$) molecular gas with an energy above ground of 412 K, we find hot gas at high velocities (–142 to –210 km s^{-1}) associated with the central 2 pc of the Galactic center. This material may be either infalling gas due to shocks or tidal stripping, or possibly gas swept from the nuclear region. We identify two high-velocity features, which we call the Southern Runner and the Cap, and correlate these features with others detected in various molecular observations of the Galactic center. The characteristic linewidths of the Southern Runner and Cap, 10 – 15 km s^{-1}, are similar to those of other hot Galactic center clouds. The estimated H_2 masses of these clouds are 4×10^3 $M_\odot$ and 2×10^3 $M_\odot$, consistent with the masses of the western streamer and northern ridge, NH3 (6,6) emission features detected within the central 10 pc at lower velocities. Three possible explanations for this emission are discussed assuming that they lie at the Galactic center, including sweeping by the supernova remnant Sgr A East, infall and/or shock from the circumnuclear disk (CND), and stripping from the central rotating low-velocity NH3 (6,6) cloud.

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Organic Molecular in the Galactic Center; Hot Core Chemistry Without Hot Cores

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We study the origin of large abundances of complex organic molecules in the Galactic center (GC). We carried out a systematic study of the complex organic molecules CH_3OH, C_2H_5OH, $(CH_3)_2O$, $HCOOCH_3$, $HCOOH$, CH_3COOH, H_2CO, and CS toward 40 GC molecular clouds. Using the LTE approximation, we derived the physical properties of GC molecular clouds and the abundances of the complex molecules. The CH_3OH abundance between clouds varies by nearly two orders of magnitude from 2.4×10^{-8} to 1.1×10^{-6}. The abundance of the other complex organic molecules relative to that of CH_3OH is basically independent of the CH_3OH abundance, with variations of only a factor 4–8. The abundances of complex organic molecules in the GC are compared with those measured in hot cores and hot corinos, in which these complex molecules are also abundant. We find that both the abundance and the abundance ratios of the complex molecules relative to CH_3OH in hot cores are similar to those found in the GC clouds. However, hot corinos show different abundance ratios than observed in hot cores and in GC clouds. The rather constant abundance of all the complex molecules relative to CH_3OH suggests that all complex molecules are ejected from grain mantles by shocks. Frequent ($\sim10^5$ years) shocks with velocities >6 km s^{-1} are required to explain the high abundances in gas phase of complex organic molecules in the GC molecular clouds. The rather uniform abundance ratios in the GC clouds and in Galactic hot cores indicate a similar average composition of grain mantles in both kinds of regions. The Sickle and the Thermal Radio Arches, affected by UV radiation, show different relative abundances in the complex organic molecules due to the differentially photodissociation of these molecules.

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Coupling the dynamics and the molecular chemistry in the Galactic center

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Most of the Galactic center (GC) gas moves in nearly circular orbits in a nuclear ring (hereafter the Galactic center ring, GCR). This is the case of cloud complexes such as Sgr A or Sgr B, where the gas is dense, warm and exhibits a rich molecular chemistry. The origin of these properties is thought to be shocks, in particular due to the large scale dynamics of the Galaxy. In addition, there are gas clouds moving in highly non-circular orbits known from observations of low density tracers such as CO(1-0). The physical conditions of the clouds moving with non-circular velocities are not well known. We have studied the physical conditions of the gas in non-circular orbits to better understand the origin of the unusual physical conditions of the GC molecular gas and the possible effect of the large scale dynamics on these physical conditions. Using published CO(1-0) data, we have selected a set of clouds belonging to all the kinematical components seen in the longitude-velocity diagram of the GC. We have carried out a survey of dense gas in all the components using the $J = 2-1$ lines of CS and SiO as tracers of high density gas and shock chemistry. We have detected CS and SiO emission in all the kinematical components. The gas density and the SiO abundance of the clouds in non-circular orbits are similar to those in the GCR. Therefore, in all the kinematical components there are dense clouds that can withstand the tidal shear. However, there is no evidence of star formation outside the GCR. The high relative velocity and shear expected in

the dust lanes along the bar major axis could inhibit the star formation process, as observed in other galaxies. The high SiO abundances derived in the non-circular velocity clouds are likely due to the large-scale shocks that created the dust lanes.

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Unveiling the nature of the highly absorbed X–ray source SAX J1748.2-2808 with XMM-Newton

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We report on the results of an EPIC XMM-Newton observation of the faint source SAX J1748.2−2808 and the surrounding field. This source was discovered during the BeppoSAX Galactic center survey performed in 1997-1998. A spatial analysis resulted in the detection of 31 sources within the EPIC field of view. SAX J1748.2−2808 is clearly resolved into 2 sources in EPIC images with the brighter contributing almost 80% of the 2–10 keV flux. Spectral fits to this main source are consistent with an absorbed power-law with a photon index of 1.4±0.5 and absorption equivalent to $14^{+6}_{-4}\times10^{22}$ cm^{-2} together with an iron line at $6.6^{+0.2}_{-0.2}$ keV with an equivalent width of 780^{+620}_{-380} eV. The significantly better statistics of the *XMM-Newton* observation, compared with *BeppoSAX*, allows to exclude a thermal nature for the X–ray emission. A comparison with other observations of SAXJ1748.2−2808 does not reveal any evidence for spectral or intensity long-term variability. Based on these properties we propose that the source is a low-luminosity high-mass X-ray binary located in the Galactic center region.

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Flaring Activity of Sgr A* at 43 and 22 GHz: Evidence for Expanding Hot Plasma

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We have carried out Very Large Array (VLA) continuum observations to study the variability of Sgr A* at 43 GHz (λ=7mm) and 22 GHz (λ=13mm). A low level of flare activity has been detected with a duration of $\sim$ 2 hours at these frequencies, showing the peak flare emission at 43 GHz leading the 22 GHz peak flare by $\sim$ 20 to 40 minutes. The overall characteristics of the flare emission are interpreted in terms of the plasmon model of Van der Laan (1966) by considering the ejection and adiabatically expansion of a uniform, spherical plasma blob due to flare activity. The observed peak of the flare emission with a spectral index $\nu^{-\alpha}$ of α=1.6 is consistent with the prediction that the peak emission shifts toward lower frequencies in an adiabatically-expanding self-absorbed source. We present the expected synchrotron light curves for an expanding blob as well as the peak frequency emission as a function of the energy spectral index constrained by the available flaring measurements in near-IR, sub-millimeter, millimeter and radio wavelengths. We note that the blob model is consistent with the available measurements, however, we can not rule out the jet model of Sgr A*. If expanding material leaves the gravitational potential of Sgr A*, the total mass-loss rate of nonthermal and thermal particles is estimated to be $\leq 2\times10^{-8}\,\mathrm{M}_\odot\,\mathrm{yr}^{-1}$. We discuss the implication of the mass-loss rate since this value matches closely with the estimated accretion rate based on polarization measurements.

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The Rotation Measure and 3.5 mm Polarization of Sgr A*

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We report the detection of variable linear polarization from Sgr A* at a wavelength of 3.5 mm, the longest wavelength yet at which a detection has been made. The mean polarization is 2.1 ± 0.1% at a position angle of $16\pm2^\circ$ with rms scatters of 0.4% and 9° over the five epochs. We also detect polarization variability on a timescale of days. Combined with previous detections over the range 150–400 GHz (750–2000 μm), the average polarization position angles are all found to be consistent with a rotation measure of $-4.4\pm0.3\times10^5\,\mathrm{rad\,m}^{-2}$. This implies that the Faraday rotation occurs external to the polarized source at all wavelengths. This implies an accretion rate $\sim 0.2-4\times10^{-8}\,\mathrm{M}_\odot\,\mathrm{yr}^{-1}$ for the accretion density profiles expected of ADAF, jet and CDAF models and assuming that the region at which electrons in the accretion flow become relativistic is within $10\,R_S$. The inferred accretion rate is inconsistent with ADAF/Bondi accretion=2E The stability of the mean polarization position angle between disparate polarization observations over the frequency range limits fluctuations in the accretion rate to less than 5%. The flat frequency dependence of the inter-day polarization position angle variations also makes them difficult to attribute to rotation measure fluctuations, and suggests that both the magnitude and position angle variations are intrinsic to the emission.

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Chandra Observations of Galactic Center: High Energy Processes at Arcsecond Resolution

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About 2 million seconds of *Chandra* observing time have been devoted to the Galactic center (GC), including large-scale surveys and deep pointings. These observations have led to the detection of about 4000 discrete X-ray sources and the mapping of diffuse X-ray emission in various energy bands. In this review, I first summarize general results from recent studies and then present close-up views of the three massive star clusters (Arches, Quintuplet, and GC) and their interplay with the Galactic nuclear environment.

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www.astro.umass.edu/~wqd/papers/arches/gc2006.pdf

The Interplay between Star Formation and the Nuclear Environment of our Galaxy: Deep X-ray Observations of the Galactic Center Arches and Quintuplet Clusters

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The Galactic center (GC) provides a unique laboratory for a detailed examination of the interplay between massive star formation and the nuclear environment of our Galaxy. Here, we present an 100 ks *Chandra* ACIS observation of the Arches and Quintuplet star clusters. We also report on a complementary mapping of the dense molecular gas near the Arches cluster made with the Owens Valley Millimeter Array. We present a catalog of 244 point-like X-ray sources detected in the observation. Their number-flux relation indicates an over-population of relatively bright X-ray sources, which are apparently associated with the clusters. The sources in the core of the Arches and Quintuplet clusters are most likely extreme colliding wind massive star binaries. The diffuse X-ray emission from the core of the Arches cluster has a spectrum showing a 6.7-keV emission line and a surface intensity profile declining steeply with radius, indicating an origin in a cluster wind. In the outer regions near the Arches cluster, the overall diffuse X-ray enhancement demonstrates a bow shock morphology and is prominent in the Fe Kα 6.4-keV line emission with an equivalent width of ~ 1.4 keV. Much of this enhancement may result from an ongoing collision between the cluster and the adjacent molecular cloud, which have a relative velocity $\gtrsim 120 kms^{-1}$. The older and less compact Quintuplet cluster contains much weaker X-ray sources and diffuse emission, probably originating from low-mass stellar objects as well as a cluster wind. However, the overall population of these objects, constrained by the observed *total* diffuse X-ray luminosities, is substantially smaller than expected for both clusters, if they have normal Miller & Scalo initial mass functions. This deficiency of low-mass objects may be a manifestation of the unique star formation environment of the Galactic center, where high-velocity cloud-cloud and cloud-cluster collisions are frequent.

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Massive perturber-driven interactions of stars with a massive black hole

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We study the role of massive perturbers (MPs) in deflecting stars and binaries to almost radial ("loss-cone") orbits, where they pass near the central massive black hole (MBH), interact with it at periapse q, and are ultimately destroyed. MPs dominate dynamical relaxation when the ratio of the 2nd moments of the MP and star mass distributions, $\mu_2 \equiv N_p \left\langle M_p^2 \right\rangle / N_\star \left\langle M_\star^2 \right\rangle$, satisfies $\mu_2 \gg 1$. The observed MPs in the nucleus of the Galaxy (giant molecular clouds and stellar clusters), and plausibly in late type galaxies generally, have $10^2 \lesssim \mu_2 \lesssim 10^5$. MPs thus shorten the relaxation timescale by 10^{2-5} relative to 2-body relaxation by stars alone. We show this increases by 10^{1-3} the rate of large-q interactions with the MBH, where loss-cone refilling by stellar 2-body relaxation is inefficient. We extend the Fokker-Planck loss-cone formalism to approximately account for relaxation by rare encounters with MPs. We show that binary–MBH exchanges driven by MPs may explain the origin of the young main sequence B stars that are observed very near the Galactic MBH, and may increase by orders of magnitude the ejection rate of hyper-velocity stars. We suggest that MP-driven relaxation plays an important role in the capture of stars on very tight orbits around the MBH, leading to their tidal orbital decay and disruption or to inspiral through the emission of gravitational waves from zero-eccentricity orbits. We show that loss-cone refilling by MPs leads to rapid orbital decay and coalescence of binary MBHs, thereby solving the stalling problem.

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Cluster Core Dynamics in the Galactic Center

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We present results of N-body simulations aimed at understanding the dynamics of young stars near the Galactic center. Specifically, we model the inspiral of a cluster core containing an intermediate mass black hole and $N \sim 50$ cluster stars in the gravitational potential of a supermassive black hole. We first study the elliptic three-body problem to isolate issues of tidal stripping and subsequent scattering, followed by full N-body simulations to treat the internal dynamics consistently. We find that our simulations reproduce several dynamical features of the observed population. These include the observed inner edge of the claimed clockwise disk, as well as the thickness of said disk. We find that high density clumps, such as that claimed for IRS13E, also result generically from our simulations. However, not all features of the observations are reproduced. In particular, the surface density profile of the simulated disk scales as $\Sigma \propto r^{-0.75}$, which is considerably shallower than that observed. Further, at no point is any significant counter-rotating population formed.

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Identification of the Infrared Counterpart to a Newly Discovered X-ray Source in the Galactic Center

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We present first results of a campaign to find and identify new compact objects in the Galactic Center. Selecting candidates from a combination of Chandra and 2MASS survey data, we search for accretion disk signatures via infrared spectroscopy. We have found the infrared counterpart to the *Chandra* source CXO J174536.1-285638, the spectrum of which has strong Brγ and HeI emission. The presence of CIII, NIII, and HeII indicate a binary system. We suspect that the system is some form of high-mass binary system, either a high-mass X-ray binary or a colliding wind binary.

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The Distance to the Galactic Center Derived From Infrared Photometry of Bulge Red Clump Stars

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On the basis of the near infrared observations of bulge red clump stars near the Galactic center, we have determined the galactocentric distance to be $R_0 = 7.52 \pm 0.10$ (stat) $\pm$ 0.35 (sys) kpc. We observed the red clump stars at l < 1.0 deg and 0.7 deg < b < 1.0 deg with the IRSF 1.4 m telescope and the SIRIUS camera in the H and Ks bands. After extinction and population corrections, we obtained $(m - M)_0 = 14.38 \pm 0.03$ (stat) $\pm$ 0.10 (sys). The statistical error is dominated by the uncertainty of the intrinsic local red clump stars' luminosity. The systematic error is estimated to be +- 0.10 including uncertainties in extinction and population correction, zero-point of photometry, and the fitting of the luminosity function of the red clump stars. Our result, $R_0 = 7.52$ kpc, is in excellent agreement with the distance determined geometrically with the star orbiting the massive black hole in the Galactic center. The recent result based on the spatial distribution of globular clusters is also consistent with our result. In addition, our study exhibits that the distance determination to the Galactic center with the red clump stars, even if the error of the population correction is taken into account, can achieve an uncertainty of about 5 percent, which is almost the same level as that in recent geometrical determinations.

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Guaranteed and Prospective Galactic TeV Neutrino Sources

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Recent observations, particularly from the HESS Collaboration, have revealed rich Galactic populations of TeV gamma-ray sources, including a collection unseen in other wavelengths. Many of these gamma-ray spectra are well measured up to $\sim$ 10 TeV, where low statistics make observations by air Čerenkov telescopes difficult. To understand these mysterious sources, especially at much higher energies–where a cutoff should eventually appear–new techniques are needed. We point out the following: (1) For a number of sources, it is very likely that pions, and hence TeV neutrinos, are produced; (2) As a general point, neutrinos should be a better probe of the highest energies than gamma rays, due to increasing detector efficiency; and (3) For several specific sources, the detection prospects for km^3 neutrino telescopes are very good, $\sim$ 1–10 events/year, with low atmospheric neutrino background rates above reasonable energy thresholds. Such signal rates, as small as they may seem, will allow neutrino telescopes to powerfully discriminate between models for the Galactic TeV sources, with important consequences for our understanding of cosmic-ray production.

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Young stars in the Galactic Centre: a potential intermediate-mass star origin

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There has been recent speculation (Davies & King 2005) that the cores of intermediate-mass stars stripped of their envelopes by tidal interaction with the supermassive black hole in the Galactic centre could form a population observationally similar to the so-called Sgr A* cluster or 'S' stars, which have close eccentric orbits around the hole. We model the evolution of such stars, and show that the more luminous end of the population may indeed appear similar to young B stars within the observational limits of the Galactic Centre region. Whether some or all of these cluster stars can be accounted for in this manner depends strongly on the assumed IMF of the loss cone stars and the scattering rate. If most of the observed stars are in fact scattered from the Galactic Centre inner cusp region itself then the population of $\sim$ 20 to current observational limits may be reproduced. However, this only works if the local relaxation time is small and relies on the cusp stars themselves being young, i.e. it is dependent on some star formation being possible in the central few parsecs. Conversely, we obtain a possible constraint on the tidal stripping rate of 'normal'-IMF stars if there are not to be red stars visible in the Sgr A* cluster.

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The K-band Spectrum of The Hot Star in IRS 8: An Outsider in the Galactic Center?

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Using adaptive optics at the Gemini North telescope we have obtained a K-band spectrum of the star near the center of the luminous Galactic center bowshock IRS 8, as well as a spectrum of the bowshock itself. The stellar spectrum contains emission and absorption lines characteristic of an O5-O6 giant or supergiant. The wind from such a star is fully capable of producing the observed bowshock. However, both the early spectral type and the apparently young age of the star, if it is single, mark it as unique among hot stars within one parsec of the center.

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Ejection of Hyper-Velocity Stars from the Galactic Centre by Intermediate-Mass Black Holes

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We have performed N-body simulations of the formation of hyper-velocity stars (HVS) in the centre of the Milky Way due to inspiralling intermediate-mass black holes (IMBHs). We considered IMBHs of different masses, all starting from circular orbits at an initial distance of 0.1 pc. We find that the IMBHs sink to the centre of the Galaxy due to dynamical friction, where they deplete the central cusp of stars. Some of these stars become HVS and are ejected with velocities sufficiently high to escape the Galaxy. Since the HVS carry with them information about their origin, in particular in the moment of ejection, the velocity distribution and the direction in which they escape the Galaxy, detecting a population of HVS will provide insight in the ejection processes and could therefore provide indirect evidence for the existence of IMBHs. Our simulations show that HVS are generated in short bursts which last only a few Myrs until the IMBH is swallowed by the supermassive black hole (SMBH). HVS are ejected almost isotropically, which makes IMBH induced ejections hard to distinguish from ejections due to encounters of stellar binaries with a SMBH. After the HVS have reached the galactic halo, their escape velocities correlate with the distance from the Galactic centre in the sense that the fastest HVS can be found furthest away from the centre. The velocity distribution of HVS generated by inspiralling IMBHs is also nearly independent of the mass of the IMBH and can be quite distinct from one generated by binary encounters. Finally, our simulations show that the presence of an IMBH in the Galactic centre changes the stellar density distribution inside $r < 0.02$ pc into a core profile, which takes at least 100 Myrs to replenish.

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