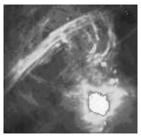
GCNEWS



The Newsletter of Galactic Center Research

Edited by Angela Cotera & Heino Falcke

Vol.8 **August 1998**

email: gcnews@mpifr-bonn.mpg.de **http://www.mpifr-bonn.mpg.de/gcnews/**

OH (1720 MHz) Masers in the Galactic Center

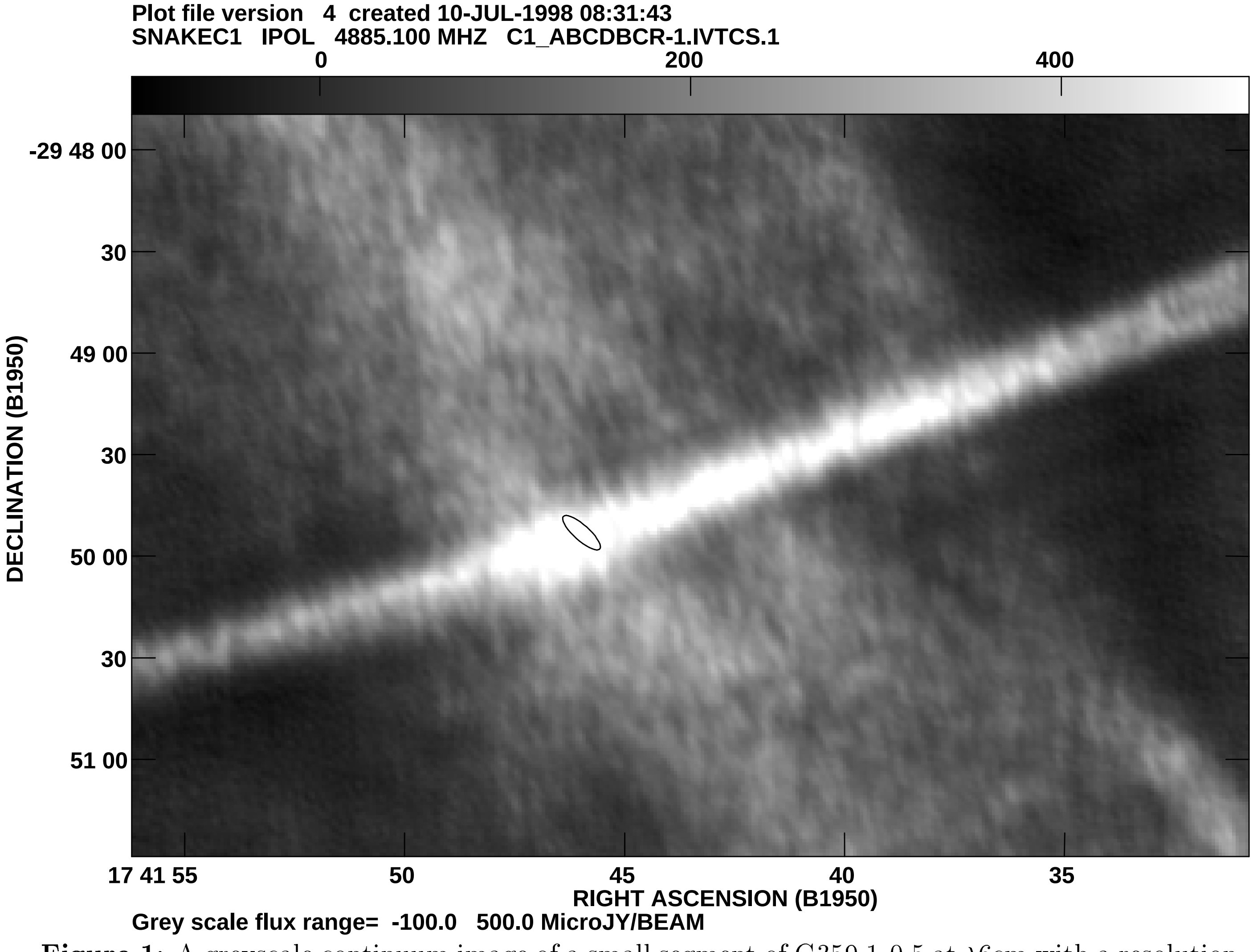


Figure 1: A greyscale continuum image of a small segment of G359.1-0.5 at λ6cm with a resolution of $5'' \times 3''$. The filamentary Snake appears to cross the remnant. The position of the OH (1720 MHz) maser is drawn as a contour with a size 20 times bigger than the actual value (Yusef-Zadeh, Uchida and Roberts 1995, see article page 4). The position angle of the maser represents the direction of the anisotropy of the scatter broadened maser source.

Table of Contents

Editorial: News from GCNEWS and GC98

Angela Cotera & Heino Falcke

Electronic Libraries

The number of electronic newsletters which cover astronomical research are growing rapidly. Well established newsletters of institutions and telescopes are also starting to rely more and more on the electronic medium, while new subject oriented newsletters, like GCNEWS, are being added to the pool of publications. Librarians are keeping pace with the trend towards electronic publishing and have started to catalog the available resources. Liz Bryson from the CFHT library, not only maintains an exceptionally good library website but also has a webpage of Electronic Publications http://www.cfht.hawaii.edu/~bryson/epubs.html featuring such newsletters as your own GCNEWS. Similarly, Sarah Stevens-Rayburn at the STScI library (http://sesame.stsci.edu/lib/abstract.html) also has a good electronic publication reference page. Both of these examples, by the way, illustrate that the job of the librarian will be changing drastically within the next few years through the advent of the "electronic library".

GCNEWS featured in ADS

Another step in this direction (at least for GCNEWS) is the agreement we reached with the ADS project - which we are certain all of you now use as a precious tool in literature research. Within the next few weeks we will be able to submit the articles (not the abstracts) that have appeared in GCNEWS to ADS where they will be included in the database and available through the usual queries. The database entries will also be linked to our website and hence GCNEWS articles will be electronically as available as are ApJ articles or other "normal" articles. GCNEWS will also get its own 'bibcode': GCN.

We believe that this will benefit everyone. The authors of the articles and abstracts which appear in GCNEWS will know that their work receives the widest possible distribution and interested researchers will find it easier to locate up to date information on a certain field. In this way, the GC community will be opening up to those with new interest in exciting developments concerning the heart of the Milky Way. (As an additional perk, perhaps this will provide even more motivation for new authors to volunteer and to follow the excellent example set by those who have already written articles for GCNEWS). Perhaps this is a good point to remind our readers that we are always open for suggestions for short articles, not only reviews and conference summaries, but also short research notes that otherwise would not make it into published literature.

GC Workshop 1998: The Central Parsecs

GC98 is currently at capacity and we have a long waiting list of people who would like to attend but cannot due to space constraints (the room is just not big enough). In this case the deadline really turned out to be a hard limit and as indicated in the very first announcement—here in GCNEWS—we also had to focus solely on the topic of the workshop "The Central X Parsecs" by reducing X such that the number N of participants became smaller than 60. Perhaps we can inverse this criterion the next time and only accept papers where X is much larger than 10 (volunteers to organize GC99 or GC2000 wanted!). The small room size and number of participants was chosen in the initial planing phase in order to create an intimate setting as is required for extensive discussion sessions.

The conference itself is not only organized by GCNEWS, but jointly with a number of other institutions in Tucson, Heidelberg, and Bonn. The program which you will find at the end of this issue promises a very exciting and dynamic workshop. Thanks go out to all who are including their work and apologies go out to those we have been unable to accomodate. The conference proceedings will be published in the ASP Conf. Ser. with very relaxed page limits and conference abstracts will appear in a special issue of GCNEWS. We also will make preprints of submitted papers available once they are submitted. A summary of the workshop highlights is also planned.

This Issue

Since the last volume of GCNEWS, we have been inundated with abstracts from all over the world. We have a record 25 abstracts which have been submitted or accepted to refereed journals in this issue and are pleased to see collegues from Russia utilizing this service. It has been just over two years since we first began this newsletter with the idea that we could improve communications between Galactic Center researchers if only we had a way to quickly learn of research going on throughout the field. Although we established the framework, it is the contributions from our subscribers that have made GCNEWS a success. By subscribing to and using the service, you have helped to keep all of us informed of the latest research in the Galactic Center. We now let the abstracts do most of the talking. Well, the abstracts and Farhad Yusef-Zadeh who has written an excellent article for this issue on the recent successes in exploring the GC using 1720 MHz Masers and the way in which they have allowed us to expand our understanding of a number of processes within the GC. It is a pleasure to read and we hope you enjoy it.

On the Nature of OH (1720 MHz) Masers in the Galactic Center

Farhad Yusef-Zadeh (Department of Physics and Astronomy, Northwestern University)

Introduction

The association of 1720 MHz OH masers with supernova remnants, a possibility which was ignored for more than 25 years (e.g. Goss and Robinson 1968), was recently brought to the spotlight by a high-resolution study of the supernova remnant W28 (Frail, Goss & Slysh 1994). These maser clumps – sometimes called supernova masers – are observed along the interface of the supernova remnant and an adjacent molecular cloud (the extreme evolutionary endpoints of the stars and gas), leading these authors to support the idea that the collision is the pumping source of the masers as had been suggested by Elitzur (1976) more than 20 years ago. The OH 1720 MHz masers are uncommon and appear to be different from those OH emission features seen along the spiral arms and are in stark contrast to OH 1665 and 1667 MHz maser spots generally observed toward star-forming regions and in circumstellar envelopes of evolved stars. Theoretical studies of the pumping of the OH maser lines (e.g. Elitzur 1976; Pavlakis & Kylafis 1996; Lockett, Gauthier and Elitzur 1998) suggest that 1665 and 1667 MHz masers are pumped by far-infrared radiation and are therefore associated with HII regions and evolved stars. The OH (1720 MHz) maser is collisionally pumped in molecular gas at temperatures and densities between 15-200 K and $(10^4 - 10^6)$ cm$(^{-3})$, respectively. Thus in the absence of the 1665/7 MHz transitions, the OH (1720 MHz) line presumably traces cooling, shocked gas.

The discovery paper by Frail et al. (1994) motivated us to search for these masers at the site of the thermal/nonthermal interaction in the complex region of the Galactic Center region where a number of nonthermal features are believed to be interacting with thermal gas (Yusef-Zadeh, Uchida and Roberts 1995). Figure 1 shows a segment of the SNR G359.1-0.5 where an OH (1720 MHz) maser is detected at the location where the Snake crosses the supernova shell. The detection of these masers in the Galactic Center region has already provided a wealth of information and has a potential to be a powerful probe of the interstellar medium of this region because of the extensive reservoir of dense molecular material observed throughout this region. Here, highlights of what we have learned from observations of OH (1720 MHz) masers in this region are briefly described.

A Probe of the Magnetic Pressure

Direct measurements of the magnetic field is quite difficult in the Galactic Center region due to the broad linewidths of molecular clouds and a large number of unrelated velocity features along the line of sight. Because, the OH (1720 MHz) maser line traces molecular gas densities on the order of 10^4 to 10^6 cm^{-3} which are similar to typical molecular densities of molecular clouds in the Galactic Center region, their high surface brightness over a narrow linewidth have made their identification simple and Zeeman splitting are measured with a high S/N ratio. The magnetic field measurements of Sgr A East with B$\approx$ 2-5 mG with a S/N of 10–30 are roughly an order of magnitude greater than sources outside the Galactic Center. Because of the relatively large Zeeman shift in the line profiles, Elitzur (1998) has recently argued that these masers show a direct evidence of maser saturation. We also note extended maser emission clearly associated with the remnants such as G359.1-0.5 (Yusef-Zadeh, Uchida and Roberts 1995). Future study of the extended masing structure should be useful in learning the structure of the magnetic field behind the shock front.

A Probe of the C-type Shock

The intense UV radiation field exciting the high density, intrinsically large linewidths of H_2 in a photodissociation region have made the detection of shocked molecular gas in the Galactic Center region quite difficult. Shocks driven into the molecular gas clouds by the ram pressure of SNRs or winds are considered to be important in two prominent molecular features in the Galactic Center: the circumnuclear disk (CND) and the Sgr A East molecular cloud.

Detection of OH (1720 MHz) masers at the boundary of Sgr A East and the CND (Yusef-Zadeh et al. 1996) was used to argue that these masers are indicators of C-type shocks (Wardle, Yusef-Zadeh and Geballe 1998). The magnetic pressure behind the shock front was equated to the pressure of preshock gas, thus constraining the shock speed to 25–30 km/s. The X-ray pressure observed within the interior of the Sgr A East shell and the detection of molecular H_2 emission at the boundary of Sgr A East are all consistent with the C-type shock hypothesis. Another independent study of the OH (1720 MHz) masers by Lockett, Gauthier and Elitzur (1998) conclude that the presence of such masers is a powerful indicator of C-type shocks.

A Probe of Low and High Energy Processes

Although shock chemistry predicts that OH is not abundant in the postshock gas as it is rapidly converted to water within the shock front, Wardle et al. (1998) argue that the weak X-ray flux from the interior of the SNR is responsible for dissociation of H_2O to OH molecule. This situation is unlike the environment of compact HII regions where OH masers are produced from water by the photodissociating flux of UV from the star. The dissociating flux is largely absorbed and reradiated in the FIR by grains, to pump the 1665/7 MHz transitions which cannot be the case for the unaccompanied 1720 MHz masers associated with SNR-molecular cloud interactions. The presence of OH (1720 MHz) masers near SNRs suggests a strong coupling between the low and high-energy activities co-existing with each other.

A Probe of the Scattering Medium

The OH (1720 MHz) masers associated with Sgr A East and the CND appear to broadened by the scattering medium toward the Galactic Center. Anisotropic scattering has been observed toward Sgr A* and a number of OH/IR stars in the Galactic Center region. What is potentially interesting about the scattered size and shape of OH (1720 MHz) masers is the small angular separation of maser spots from each other from which the scattering properties on small angular scales can be studied. The correlation of the position angles of scatter-broadened maser spots are used to measure the length scale of the magnetic fluctuations in the turbulent medium of the Galactic Center. Recent study by Yusef-Zadeh et al. (1998) estimates the size of this fluctuation to be of the order of 0.1-0.2 pc.

A Probe of the Gas Dynamics

The maser sources generally arise at the edge of supernova shells where the acceleration is tangential to the line of sight and the condition for velocity coherence is achieved by having a small velocity gradient along the line of sight. Most sources with OH (1720 MHz) masers outside the Galactic Center show small velocity dispersion along the rim of the supernova shells. This implies that the radial velocity of the masers is close to the systemic velocity of the molecular cloud. However, the masers associated with the shell of Sgr A East show a large velocity dispersion across the shell. This large velocity difference is considered to be to due to a strong shear that Sgr A East is experiencing near the deep gravitational potential of the Galactic Center. In this scenario, Yusef-Zadeh et al. (1998) argue that the Sgr A East molecular cloud has to be located within 5 pc behind the Galactic Center if tidal shear is responsible for the observed velocity difference across the shell of the SNR.

References

Elitzur, M. 1976, ApJ, 203, 124

Elitzur, M. 1998, ApJ, in press.

Frail, D.A., Diamond, P.J., Cordes, J.M. and van Langevelde, H.J. 1994, ApJ, 427, L43

Frail, D.A., Goss, M.W. and Slysh, V.I. 1994, ApJ, 424, L111

Goss, W.M. and Robinson, B.J. 1968, ApJ, 2, 81

Lockett, P., Gauthier, E. and Elitzur, M. 1998, ApJ, submitted

Pavlakis, K.G. and Kylafis, N.D. 1996, ApJ, 467, 300

Wardle, M., Yusef-Zadeh, F., & Geballe 1998, ApJ, submitted
Yusef-Zadeh, F., Uchida, K.I., & Roberts, D.A. 1995, Science 270, 1801.
Yusef-Zadeh, F., Roberts, D.A., Goss, W.M., Frail, D. & Green, A. 1996, ApJ 466, L25.
Yusef-Zadeh, F., Roberts, D.A., Goss, W.M., Frail, D. & Green, A. 1998, ApJ submitted.
Yusef-Zadeh, F. & Morris, M. 1987, ApJ, 320, 545.

Abstracts

TGRS Measurements of the Positron Annihilation Spectrum from the Galactic Center

M. J. Harris[1,2], *B. J. Teegarden*[1], *T. L. Cline*[1], *N. Gehrels*[1], *D. M. Palmer*61, 2 *R. Ramaty* [1] *& H. Seifert*[1,2]

(1) NASA/Goddard Spaceflight Center, (2) Universities Space Research Association.

We have obtained spectra of the Galactic center at energies 400–600 keV from high-resolution data acquired by the TGRS Ge spectrometer on board the *WIND* mission during 1995–1997. The data were obtained using an on-board occulter, and are relatively free from systematics and backgrounds. Analysis of the spectra reveals a well-resolved electron-positron annihilation line at 511 keV and the associated continuum due to annihilation via positronium formation. Measurements of the line width and the continuum-to-line ratio allow some constraints to be placed on the interstellar sites where annihilation occurs.

ApJ, in press
email: harris@tgrs2.gsfc.nasa.gov
xxx.lanl.gov/abs/astro-ph/9803247

Radio Continuum Structure of IRS 13 and Proper Motions of Compact HII Components at the Galactic Center

Jun-Hui Zhao[1] *& W. M. Goss*[2]
T. L. Cline[1], *N. Gehrels*[1], *D. M. Palmer*61, 2 *R. Ramaty* [1] *& H. Seifert*[1,2]

(1) (1) Harvard-Smithsonian Center for Astrophysics, (2) NRAO-AOC, Socorro, NM

A compact HII region, IRS 13, is located 3″to the SW of Sgr A*, the compact radio source at the Galactic Center. The source is double, IRS 13E and 13W, at 7 and 13 mm as observed with resolutions of 0.06″. A rising spectrum with spectral index of $\alpha = 0.9$ is observed for IRS 13E probably arising from a high density, ionized stellar wind. IRS 13W has a flat spectrum; in addition, the radio morphology suggests that the emitting material in IRS 13W has been swept off from the stellar envelope associated with IRS 13E by a strong wind and/or an outflow emanating from the IRS 16 complex and/or Sgr A*. Based on two epoch observations between 1991 and 1996, IRS 13E shows no significant proper motion < 4 mas y^{-1} (3σ) while IRS 13W shows a proper motion $\mu_\alpha = 0.4 \pm 0.7$, $\mu_\delta = 6.2 \pm 1.1$ mas y^{-1}, with respect to Sgr A*. In addition, proper motions of fifty-seven compact HII components at the Galactic Center are determined. The proper motion observations suggest that the minicavity is expanding with a speed of 200 km s^{-1}. The mean transverse velocity of 700 km s^{-1} is inferred for the IRS 9 complex which is located at the SW rim of the Eastern cavity. Large proper motions (up to 30 mas y^{-1}, or ~1200 km s^{-1}) are found for a number of HII components associated with filamentary structures, such as the Bullet and the Loop. The large proper motion measured from the compact HII components can be explained by motions of clumpy HII gas accelerated by either strong winds and outflows or explosive events at the Galactic Center. Large pattern speeds due to wave motions in the circumnuclear medium at the Galactic Center can also be responsible for some components of the observed proper motions.

ApJL 1998 in press
email: jzhao@cfa.harvard.edu

A kiloparsec-scale polarized plume associated with the Galactic Centre

A.R. Duncan[1], R.F. Haynes[2], W. Reich[3], P. Reich[3] & A.D. Gray4

(1) Physics Department, The University Of Queensland, (2) Australia Telescope National Facility, CSIRO, NSW, Australia , (3) Max-Planck-Institut für Radioastronomie, Bonn, (4) National Research Council Canada

Polarimetric data from the Parkes radio telescope at frequencies of 1.4, 2.4 and 4.8 GHz reveal the presence of a large "plume" of polarized emission to the north of the Galactic Centre (GC). This plume extends at least 15° in Galactic longitude, centred near $l = -3°$, and probably covers 15° or more in latitude (a linear extent of ≈ 2 kpc, assuming a distance to the GC of 8.5 kpc). Large rotation measures (RMs) and depolarizations are observed over the plume. Higher resolution observations at a frequency of 1.4 GHz with the Very Large Array (VLA) show this patchy polarized emission to extend to angular scales of several arcmin. The lack of correlation between polarized-intensity and total-intensity images (for both VLA and Parkes data) indicate that the polarization detected is the result of Faraday rotation, on small angular scales, of a uniform, polarized background. Recent γ-ray results show the presence of a similar plume of electrons and positrons lying to the north of the GC. Because of similarities in the location and size, an association between the radio and γ-ray plumes seems highly probable. The detection of large RMs in the presence of both electrons and positrons is rather unexpected. It is possible that the plume carries an excess of one charge carrier over the other, or that the distribution of electrons and positrons within the plume is "clumpy". The VLA data also reveal large RMs in the fields observed, up to approximately ± 300 rad m^{-2}, and clearly show the presence of Faraday depolarization. The patches of large RM seen in the VLA images are approximately 35 pc in diameter. Assuming that electrons (positrons) dominate in the observed regions, which lie near $b = +4°$, we estimate a thermal electron (positron) density of ≈ 3 cm $^{-3}$ and a magnetic field strength of several μG.

MNRAS, in press

email: p098wre@sun42.mpifr-bonn.mpg.de

ftp://ftp.physics.uq.edu.au/pub/GCPlume

Dark matter concentration in the Galactic Centre

David Tsiklauri & Raoul D. Viollier

Physics Department, University of Cape Town, South Africa

It is shown that the matter concentration observed through stellar motion at the galactic center (Eckart & Genzel, 1997, MNRAS, 284, 576 and Genzel et al., 1996, ApJ, 472, 153) is consistent with a supermassive object of 2.5×10^6 solar masses composed of self-gravitating, degenerate heavy neutrinos, as an alternative to the black hole interpretation. According to the observational data, the lower bounds on possible neutrino masses are $m_\nu \geq 12.0$ keV/c^2 for $g = 2$ or $m_\nu \geq 14.3$ keV/c^2 for $g = 1$, where g is the spin degeneracy factor. The advantage of this scenario is that it could naturally explain the low X-ray and gamma ray activity of Sgr A*, i.e. the so called "blackness problem" of the galactic center.

ApJ, Vol. 500, June 20

email: TSIKLAURI@physci.uct.ac.za

Hyperstrong Radio-Wave Scattering in the Galactic Center. I. A Survey for Extragalactic Sources Seen Through the Galactic Center

T. Joseph W. Lazio[1,3] & James M. Cordes[2]

(1) Naval Research Laboratory, Washington, DC, (2) Department of Astronomy and National Astronomy & Ionosphere Center, Cornell University, (3) NRC-NRL Research Associate

The scattering diameters of Sgr A* and several nearby OH masers ($\sim 1''$ at 1 GHz) indicate that a region of enhanced scattering is along the line of sight to the Galactic center. The scattering diameter of an extragalactic source seen through this scattering region will be larger by the ratio of the Sun-GC distance to the GC-scattering region separation. This ratio could be a factor of a few, if the scattering region is far from the GC and only a random superposition with it, to more than 100, if the scattering region is within the GC. We have used the VLA to survey 10 (11) fields at 20 cm

(6 cm) that are between 7′ and 137′ from Sgr A* . Our objective was to identify extragalactic sources and measure their scattering diameters so as to constrain the GC-scattering region separation. In order to find sources within these fields, we have employed pdfclean, a source detection algorithm in which sources are identified in an image by comparing the intensity histogram of the image to that expected from a noise-only image. We found over 100 sources, with the faintest sources being approximately 3 mJy. The average number of sources per field is approximately 10, though fields close to Sgr A* tend to contain fewer sources. In a companion paper we combine our survey with previous observations of the GC, and we assess the likelihood that the scattering region is so close to the GC that the resulting scattering diameters cause extragalactic sources to be resolved out by our observations. A number of Galactic sources is included in our source catalog. We discuss the double-lobed source 1LC 359.872+0.178, potentially an X-ray quiet version of 1E 1740.7−2942, a shell-like structure with a central point source, and a possible radio transient.

to appear in ApJS
email: lazio@rsd.nrl.navy.mil
xxx.lanl.gov/abs/astro-ph/9804156

Hyperstrong Radio-Wave Scattering in the Galactic Center. II. A Likelihood Analysis of Free Electrons in the Galactic Center

T. Joseph W. Lazio[1,3] *& James M. Cordes*[2]

(1) Naval Research Laboratory, Washington, DC, (2) Department of Astronomy and National Astronomy & Ionosphere Center, Cornell University, (3) NRC-NRL Research Associate

The scattering diameters of Sgr A* and several nearby OH masers ($\approx 1''$ at 1 GHz) indicate that a region of enhanced scattering is along the line of sight to the Galactic center. We combine radio-wave scattering data and free-free emission and absorption measurements in a likelihood analysis that constrains the following parameters of the GC scattering region: The GC-scattering region separation, Delta$_{GC}$; the angular extent of the region, ψ_ℓ and ψ_b; the outer scale on which density fluctuations occur, l_0; and the gas temperature, T$_e$. The maximum likelihood estimates of these parameters are Delta$_{GC}$ = 133^{+200}_{-80} pc, 0.5^o <Psi$_\ell$ $\lesssim 1^o$, and $(l_0/1\,pc)^{2/3}\mathrm{T}_e^{-1/2} = 10^{-7\pm0.8}$. The parameter Psi$_b$ was not well constrained and we adopt $\psi_b = 0.5'$. The close correspondence between Delta$_{GC}$ and Psi$_l^{gc}$ suggests that the scattering region encloses the GC. As host media for the scattering, we consider the photoionized surface layers of molecular clouds and the interfaces between molecular clouds and the 10^7 K ambient gas. We are unable to make an unambiguous determination, but we favor the interface model in which the scattering medium is hot (T$_e \sim 10^6$ K) and dense ($n_e \sim 10$ cm^{-3}). The GC scattering region produces a 1 GHz scattering diameter for an extragalactic source of 90″, if the region is a single screen, or 180″, if the region wraps around the GC, as appears probable. We modify the Taylor-Cordes model for the Galactic distribution of free electrons in order to include an explicit GC component. We predict that pulsars seen through this region will have a dispersion measure of approximately 2000 pc cm^{-3}, of which approximately 1500 pc cm^{-3} arises from the GC component itself. We stress the uniqueness of the GC scattering region, probably resulting from the high-pressure environment in the GC.

to appear in ApJS
email: lazio@rsd.nrl.navy.mil
xxx.lanl.gov/abs/astro-ph/9804156

A model for OH(1720 MHz) masers with supernova remnants, and an application to Sgr A East

Mark Wardle[1], *Farhad Yusef-Zadeh*[2] *& T.R. Geballe*[3]

(1) Special Research Centre for Theoretical Astrophysics, University of Sydney, (2) Department of Physics and Astronomy, Northwestern University, (3) Joint Astronomy Centre, Hilo, Hawaii

OH(1720 MHz) masers unaccompanied by 1665/7 MHz line masers have recently been proposed as indicators of the interaction of supernova remnants (SNRs) and molecular clouds. We present a model for the masing region in which water produced in a C-type shock wave driven into the molecular cloud is dissociated as a result of the X-ray flux from the SNR. We note that

the magnetic field strengths inferred from Zeeman splitting of the 1720 MHz line measure the internal pressure of the supernova remnant. In addition, we discuss the interaction of Sgr A East, a SNR candidate, with the 50 km/s cloud at the Galactic Centre and present near-infrared observations of H_2 emission towards the regions where OH(1720 MHz) maser emission is concentrated. The magnetic field strength obtained from earlier Zeeman measurements is consistent with rough pressure equilibrium between the postshock gas and the X-ray gas filling Sgr A East detected by ASCA. Further, the intensity of the v=1–0 S(1) line of H_2 is consistent with the shock strength expected to be driven into the molecular gas by this pressure. The relative intensities of the H_2 lines in Sgr A East imply mainly collisional excitation.

submitted to ApJ Lett
email: wardle@Physics.usyd.edu.au
xxx.lanl.gov/abs/astro-ph/9804146

The interaction of the Galactic center filament system G359.54+0.18 with its ambient medium

J. Staguhn[1,5], *J. Stutzki*[1]
K.I. Uchida[2,3] *& F. Yusef-Zadeh*[4]

(1) Universität zu Köln, Köln, (2) Max Planck Institut für Radioastronomie, Bonn, (3) Ohio State University, Department of Astronomy, (4) Dearborne Observatory, Northwestern University, (5) University of Maryland, Department of Astronomy,We present a multi-wavelength study of the Galactic center filament system G359.54+0.18 and potentially associated, with nearby molecular clouds. The data include, (1) 3 mm multi-line observations of CS, HCO^+, and other molecular species, (2) observations of low-J transitions of ^{12}CO and ^{13}CO, (3) 5 GHz radio interferometric continuum emission observations and (4) H79α recombination line observations. The high-sensitivity VLA images reveal continuum emission with a clumpy morphology towards the eastern tip of the nonthermal filaments. The transition from filamentary to clumpy structure appears to be continuous, implying association between the two. A dense molecular cloud is situated adjacent to the eastern border of the clumped continuum emission region. The cloud is part of the negative velocity feature, an elongated complex of Galactic center molecular clouds distinguished by its coherent kinematic structure across about a degree in longitude. A 3σ detection of H79α recombination line emission indicates that the extended continuum component is thermal in nature and links it kinematically to the molecular gas. A steep velocity gradient in the molecular cloud towards the interface to the HII region and the excitation conditions of the gas derived from our multiline survey also imply interaction between the molecular cloud and the HII region. Higher angular resolution data confirm the association between the filaments and a second molecular cloud at a position where the nonthermal filaments are bent, as was previously suggested by Bally & Yusef-Zadeh (1989). The morphological and kinematic evidence for the interaction of the G359.54+0.18 nonthermal filaments with an HII region and molecular clouds makes G359.54+0.18 the fourth association of this kind observed in the Galactic center region.

to appear in A&A
email: staguhn@astro.umd.edu
http://www.astro.umd.edu/ staguhn

X-ray Imaging Spectroscopy of the Galactic Center Region

Yoshitomo Maeda

Deptpartment of Physics, Kyoto University

We present the *ASCA* results of the first high quality X-ray images and spectra of the Galactic Center in the wide X-ray band of 0.7 - 10 keV. We found a new X-ray source AX J1745.6−2901 about $1'.3$ south-west from the nuclear supermassive black hole candidate Sgr A*. We discovered a type-I X-ray burst and eclipses from AX J1745.6−2901, hence established AX J1745.6−2901 to be an eclipsing low-mass X-ray binary. Excess soft X-rays during the eclipse were detected, which is well explained by the scattering process of interstellar dust-grains. From the entire $\sim$1 square degree field near the Galactic Center, we found a diffuse emission with K-shell transition lines from highly ionized elements (silicon, sulfur, argon, calcium: here "the lighter elements"), in addition to that of highly ionized iron, which has been previously reported . The Kα flux from highly ionized iron is symmetrically extended along the Galactic plane, while those of the lighter elements are more irregularly distributed, both with the peaks at a few arcmin-radius region near Sgr A*. Kα lines from neutral or low ionized iron are also found from molecular clouds. The morphology, spectrum and iron line flux are fully consistent with reflected X-rays from the cold molecular clouds, but we found no apparent bright source to irradiate the clouds. The presence of the Kα line from highly ionized iron gives firm evidence for a diffuse high-temperature plasma of $kT \cong 10$ keV, while those of the lighter elements indicate the presence of much less temperature plasma of $\sim$1 keV. The X-rays in the brightest region near Sgr A* would come from a hot gas filling the interstellar space with the thermal energy of about 2×10^{50} erg. In the entire $\sim$1 square degree field, the lower temperature plasma is interpreted to be attributable to a superposition of 10^{1-2} supernova remnants, while the origin of the higher temperature plasma is more debatable. The higher temperature plasma with the total kinetic energy as large as 10^{54} ergs, may come from a diffuse hot gas. We suggest that the Galactic center exhibited intermittent activities with a time-averaged energy generation rate ($\sim 10^{41-42}$ erg s^{-1}) comparable to the Seyfert nuclei, a class of active galactic nuclei. The intermittent activity is also one possibility to explain the reflected X-rays with no apparent irradiating sources; the clouds has been irradiated by X-rays from the Galactic center which was bright in the past but is dim at present. A superposition of faint discrete sources such as 10^5 of cataclysmic variables (CV), would be another possibility. This requires an extremely high density of CVs near the center, and also predicts a high rate of type-Ia supernova explosion. We also carried out the Chris-cross mapping up to 10 degree around the Galactic Center with *ASCA* and detected the Galactic bulge and ridge emissions around the Galactic Center but with much reduced flux level. The observed Galactic ridge spectra often show the Kα-lines from highly-ionized silicon, sulfur, argon, calcium, and iron. The bulge emission shows a high emissivity for the silicon Kα-line, which may be another remain of the past activities in the Galactic Center.

PhD thesis

email: maeda@astro.psu.edu

Equivalent width, shape and proper motion of the iron fluorescent line emission from the molecular clouds as an indicator of the illuminating source X-ray flux history

R. Sunyaev[1,2] *& E. Churazov,*[1,2]

(1) Max-Planck-Institut für Astrophysik, Garching, (2) Space Research Institute (IKI), Moscow

Observations of the diffuse emission in the 8–22 keV energy range, elongated parallel to the Galactic plane and detection of the strong 6.4 keV fluorescent line with $\sim$ 1 keV equivalent width from some giant molecular clouds (e.g. Sgr B2) in the Galactic Centre region suggest that the neutral matter of these clouds is (or was) illuminated by powerful X-ray radiation, which gave rise to the reprocessed radiation. The source of this radiation remains unknown. Transient source close to the Sgr B2 cloud or short outburst of the X-ray emission from supermassive black hole at the Galactic Centre are the two prime candidates under consideration. We argue that new generation of X-ray telescopes combining very high sensitivity and excellent energy and angular resolutions would be able to discriminate between these two possibilities studying time dependent changes of the morphology of the surface brightness distribution, the equivalent width and the shape of the fluorescent line in the Sgr B2 and other molecular clouds in the region. We note also that detection of broad and complex structures near the 6.4 keV line in the spectra of distant AGNs, which are X–ray weak now, may prove the presence of violent activity of the central engines of these objects in the past. Accurate measurements of the line shape may provide an information on the time elapsed since the outburst. Proper motion (super or subluminal) of the fluorescent radiation wave front can give additional information on the location of the source. Observations of the described effects can provide unique information on the matter

to appear in MNRAS

email: churazov@MPA-Garching.MPG.DE

xxx.lanl.gov/abs/astro-ph/9805038

Gamma-ray limits on Galactic ^{60}Fe nucleosynthesis and implications on the Origin of the ^{26}Al emission

Juan E. Naya[1,3], *Scott D. Barthelmy*[1,3]
Lyle M. Bartlett[1,4], *Neil Gehrels*[1], *Ann Parsons*[1]
Bonnard J. Teegarden[1], *Jack Tueller*[1]
& Marvin Leventhal[2]

(1) NASA/Goddard Space Flight Center, (2) Dept. of Astronomy, University of Maryland, (3) Universities Space Research Association, Seabrook, Maryland, (4) NAS/NRC Resident Research Associate,

The Gamma Ray Imaging Spectrometer (GRIS) recently observed the gamma-ray emission from the Galactic center region. We have detected the 1809 keV Galactic ^{26}Al emission at a significance level of 6.8σ but have found no evidence for emission at 1173 keV and 1332 keV, expected from the decay chain of the nucleosynthetic ^{60}Fe. The isotopic abundances and fluxes are derived for different source distribution models. The resulting abundances are between 2.6 ± 0.4 and 4.5 ± 0.7 $M_\odot$ for ^{26}Al and a 2σ upper limit for ^{60}Fe between 1.7 and 3.1 $M_\odot$. The measured ^{26}Al emission flux is significantly higher than that derived from the CGRO/COMPTEL 1.8 MeV sky map. This suggests that a fraction of the ^{26}Al emission may come from extended sources with a low surface brightness that are invisible to COMPTEL. We obtain a ^{60}Fe to ^{26}Al flux ratio 2σ upper limit of 0.14, which is slightly lower than the 0.16 predicted from current nucleosynthesis models assuming that SNII are the major contributors to the galactic ^{26}Al. Since the uncertainties in the predicted fluxes are large (up to a factor of 2), our measurement is still compatible with the theoretical expectations.

ApJ Letters, in press
email: naya@tgrs2.gsfc.nasa.gov

The Pistol Star

Donald F. Figer[1], *Francisco Najarro*[2,5],
Mark Morris[1], *Ian S. McLean*[1],
Thomas R. Geballe[3], *Andrea M. Ghez*[1],
& Norbert Langer[4]

(1) University of California, Los Angeles, (2) Institut für Astronomie und Astrophysik der Universität München, (3) Joint Astronomy Centre, University Park, Hilo, Hawaii, (4) Institut für Theoretische Physik und Astrophysik, Potsdam, (5) CSIC, Instituto de Estructura de la Materia, Dpto. Fisica Molecular, Madrid

We present new near-infrared data and an analysis which indicates that the "Pistol Star" is one of the most luminous stars known, adding another test point for massive star formation and stellar evolution theories. We estimate an extinction of $A_K = 3.2 \pm 0.5$ using the near-infrared colors of the star and surrounding stars in the young Quintuplet cluster. Using our wind/atmosphere code, we find two families of models which fit the spectral energy distribution and detailed line profiles. The lower luminosity models give L = $10^{6.6\pm0.2}$ $L_\odot$ and T_{eff} = $10^{4.15\pm0.01}$ K, while the higher luminosity models give L = $10^{7.2\pm0.2}$ $L_\odot$ and T_{eff} = $10^{4.33\pm0.01}$ K; the error in luminosity assumes an uncertainty of ±0.5 in A_K, while the error in $T_\odot$ is constrained by detailed line modeling. The models also reveal a helium enriched surface. As previously existing stellar evolution models do not extend to such high luminosities, we employ new evolutionary tracks for very massive stars to determine the initial mass and age of the Pistol Star, and estimate $M_{initial}$ = 200–250 $M_\odot$ and an age of 1.7–2.1 Myrs. The inferred luminosity and temperature place the star in a sparsely populated zone in the HR diagram where "Luminous Blue Variables" (LBVs) are often found. This is consistent with our evolutionary models which predict that the star is in an unstable evolutionary stage. We interpret the star and its surrounding nebula as an LBV which has recently ejected large amounts of material. Our K-band speckle imaging data reveal the star to be single down to a projected separation of 110 AU.

ApJ, in press
email: figer@gc.astro.ucla.edu
http://www.astro.ucla.edu/ figer

Angular momentum transport in the central region of the Galaxy

Leonid M. Ozernoy[1,2], *Alexei M. Fridman*[3,4],
& Peter L. Biermann[5]

(1) Computational Sciences Institute and Department of Physics & Astronomy, George Mason U., Fairfax, VA, (2) Laboratory for Astronomy and Solar Physics, Goddard Space

Flight Center, (3) Institute of Astronomy, Russian Academy of Sciences, Moscow, (4) Moscow State University, (5) Max Planck Institut für Radioastronomie, Bonn

We discuss mechanisms for angular momentum transport in the clumpy medium of the circumnuclear disk at the Galactic center. The viscosity due to clump-clump collisions is found to be less than some critical viscosity; this meets the conditions at which a collective mode of nonaxisymmetric shear perturbations in the disk is able to grow until going into the saturation regime where fully developed turbulence is established. We find that the angular momentum transfer due to this turbulent viscosity turns out to comparable to the transport due to magnetic torques. Taken together, the turbulent and magnetic transfer of angular momentum are able to provide the inflow of mass into the central parsec with a rate of about $10^{-2} M_\odot/\mathrm{yr}$, consistent with the available data.

to appear in A&A
email: OZERNOY@achamp.gsfc.nasa.gov
xxx.lanl.gov/abs/astro-ph/9805098

High-Energy Gamma-Ray Emission from the Galactic Cente

H.A. Mayer-Hasselwander[1], D.L. Bertsch[2], B.L. Dingus[3], A. Eckart[1], J.A. Esposito[2,10], R. Genzel[1], R.C. Hartman[2], S.D. Hunter[2], G. Kanbach[1], D.A. Kniffen[4], Y.C. Lin[5], P.F. Michelson[5], A. Mücke[1], C. von Montigny[6], R. Mukherjee[7], P.L. Nolan[5], M. Pohl[8], O. Reimer[1], E.J. Schneid[9], P. Sreekumar[2,10], & D.J. Thompson[2]

(1) Max-Planck-Institut für extraterrestrische Physik, Garching, (2) NASA Goddard Space Flight Center, (3) University of Utah, Salt Lake City, Utah, (4) Dept. of Physics and Astronomy, Hampden-Sydney College, Hampden-Sydney, VA ,(5) W.W. Hansen Experimental Physics Laboratory and Department of Physics, Stanford University, (6) Landessternwarte Künigstuhl, Heidelberg, (7) Barnard College & Columbia University, Columbia Astroph. Lab, New York, (8) Danish Space Research Institute, Copenhagen, (9) Northrop Grumman Corporation, Bethpage, NY, (1) USRA Research Associate

The EGRET instrument on the Compton Gamma-Ray Observatory has observed the Galactic Center (GC) region with good coverage at a number of epochs. A st rong excess of emission is observed, peaking at energies ¿500 MeV in an error ci rcle of 0.2 degree radius including the position l3D0 and b3D0 . The close co incidence of this excess with the GC direction and the fact that it is the strongest emission maximum within 15 degrees from the GC is taken as compelling evide nce for the sources location in the GC region. The history of the emission intensity, observed over 5 years, leaves room for possible time variation; however, it does not provide evidence. The angular extent of the excess ap pears only marginally compatible with the signature expected for a single compact object. The emission therefore may stem from one or more compact objects o r may originate from diffuse interactions within 85 pc from the center of the Gal axy at 8.5 kpc distance. The spatial distribution of the emission does not correlate with the details of the CO-line surveys. Thus, in spite of the existence of a strong emission peak, earlier conclusions based on an appare nt gamma-ray deficit, postulating the masses of the wide- line clouds in the G C area to be an order of magnitude lower than indicated by naive CO interpretation, are supported. However, the total gas mass in the Nuclear Bulge (NB) derived from the gamma-ray emission is found to be in agreement with t he mass which in recent studies has been derived from molecular-line and FIR surveys. The g-ray emission spectrum is peculiar and different from the spectrum of the large-scale galactic diffuse emission. A diffuse emission scenario requires an enhanced and peculiar Cosmic Ray (CR) spectrum as sugg ested for the electrons in the Radio Arc. A compact sources model hints at an or igin in pulsars. While the spectrum suggests middle-aged pulsars like Vela, too many are required to produce the observed flux. The only detected very young pu lsar, the Crab pulsar, has an incompatible spectrum. However, it is not proven t hat the Crab spectrum is characteristic for all young pulsars: thus, a single or a few very young pulsars (at the GC not detectable in radio emission), provid ed their gamma-ray emission is larger than that of the Crab pulsar by a factor of 13, are likely candidates. Alternatively, more exotic scenarios, related t o the postulated central black hole or dark matter (neutralino) annihilation, may be invoked.

A&A, in press
email: hrm@mpe.mpg.de

An extraordinary cluster of massive young stars in the Milky Way's nucleus

E. Serabyn[1], *D. Shupe*[2], *& D. F. Figer*[3]

(1) California Institute of Technology, (2) Jet Propulsion Laboratory, California Institute of Technology, (3) Dept. of Physics and Astronomy, UCLA,

The mass distribution of newborn stars (the stellar initial mass function, or IMF) is key to the evolution of galaxies, as it determines whether a galaxy's interstellar medium is funneled predominantly into dim, long-lived, low-mass stars, as is the case in normal galactic disks, or into bright, short-lived, massive stars, as is perhaps the case in "starburst" nuclei. Our own Galactic nucleus is not a full-fledged starburst, but its star-formation rate per volume is nevertheless well above that of the Galactic disk (by a factor of $\sim 10^3$). Even so, the Milky Way's nuclear IMF remains uncertain, because high obscuration and the large background population of bright, elderly giant stars have impeded the detection of normal hydrogen-burning (or "main-sequence") stars. Our high-resolution infrared observations of a compact stellar cluster in the nucleus now reveal the presence of numerous young, massive main sequence stars, several of which may number among the Galaxy's most massive. Dwarfing all other known young Galactic clusters, the "Arches" cluster may in fact be a weaker analog of the "super star-clusters" found in starburst nuclei.

to appear in Nature
email: figer@gc.astro.ucla.edu
http://www.astro.ucla.edu/ figer/papers.html

A supermassive Black Hole or a Compact Object Without Events Horizon

L.V. Verozub & E.Yu. Bannikova

Kharkov State University

Previously it was shown that gravitation theory allows the existance of supermassive stable compact configurations of the degenerated electronic gas (L.V.Verozub, Astr. Nacr. 317 (1996) 107) without events horizon. In the present paper the simplest model of such kind of objects in gas environment has been considered. It is shown that at the spherically symmetric accretion onto the object the luminosity is about $10^{37} erg/s$ for the mass accretion rate of the order of $\dot{M} = 3D10^{-6} M_{\odot}/year$. The wavelength of the radiation maximum is about $400 \div 500 \dot{A}$. There is an ionization zone around the central objects with the radius about $10^{-3} pc$.

LANL E-print
email: verozub@gravit.kharkov.ua
xxx.lanl.gov/abs/astro-ph/9805299

Explaining the spectrum from the Galactic Centre using a two temperature plasma

Rohan Mahadevan

(1) Institute of Astronomy, University of Cambridge

The radio source Sagittarius A* (Sgr A*), is thought to be a supermassive black hole located at the centre of our Galaxy, [1,2] that is accreting gas from the surrounding region. Using the high inferred accretion rates,[3] however, standard accretion models[4] are unable to explain the low luminosity and observed spectrum from Sgr A*.[5–8] A new accretion model has been proposed – an advection dominated accretion flow (ADAF),[9–12] where most of the accretion energy is stored in the gas and lost into the black hole. The gas therefore has a two–temperature structure[10,13,14] with the protons being much hotter than the electrons. The model explains the low luminosity from Sgr A* [15–18] and most of the millimeter to hard X–ray spectrum, but has had serious difficulty in agreeing with the low energy radio observations.[18] Here we report an emission process associated with the protons that naturally resolves the observed discrepancy. This provides, for the first time, observational evidence for a two–temperature plasma in hot accretion flows, and gives strong support to the idea that an ADAF does accrete onto a 2.5×10^6 solar mass black hole at the Galactic Centre.

to appear in Nature
email: rohan@cfata1.harvard.edu
xxx.lanl.gov/abs/astro-ph/9806018

Massive Stars in the Quintuplet Cluster

Donald F. Figer, Ian S. McLean, & Mark Morris

University of California, Los Angeles, Division of Astronomy, Department of Physics & Astronomy

We present near-infrared photometry and K-band spectra of newly-identified stars in the Quintuplet Cluster, one of the three known massive clusters projected within 50 pc of the Galactic Center. We find that the cluster contains a variety of massive stars, including more unambiguously identified Wolf-Rayet stars than any other cluster in the Galaxy, and over a dozen other stars in earlier stages of evolution, i.e., LBV, Ofpe/WN9, and OBI. One newly identified star may be the second "Luminous Blue Variable" identified in the cluster, after the "Pistol Star." While we are unable to provide certain spectral classifications for the five enigmatic Quintuplet-proper stars, we tentatively propose that they are extremely dusty versions of the WC stars found elsewhere in the cluster, and similar to the dozen or so known examples in the Galaxy. Given the evolutionary stages of the identified stars, the cluster appears to be about 3.5 Myr old. The total mass is estimated to be $\sim 10^4$ $M_\odot$, and the mass density in stars is $\gtrsim$ a few thousand $M_\odot$ pc^{-3}. The newly-identified stars increase the estimated ionizing flux from this cluster by about an order of magnitude with respect to earlier estimates, to $10^{50.9}$ photons s^{-1}, or roughly what is required to ionize the nearby "Sickle" HII region (G0.18−0.04). The total luminosity from the massive cluster stars is $\approx 10^{7.5}$ $L_\odot$, enough to account for the heating of the nearby molecular cloud, M0.20−0.033. We propose a picture which integrates most of the major features in this part of the sky, excepting the non-thermal filaments. We compare the cluster to other young massive clusters and globular clusters, finding that it is unique in stellar content and age, except, perhaps, for the young cluster in the central parsec of the Galaxy. In addition, we find that the cluster is comparable to small "super star clusters."

submitted to ApJ
email: figer@gc.astro.ucla.edu
http://www.astro.ucla.edu/ figer/papers.html

Stellar Gas Flows Into A Dark Cluster Potential At The Galactic Center

Fulvio Melia[1,3] & Robert Coker[2,4]

(1) Physics Department and Steward Observatory, The University of Arizona, (2) Physics Department, The University of Arizona, (3) Presidential Young Investigator, (4) NASA, GSRP Fellow.

The evidence for the presence of a concentration of dark matter at the Galactic center is now very compelling. There is no question that the stellar and gas kinematics within ≈ 0.01 pc is dominated by under-luminous matter in the form of either a massive black hole, a highly condensed distribution of stellar remnants, or a more exotic source of gravity. The unique, compact radio source Sgr A* appears to be coincident with the center of this region, but its size (less than about 3×10^{14} cm at $\lambda 1.35$ cm) is still significantly smaller than the current limiting volume enclosing this mass. Sgr A* may be the black hole, if the dark matter distribution is point-like. If not, we are left with a puzzle regarding its nature, and a question of why this source should be so unique and lie only at the Galactic center. In this paper, we examine an alternative to the black hole paradigm—that the gravitating matter is a condensed cluster of stellar remnants—and study the properties of the Galactic center wind flowing through this region. Some of this gas is trapped in the cluster potential, and we study in detail whether this hot, magnetized gas is in the proper physical state to produce Sgr A*'s spectrum. We find that at least for the Galactic center environment, the temperature of the trapped gas never attains the value required for significant GHz emission. In addition, continuum (mostly bremsstrahlung) emission at higher frequencies is below the current measurements and upper limits for this source. We conclude that the cluster potential is too shallow for the trapped Galactic center wind to account for Sgr A*'s spectrum, which instead appears to be produced only within an environment that has a steep-gradient potential like that generated by a black hole.

ApJ, submitted
email: rfc@physics.Arizona.EDU
xxx.lanl.gov/abs/astro-ph/9806195

Microlensing Event Rates and Optical Depth toward the Galactic Center

S.J. Peale

(1) Dept. of Physics, University of California, Santa Barbara

The dependence of microlensing time scale frequency distributions and optical depth toward the galactic center on galactic model parameters is explored in detail for a distribution of stars consisting of the Zhao (1996) bar and nucleus and the Bahcall and Soneira (1980) double exponential disk. The high sensitivity of these two microlensing measures to the circular velocity model, velocity dispersions, bulge mass, direction of the line of sight, bar axis orientation, star spatial distribution and the stellar mass function means no single galaxy property can be constrained very well without constraining most of the others. However, this same sensitivity will make microlensing a powerful member of the suite of observational techniques that will eventually define the galaxy properties. The model time scale frequency distributions are compared with that determined empirically by the MACHO group throughout. Although the MACHO empirical data are matched quite well with a nominal velocity model and with a mass function only of hydrogen burning stars that varies as $m^{-2.2}$ to $m^{-2.5}$ in the M star region, uncertainties in galactic structure, kinematics and content together with the paucity of published microlensing data preclude any claim of the model representing the real world. A variation of the mass function $\sim m^{-1}$ in the M star region obtained from recent star counts, both local and in the galactic bulge, fails to yield a sufficient number of short time scale events compared to the MACHO data. The high sensitivity of the microlensing measures to the direction of the line of sight may mean that sufficient microlensing data is already in hand to constrain the bar distribution of stars. The procedure developed here for determining the time scale frequency distribution is particularly convenient for rapidly incorporating model changes as data from all sources continues to accumulate.

to appear in ApJ
email: peale@io.physics.ucsb.edu
xxx.lanl.gov/abs/astro-ph/9806368

BeppoSAX observations of a new X–ray burster in the Galactic Center region, possibly coincident with a recurrent transient.

L. Sidoli[1,2], *S. Mereghetti*[1], *G.L. Israel*[3,4], *G. Cusumano*[5], *L. Chiappetti*[1] *& A. Treves*[6]

(1) Istituto di Fisica Cosmica del C.N.R., Milano, (2) Dipartimento di Fisica, Università di Milano, (3) Osservatorio Astronomico di Roma, (4) Affiliated to I.C.R.A., (5) Istituto di Fisica Cosmica ed Applicazioni all'Informatica del C.N.R. (6) Università di Milano

We report BeppoSAX NFI observations of the X–ray source SAX J1747.0–2853 recently discovered in the region of the Galactic Center. The presence of type I X–ray bursts indicates that this source, positionally coincident with the transient GX 0.2–0.2 observed in 1976, is a neutron star accreting from a low mass companion.

to appear in A&A Letters, Aug 199
email: sidoli@ifctr.mi.cnr.it
xxx.lanl.gov/abs/astro-ph/9807054

A Model of the EGRET Source at the Galactic Center: Inverse Compton Scattering Within Sgr A East and its Halo

Fulvio Melia[1,3,4], *Farhad Yusef-Zadeh*[2] *&Marco Fatuzzo*[1]

(1) Physics Department, The University of Arizona, (2) Department of Physics and Astronomy, Northwestern University, (3) Steward Observatory, The University of Arizona, (4) Presidential Young Investigator.

Continuum low-frequency radio observations of the Galactic Center reveal the presence of two prominent radio sources, Sgr A East and its surrounding Halo, containing non-thermal particle distributions with power-law indices $\sim 2.5-3.3$ and ~ 2.4, respectively. The central $1-2$ pc region is also a source of intense (stellar) UV and (dust-reprocessed) far-IR radiation that bathes these extended synchrotron-emitting structures. A recent detection of γ-rays (2EGJ1746-2852) from within $\sim 1^o$ of the Galactic Center by EGRET onboard the Compton GRO shows that the emission from this environment extends to very high energies. We

suggest that inverse Compton scatterings between the power-law electrons inferred from the radio properties of Sgr A East and its Halo, and the UV and IR photons from the nucleus, may account for the possibly diffuse γ-ray source as well. We show that both particle distributions may be contributing to the γ-ray emission, though their relevant strength depends on the actual physical properties (such as the magnetic field intensity) in each source. If this picture is correct, the high-energy source at the Galactic Center is extended over several arcminutes, which can be tested with the next generation of γ-ray and hard X-ray missions

ApJ, in press
email: melia@spacetime.physics.Arizona.EDU
xxx.lanl.gov/abs/astro-ph/9806324

High Proper Motion Stars in the Vicinity of Sgr A*: Evidence for a Supermassive Black Hole at the Center of Our Galaxy

A. M. Ghez[1,2,3], *B. L. Klein*[1], *M. Morris*[1] *& E. E. Becklin*[1]

(1) Dept. of Physics and Astronomy, UCLA, (2) Sloan Fellow (3) Packard Fellow

Over a two year period, we have conducted a diffraction-limited imaging study at 2.2 μm of the inner $6'' \times 6''$ of the Galaxy's central stellar cluster using the W. M. Keck 10-m telescope. The K band images obtained in 1995 June, 1996 June, and 1997 May have the highest angular resolution obtained at near-infrared wavelengths from ground or space ($\theta_{res} = 0.05'' = 0.002$ pc) and reveal a large population of faint stars. We use an unbiased approach for identifying and selecting stars to be included in this proper motion study, which results in a sample of 90 stars with brightness ranging from K = 9 to 17 mag and two-dimensional velocities as large as 1,400 ± 100 km/sec. Compared to earlier work (Eckart et al. 1997; Genzel et al. 1997), the source confusion is reduced by a factor of 9, the number of stars with proper motion measurement in the central 25 $arcsec^2$ of our galaxy is doubled, and the accuracy of the velocity measurements in the central 1 $arcsec^2$ is improved by a factor of 4. The peaks of both the stellar surface density and the velocity dispersion are consistent with the position of the unusual radio source and black hole candidate, Sgr A*, suggesting that Sgr A* is coincident ($\pm$ 0.1$''$) with the dynamical center of the Galaxy. As a function of distance from Sgr A*, the velocity dispersion displays a falloff well fit by Keplerian motion ($\sigma_v \sim r^{-0.5 \pm 0.1}$) about a central dark mass of $2.6(\pm 0.2) \times 10^6 M_\odot$ confined to a volume of at most $10^{-6} pc^3$, consistent with earlier results. Although uncertainties in the measurements mathematically allow for the matter to be distributed over this volume as a cluster, no realistic cluster is physically tenable. Thus, independent of the presence of Sgr A*, the large inferred central density of at least $10^{12} M_\odot/pc^3$, which exceeds the volume-averaged mass densities found at the center of any other galaxy, leads us to the conclusion that our Galaxy harbors a massive central black hole. x

ApJ, accepted
email: ghez@athena.astro.ucla.edu
xxx.lanl.gov/abs/astro-ph/9807210

The Nature of the Mid-Infrared Background Radiation in the Galactic Bulge from the IRTS Observations

Kin-Wing Chan[1], *T. L. Roellig*[1], *T. Onaka*[2], *I. Yamamura*[2,4] *& T. Tanabé*[3]

(1) NASA/Ames Research Center, (2) Department of Astronomy, University of Tokyo, (3) Institute of Astronomy, University of Tokyo, (4) Astronomical Institute "Anton Pannekoek", University of Amsterdam

Using the Mid-Infrared Spectrometer (MIRS) on board the Infrared Telescope in Space (IRTS) we obtained the 4.5 to 11.7 μm spectra of the stellar populations and diffuse interstellar medium in the Galactic bulge ($l \approx 8.7°$, $b \approx 2.9$, 4.0, 4.7, and 5.7°). Below galactic latitudes of 4.0°, the mid-infrared background spectra in the bulge are similar to the spectra of M and K giants. The UIR emission bands (6.2, 7.7, 8.6, and 11.3 μm) are also detected in these regions and likely arise from the diffuse interstellar medium in the disk. Above galactic latitudes of 4.0°, the mid-infrared background spectra are similar to the spectra of those oxygen-rich evolved stars with high mass-loss rates detected by IRAS. One likely interpretation is that this background emission arises predominantly from those stars with very low luminosities that

have not been detected by IRAS. The age for such low-luminosity evolved stars could be 15 Gyr, and the existence of a large number of evolved stars with high mass-loss rates in the bulge has a significant impact on our understanding of the stellar content in the Galactic bulge.

to appear in ApJ Letters
email: kwc@ssa1.arc.nasa.gov
xxx.lanl.gov/abs/astro-ph/9807294

Detection of H_3^+ in the Diffuse Interstellar Medium: The Galactic Center and Cygnus OB2 No. 12

T. R. Geballe[1], *B. J. McCall*[2]
K. H. Hinkle[3] *& T. Oka*[2]

(1) Joint Astronomy Centre, Hilo, Hawaii (2) Department of Astronomy and Astrophysics, Department of Chemistry, and the Enrico Fermi Institute, University of Chicago, (3) National Optical Astronomy Observatories, Tucson, (Operated by the Association of Universities for Research in Astronomy, Inc. under cooperative agreement with the National Science Foundation)

Absorption lines of H_3^+ have been detected in the spectra of two infrared sources in the galactic center and also towards the heavily reddened star Cygnus OB2 No. 12, whose line of sight is believed to include only diffuse interstellar gas. The absorptions toward the galactic center sources (IRS3 and GCS3-2) probably are due to H_3^+ both in diffuse gas and in molecular clouds. The ratios of H_3^+ line equivalent width to extinction toward these three sources are much greater than those toward dense clouds where H_3^+ has been detected previously. Analysis of the spectra coupled with a simple model for the abundance of H_3^+ in the diffuse interstellar medium implies that the observed H_3^+ is present at low densities along long pathlengths. These are the first detections of H_3^+ in the diffuse interstellar medium.

accepted by ApJ
email: t.geballe@jach.hawaii.edu

The Central Parsecs - Galactic Center Workshop '98

Tucson, Arizona, Sep. 7-11

Monday, September 7th

Session I: What is the Central Mass Concentration? What are the size and spectrum of Sgr A*?

Session moderator: Eric Becklin

08:55-09:00	Introduction and Workshop Welcome	(Angela Cotera)*
09:00-09:30	The Dark Mass in the Center of the Milky Way	(Reinhard Genzel)*
09:30-09:50	New Proper Motion Data	(Andreas Eckart)*
09:50-10:10	High Proper Motion Stars in the Vicinity of Sgr A*	(Andrea Ghez)*
10:10-10:30	NICMOS observations of the central Parsec	(Marcia Rieke)*
10:30-11:00	Coffee Break	
11:00-11:20	Constraints on the mass of SgrA* from its proper motion	(Mark Reid)*
11:20-11:40	Deep Imaging at 1.6 microns, Short-Term Variability, and Ionized Emission	(Susan Stolovy)*
11:40-12:40	Discussion	
12:40	Lunch (On Site)	

Session II: Can the VLBI constrain the size and structure of Sgr A*?

Session moderator: Anton Zensus

14:30-14:50	Corruption of the Visibility of Sgr A* by Intervening Plasma	(Don Backer)*
14:50-15:10	7mm evidence for intrinsic source size and structure of Sgr A*	(K.Y. Lo)*
15:10-15:30	7 mm VLBI Imaging of Sgr A*	(Geoff Bower)*
15:30-15:50	Millimeter Observations of Sgr A*	(Thomas Krichbaum)*
15:50-16:20	Coffee Break	
16:20-16:40	86GHz VLBI observations of Sgr A*	(Shep Doeleman)*
16:40-17:00	Flare of Sgr A* at 100 Ghz	(Masato Tsuboi)*
17:00-18:00	Discussion	

Tuesday, September 8th

Session III: How do we reconcile Models and Observations of Sgr A*?

Session moderator: Reinhard Genzel

09:00-09:30	Introduction	(Fulvio Melia)*
09:30-09:50	Explaining the spectrum of Sgr A* using a two temperature plasma	(R. Mahadevan/R. Narayan)*
09:50-10:10	The Influence of an Advection-dominated Accretion Flow on the Appearance of Sgr A*	(T. Beckert)*
10:10-10:40	Coffee Break	
10:40-11:00	The jet model for Sgr A* and the nature of the submm-bump	(Heino Falcke)*

11:00-11:20 Sgr A* - The radio spectrum . . . . (Wolfgang Duschl)*
11:20-12:20 Discussion
12:20 Lunch

Session IV: Morphology and Gas Dynamics within Sgr A West: How are the various components of Sgr A West related?

Session moderator: Peter Mezger

14:20-14:50 The Various Components of Sgr A West and their Interrelationship . . . . (Farhad Yusef-Zadeh)*
14:50-15:10 3D Simulations of the Gas Dynamics in the Central Region . . . . (Robert Coker)*
15:10-15:30 Proper Motions and Structure of the Radio Components around Sgr A* . . . . . (Jun-Hui Zhao)*
15:30-15:50 The Relationship Between the Radio and Infrared Sources in the Central Parsec . . . (Dan Gezari)*
15:50-16:20 Coffee Break
16:20-16:40 Mid-infrared observations of Sgr A West from Keck . . . . (Angela Cotera)*
16:40-17:00 Theoretical studies of the Circumnuclear Disk . . . . (Robert Sanders)*
17:00-18:00 Discussion

Wednesday, September 9th

Session V: How, when, where and why are stars formed in the GC?

Session moderator: Kris Sellgren

13:00-13:30 Stellar Interactions in Dense Clusters . . . . (Fred Rasio)*
13:30-13:50 Stellar Content of the Galactic Center . . . . (Bob Blum)*
13:50-14:10 Stellar Content of the central 30pc . . . . (Peter G. Mezger)*
14:10-14:30 Properties of stars in the galactic center . . . . (Thomas Ott)*
14:30-15:00 Coffee Break
15:00-15:20 The Arches Cluster . . . . (Gene Serabyn)*
15:20-15:40 NICMOS observations of the Quintuplet Cluster . . . . (Don Figer)*
15:40-16:00 Theoretical modelling of stars . . . . (Paco Najarro)*
16:00-17:00 Discussion

Thursday, September 10th

Session VI: What is the metallicity as determined by old and new stars?

Session moderator: Wolfgang Duschl

09:00-09:20 Stellar abundances at the GC . . . . (Solange Ramirez)*
09:20-09:40 OH/IR stars as signposts for ancient starburst activity in the Galactic center (Lorant Sjouwerman)*
09:40-10:00 Discussion
10:00-10:30 Coffee Break

Session VI: How do the various components of the inner 100 parsecs interact?

Session moderator: Miller Goss

10:30-10:50 Wide-field Imaging of the Galactic Center . . . . (Namir Kassim)*
10:50-11:10 Sgr East and it's interactions with the surrounding gas . . . . (Robert Zylka)*
11:10-11:30 Recombination lines from the SgrA complex near 20 cm . . . . (K.R. Anantharamaiah)*
11:30-12:00 Discussion
12:00 Lunch
14:00-14:20 OH 1720 MHz Masers at the GC . . . . (Mark Wardle)*

14:20-14:40	Free Electrons and Radio-Wave Scattering in the GC	(T. Joseph Lazio)*
14:40-15:30	Discussion	
15:30-16:00	Coffee Break	

Session VII: What is the strength of the magnetic field in the GC and what are its large and small scale effects?

Session moderator: Yoshiaki Sofue

16:00-16:20	Magnetic Fields in the Sagittarius A region	(Doug Roberts)*
16:20-16:40	Far-infrared/Submillimeter Polarimetric Observations of the Galactic Center	(Giles Novak)*
16:40-17:00	The Galactic Center Radio Threads: A Multifrequency, Polarimetric Study	(Cornelia Lang)*
17:00-18:00	Discussion	

Friday, September 11th

Session VIII: How standard are the central regions of our Galaxy? What would the GC look like from 1 Mpc?

Session moderator: Heino Falcke

08:00-08:20	The GC in comparison to AGN	(Ski Antonucci)*
08:20-08:40	Is the GC a broad line/Seyfert/LINER Galaxy?	(George Rieke)*
08:40-09:00	The MIR Spectrum in the GC: a Starburst Nucleus	(Janet Simpson)*
09:00-09:30	Discussion	
09:30-10:00	Coffee Break	

Session IX: What can we learn from High-energy emission in the GC?

Session Moderator: Fulvio Melia*

10:00-10:20	AXAF X-ray Observations of the Galactic Center	(Gordon Garmire)*
10:20-10:40	Cosmic rays in the GC	(Peter Biermann)*
10:40-11:00	Gamma -rays from the GC: A Point-like or Diffuse Source?	(Sera Markoff)*
11:00-11:20	The Galactic Center EGRET Source and the Broad-band Spectrum of Sgr A East	(Marco Fatuzzo)*
11:20-11:40	Cold Matter measurements in the GC with the X-ray satellite ASCA	(Masaaki Sakano)*
11:40-12:00	Coffee Break	
12:00-12:30	Discussion	
12:30-13:00	Closing Thoughts and Workshop Summary	(Charles Townes)*

POSTER SESSION

(only the first Author is listed here)

Accretion Disk Instabilities in the Vicinity of Black Holes	(W. Auer)*
Acceleration processes towards a quasi-monoenergetic electron distribution	(Zeno Jauch)*
ASCA Observations of the Sgr A region	(Y. Maeda)*
Life Time of the Radio Arc Filaments determined by mm-Wave Observations with the 100-m Telescope	(Y. Sofue)*
Spatially Resolved Dust Shells in the Central Parcec	(Angelle Tanner)*
Physical Properties of OH/IR Stars Close to the Galactic Center	(Anders Winnberg)*

This workshop is jointly organized by the Galactic Center Newsletter, the Sonderforschungsbereich 328 (Heidelberg), the Physics Department and the Steward Observatory of the University of Arizona, and the Max-Planck-Institut fuer Radioastronomie (Bonn).

email: gc98@mpifr-bonn.mpg.de . . . . web: http://www.mpifr-bonn.mpg.de/gc98

And Finally ... !

"Emails to the Editors"

- There has been a slight change in our policy for subscriptions. For all new subscribers we now require full identification, i.e. name, address, and phone number. While we cannot check the accuracy of the information given to us in each an every case, this information allows us to make some consistency checks especially in the (still rare) cases where we receive a subscription from a subscriber with a non-institutional affiliation. We hope that this will help filter out the (still small) number of phony subscriptions and pranks we receive. Also, as a matter of principle, we would like to know who is using our free internet service.
- Mr. "Makro MC" from Germany wasn't quite so happy about this change, complained to us—quoting the freedom of the internet and the need for dissemination of information, and refused to identify himself. However, we feel that in cases where our wish for information is ignored, we take the freedom of discrimiantion and hence you will not find "Makro MC" on our subsciber list.
- Another email we have received read: "i want to learn as much as i can need more data thanks latter dragon" from dragonfear@webtv.net. Even though we were impressed by the poetic style of the writer, Mr. or Ms. Dragonfear also didn't make it in our webpage and is only honored through this footnote at the end of the Newsletter.
- And finally, on a more serious note we got another example of internet-hooliganism when we received this cry for help:

  "Please Please Please get me off your mailing list, ive just recieved another 15 e-mails from you of over 1275K, its clogging my e-mail up and affecting my buisness, i never signed up to your mailing list, some idiot did that for me, details of which i can supply if you so wish, just please get me off the list."

  In cases like this we try to be as cooperative as possible and provide the necessary information (i.e. time and web-site of the phony registration). That should help to track down and identify the offender.

- Please note that the address of one of the editors (Cotera) has changed, the new address is given below.
- The next issue of GCNEWS will be a special issue with conference abstracts that will appear at the beginning of the conference.

GCNEWS is brought to you by

Angela Cotera	Heino Falcke
Steward Observatory Rm. 274	Max-Planck-Institut für Radioastronomie
University of Arizona	Auf den Hügel 69
Tucson, AZ 85721	D-53121 Bonn, Germany
(cotera@as.arizona.edu)	(hfalcke@mpifr-bonn.mpg.de)
+1 (602) 315-1899	+49 (228) 525-217

GCNEWS appears quarterly. The electronic version is free of charge, for hard copies a fee for postage and copying may be required. We are grateful to the Max-Planck-Institut für Radioastronomie in Bonn for providing us with Internet access. The Newsletter is made possible in part by the DFG under grant Fa 358/1-2.