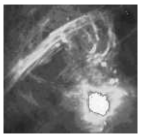
GCNEWS



The Newsletter of Galactic Center Research

Edited by Angela Cotera, Heino Falcke & Sera Markoff

Vol. 15 **July 2002**

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

SMA at Mauna Kea monitoring Sgr A*

Figure 1: The partially completed Sub-Millimeter Array (SMA) on Mauna Kea, Hawaii. The SMA is a collaborative project of Smithsonian Astrophysical Observatory and the Institute of Astronomy and Astrophysics of the Academia Sinica of Taiwan (Moran 1998). The SMA has been used to monitor Sgr A* at high frequencies as described in the invited article by Zhao in this issue.

Table of Contents

In the News

Galatic Center Workshop 2002: The Central 300 Parsecs

Angela Cotera & Tom Geballe

We all know that the Galactic Center is a paradise for research in astrophysics. Now we finally get to have a conference about it in Paradise. But time is running out, especially if you wish to be considered for a talk or poster or if you want to get the earlybird registration rate.

The **August 1st, Abstract Deadline**, is fast approaching. Detailed information on how to submit your abstract can be found on the conference webpages (`http://www.gemini.edu/science/gc_conf/`). Since we know that during the summer, many people are on travel, you will be able to provide a *revised* version of your abstract until September 13th. However, an original must still be submitted by the August 1st deadline. In addition, the early registration deadline is also August 1st, so be sure to register when you submit your abstract. (O.K, have we mentioned August 1st enough?)

Another important date to keep in mind is the **September 3rd, Hotel Registration Deadline**. If you miss this deadline, you may be unable to get a room at the hosting hotel. Again, see the web pages regarding making a room reservation.

As of press time, there are about 40 participants registered, and the program is beginning to fill out. Since once again we are trying to facilitate quality discussion sessions, we anticipate limiting the number of participants to 100. If we are unable to accommodate all those who wish to attend, the primary selection criteria will be relevance to the science program, for those who have met the abstract deadline. Late papers (oral and poster) will be accommodated on a space available basis.

We are currently planning on having over 50 oral presentations, and anticipate approximately the same number of posters. We expect to have a lively, informative workshop. In assembling the science program the SOC has established as a priority for each session the inclusion of observational results from the infrared, radio and X-ray, as well as the latest theoretical work. In addition, the SOC encourages research groups to have their junior members give oral presentations.

We have received a grant from the NSF which will allow us to waive the conference fee for a handful of graduate students and postdoctoral researchers. Additional information on the qualification criteria for financial assistance can be found on the conference webpages.

In organizing the workshop, we are seeking to create an atmosphere that will enable you to both share your latest research results and discuss your research with those most interested in your work. For instance, included in the conference fee are a continental breakfast each day of the workshop, and three group lunches such that you can maximize the opportunities to continue the interesting discussions begun during the sessions and coffee breaks.

We look forward to seeing you in Hawaii. Aloha!

Sgr A* Observing Campaign

Angela Cotera

In late June, one of our favorite objects, Sgr A*, was the object of an unprecedented, worldwide, simultaneous, multiwavelength observing campaign. The campaign was initiated when Chandra approved an 8 day observation of Sgr A* as a follow up to the detection of a flare in 2001 (Baganoff et al., 2001, Nature, 413, 45). During the observation of the flare, Baganoff et al., missed contemporaneous OVRO submillimeter observations by mere hours. Thus the multiwavelength simultaneous observing campaign was envisioned. During previous year Mark Morris (UCLA), and Fred Baganoff (MIT), organized simultaneous observations with collaborators at OVRO (3mm), SMA (1mm), the VLBA (7mm), ATCA (3mm), VLT (M band), Keck I (MIR), and Baade Magellan (MIR).

Observations were successfully made at the majority of the participating telescopes, with the execption of weather problems for those in Chile. The full results of the campaign are not yet known, although work on the data is underway as we go to press. However, we anticipate that the results will be presented at the conference in November, so keep your eyes on Session V! The outstanding science represented by this collaboration of so many researchers at so many institutions will undoubtably contribute to a very exciting conference.

A first glimpse at the amazing variability that Sgr A* was showing even before the campaign can be made with the invited article by Jun-Hui Zhao in this issue. It describes the first results of the SMA that monitored Sgr A* at the highest radio frequencies.

Sub-Millimeter Array Observations of Sagittarius A*: Flares at 1 Millimeter Wavelength

Jun-Hui Zhao(Harvard-Smithsonian Center for Astrophysics)

Abstract

We summarize the results from recent observations of Sgr A* at short-/sub-millimeter wavelengths made with the partially finished Sub-Millimeter Array (SMA) on Mauna Kea. A total of 25 epochs of observations were carried out over the past 15 months. Noticeable variations in flux density at λ1.3 mm were observed showing three "flares". The SMA observations suggest that Sgr A* is highly pulsed towards the submillimeter wavelengths during a flare suggesting the presence of a break wavelength around λ3 mm. Cross-correlations of the SMA data at λ1 mm with the λ1 cm data obtained with the VLA show negative lags, suggesting that sub-millimeter wavelengths tend to peak first. The SMA observations indicate that Sgr A* is constantly powered by the central engine but the flaring plasma might well be confined within the characteristic radius ($\sim$40 R_{sc}) at λ3 mm. The SMA data appears to provide unique, important information for understanding the puzzling phenomenon of Sgr A*. The trial observations of Sgr A* have demonstrated that the SMA is a powerful telescope for studying the nature of accretion flows, possible outflows and their immediate environments surrounding a supermassive black hole.

1. Introduction

Sgr A*, a compact radio source, is believed to be associated with the supermassive black hole at the Galactic center (Eckart & Genzel 1997; Ghez *et al.*, 1998). The inferred bolometric luminosity (L$\sim$ $10^{-8.5}$ L_{Edd}) is far below the Eddington luminosity assuming that the mass of the black hole is M=2.6×10^6 $M_\odot$ hereafter. Sgr A* represents an extremely dim AGN. Because of its compactness, we have known little about its intrinsic structure. The apparent structure at radio wavelengths up to λ3 mm appears to be mainly dominated by the scattering structure due to the ISM. Its intrinsic size measured at λ3 mm is less than 0.27 mas (Doeleman *et al.* 2001) suggesting that a characteristic source size at λ3 mm is $\sim$ 40 Schwarzschild radii (R_{sc} hereafter). The compactness of the source appears to be just beyond our current capability to image its detailed structure using the available telescopes. Alternatively, a promising way to explore this extremely compact source is to monitor the variations of the emitting flux density at multi-wavelengths from radio to X-ray.

The variations in radio flux density of Sgr A* have been known for two decades (Brown & Lo 1982). The nature of the radio variability has not been well understood. At the long wavelengths, the flux density of Sgr A* might be modulated by the scintillation due to the turbulence in the ISM (Zhao *et al.* 1989).

The radio light curves observed with the VLA at wavelengths from λ20 to 1.3 cm during the period of 1990-1993 suggests that the amplitude variations increased towards short wavelengths and that the rate of radio flares appeared to be about three per year (Zhao *et al.* 1992; and Zhao & Goss 1993). The typical time scale of these radio flares is about a month. The observed large amplitude variations in flux densities at λ3 mm (Wright & Backer 1993; Tsuboi, Miyazaki and Tsutsumi 1999) are consistent with the wavelength-dependent train of the fluctuation amplitude as observed at centimeter wavelengths. Based on the radio-monitoring data obtained with the 3.5 km Green Bank Interferometer (GBI) at λ11 and 3.6 cm, a characteristic time scale of 50-200 days was derived at both wavelengths and the structure function of λ11 cm data suggested a quasi-periodic variation with a period of 57 days (Falcke 1999).

A presence of a 106 day cycle in the radio variability of Sgr A* was revealed based on an analysis of data observed with the VLA in the period of 1977-1999 (Zhao, Bower and Goss 2001). The periodic oscillation at a period around 100 days appears to be persist in the densely sampled light curves obtained with the VLA at λ2, 1.3 and 0.,7 cm over the past two years (McGary *et al.* 2002). The period of the cycle appears to increase to 130 days suggesting a quasi-periodic nature of the variability in radio flux density (Bower *et al.* 2002; Zhao *et al.* 2002). In addition, a low frequency oscillation feature is also revealed (Zhao *et al.* 2002).

A monitoring program at λ2 and 3 mm was carried out with the Nobeyama Millimeter Array (NMA) and several flares were observed in the period of 1996 to 2001 (Tsutsumi *et al.* 2002). The folded light curve of their λ2 to 3 mm data with a module of 100-120 days shows that the flaring phase can be separated from that of the quiescent state. The NMA data provides additional evidence for a quasi-periodic fluctuation of the flux density at millimeter

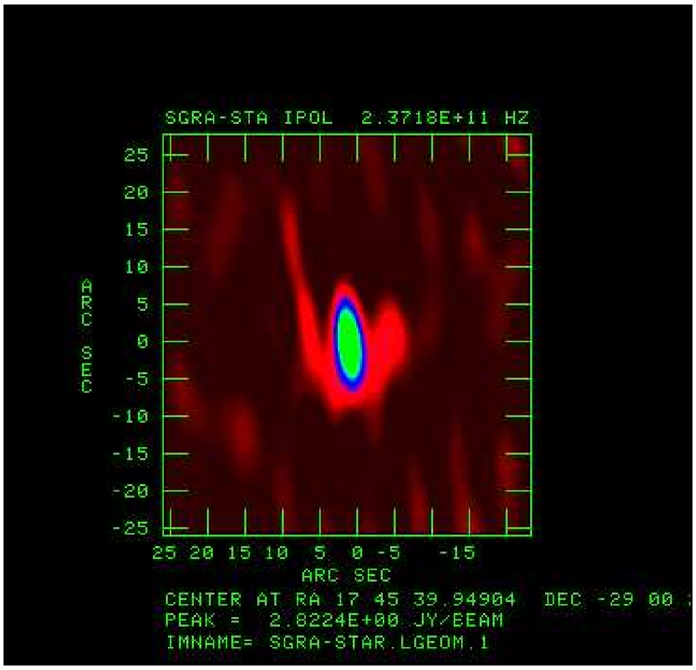


Figure 2: A false-color image of Sgr A* (blue) and its vicinity (red) made from 3.5 hr observations using the four elements of the partially finished SMA on May 23, 2002. The total integration time on the source is about 1.5 hr. The r.m.s. noise is ~30 mJy/beam. The FWHM beam is $7.4'' \times 2.3''$(P.A. = 7°).

wavelengths.

The radio variabilities are likely to be associated with the activities occurring in the accretion region around the supermassive black hole. Observations at wavelengths from short- to sub-millimeters can penetrate into the deep region of this intriguing source. Critical information about inner accretion region near the black hole can be obtained by decoding the light curves.

Good news is that the Sub-Millimeter Array (SMA) is now coming on line (see Fig. 1). With this powerful sub-millimeter array (Moran 1998), we have started a trial program in monitoring Sgr A* at short- to sub-millimeter wavelengths. In this article, we summarize the preliminary results obtained from the SMA observations of Sgr A*.

2. Observations and Calibrations

The observations of Sgr A* at λ1.3 mm and 0.87 mm were done using the partially completed SMA with three or four antennas ranging the baselines from 7 to 55 kilo wavelengths at λ1.3 mm. A total of 25 epochs of observations were made in reasonable good weather conditions (the atmospheric opacity less than 0.3 at λ1.3 mm). The observations were carried out with a total bandwidth of 328 MHz for each sideband. A typical r.m.s. noise of $\sim$ 20 mJy can be achieved from an observation with four antennas for an on-source integration time of 2 hrs. The sensitivity of the partially completed SMA is already adequate for monitoring a variable source in a flux density > 1 Jy at λ1.3 mm. In each epoch of observation, the flux density scale was determined by observing a compact planet (Neptune and Uranus). Sgr B2-north (~50 Jy at λ1.3 mm) was used to check the fringe and the first order of absolute flux density calibration. Further calibration was done by observing two nearby QSOs, OV236 and NRAO 530. The systematic errors, such as errors due to a poor pointing model, were corrected and minimized in the calibration process.

In addition, Sgr A* is located in the complex, extended source Sgr A West. Based on the SMA image (Fig. 2), we find that, for baselines $\sim$ 20kλ or longer, Sgr A* is dominant in the correlated flux density and the confusing flux density at λ1 mm from the surrounding free-free and dust emission is less than 0.3 Jy. The flux density measurements were done initially in the visibility domain and were then double checked by constructing images using the visibility data. The typical uncertainty at λ1 mm is in a range of 10 to 20%.

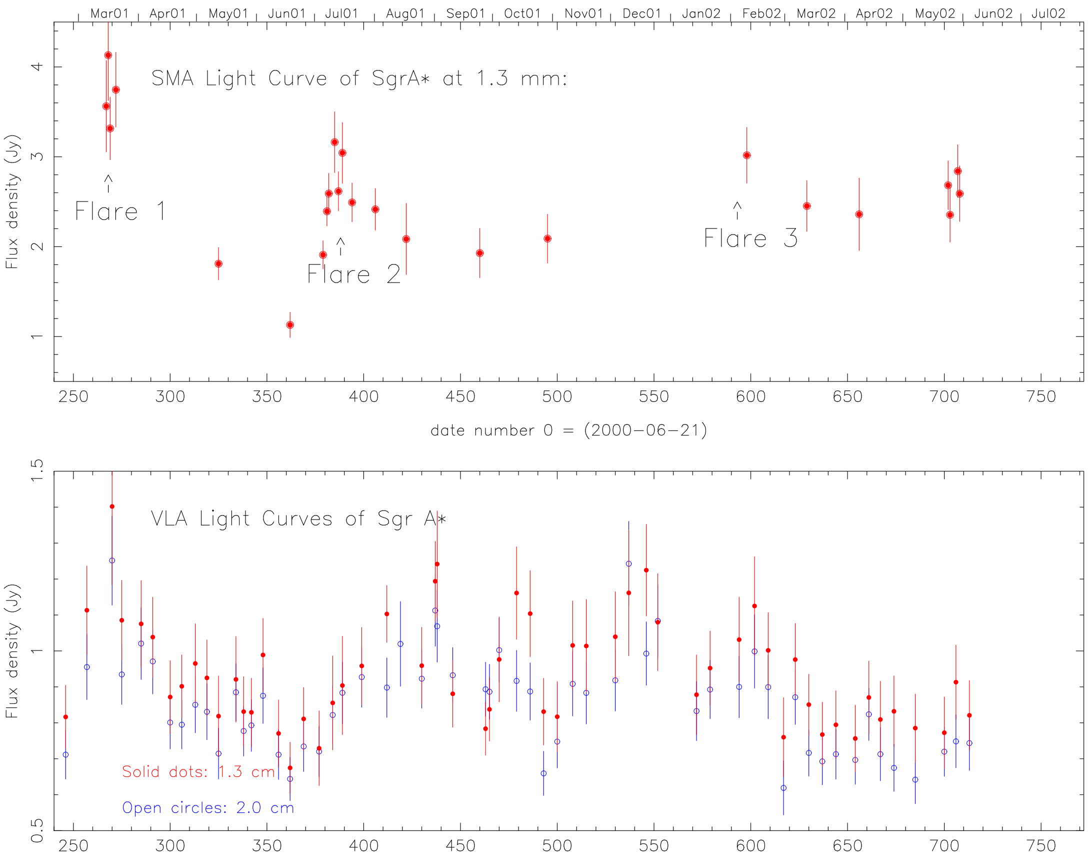


Figure 3: The SMA light curve at λ1.3 mm observed in the period between March 2001 and May 2002 (upper panel). In the same period, the densely sampled radio light curves at λ1.3 and 2 cm were observed with the VLA (lower panel, McGary 2002).

3. Results

3.1 Light Curve and Flares

Fig. 3 shows the SMA light curve at λ1.3 mm suggesting that Sgr A* varies significantly. The light curve of Sgr A* appears to be characterized with a few "flares" while the calibrators show secular variation with opposite drifts in flux density over the past year. Three "flares" were observed over a 1-year period. Both the 2001-March and 2002-February flares (Flare 1 and Flare 3 as marked in Fig. 3) were partially observed in their dropping phase while the 2001-July flare (Flare 2) was observed covering its entire cycle from its rising to maximum and then a slow decrease. Flare 1 (started from 4.1±0.5 Jy after an unseen peak and decreased to 1.1 ± 0.15 Jy in three months) appeared to be relatively stronger than others. The rising time in Flare 2 took about 2 weeks, reaching a peak of 3.2 ± 0.3 Jy on July 10, 2001. Then, a slow decrease lasted about 3 months. Then we were not able to observe Sgr A* for next 3 months for the solar avoidance restricted by the current SMA system. The monitoring program was resumed in early February 2002. A tail of a possible flare (Flare 3) appeared to be observed in early 2002.

In addition, we checked variations in short time scales and found no evidence for significant variations ($2\frac{[S_{max}-S_{min}]}{[S_{max}+S_{min}]} < 40\%$) in a time scale of 1 hr.

3.2 Spectrum during A "Flare"

We also observed Sgr A* at λ0.87 mm with the SMA on March 22, 2001. We made the first measurement of Sgr A* ($S_{\lambda 0.87\mathrm{mm}} = 6.7 \pm 1.5$ Jy) at the sub-millimeter band using the three-element array of the partially completed SMA. Fig. 4 shows a spectrum derived from the mean flux density observed near the peak of Flare 1. The spectrum

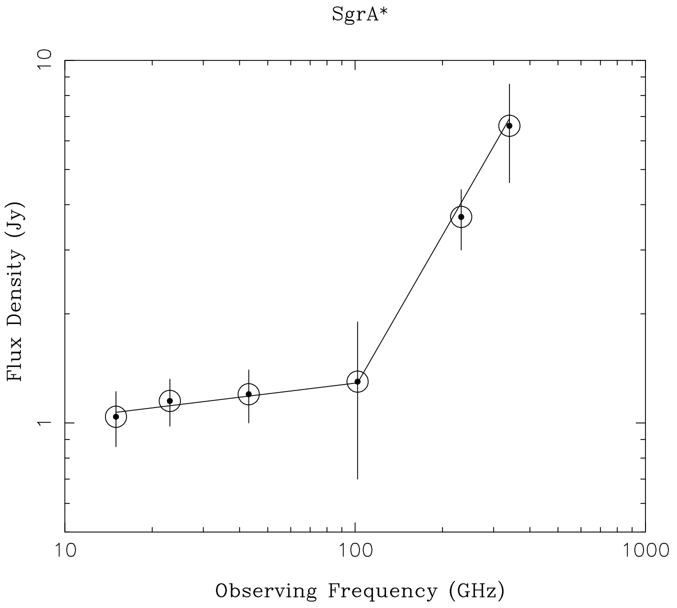


Figure 4: A spectrum of Sgr A* made from the observations near the peak of Flare 1. The λ0.87 and 1.3 mm measurements were made with the SMA. The measurements at λ3 mm were obtained from Nobeyama observations (Tsutsumi *et al.* 2002). The data at λ0.7, 1.3 and 2 cm were from McGary *et al.* (2002).

suggests a break frequency at 100 GHz (or a break wavelength at $\sim\lambda$3 mm). The spectral index is about 0.1±0.1 below 100 GHz, and 1.4±0.4 above 100 GHz. The intensity of the flare appeared to be highly pulsed towards sub-millimeter wavelengths. A flux density excess at sub-millimeter wavelengths has been observed (Zylka, Mezger, & Lesch 1992; Serabyn *et al.* 1997; Falcke *et al.* 1998). The flare spectrum shows a large excess in flux density at sub-millimeter wavelengths, suggesting that flares at sub-millimeter are more prominent.

3.3 Correlation with The VLA Data

The SMA data at λ1 mm appears to show a correlation with the light curves observed with the VLA. The SMA light curve presented about three "flares" from Sgr A* in the past year. Based on the sparsely sampled data points from the SMA observations alone, one can not make any conclusive confirmation on the quasi-periodic fluctuations in flux density. The existing SMA light curve is suggestive. Considering the nature of the "flares" with a strong pulsing intensity towards sub-millimeter wavelengths, studying the variability of Sgr A* is an excellent scientific project to the newly built SMA. On the other hand, the excellent site condition on Mauna Kea, the angular resolution and the sensitivity of the array, the SMA is an important telescope for solving the puzzling nature of Sgr A*.

With available data obtained with the SMA during the past year, we are now able to derive some interesting results from a cross-correlation analysis of the SMA data with the VLA data at λ1 cm. Because of the large "sampling gaps" in the SMA light curve, we are still seeking for an effective tool to derive a global cross-correlation properties of the light curves. Meanwhile, we can break the light curves into three "flaring" segments (see Fig. 5). Cross-correlation analysis suggests that the SMA data at λ1 mm in all the three segments tend to have negative lags with respective to the VLA data at λ1 cm although there is a large uncertainty in the lags for Flares 1 and Flare 3 due to their unseen peaks. Flare 2 does show a significant lag ($t_{lag} = -24 \pm 8$ days).

There appears to be a tendency that the flares at λ1 mm peak first and the delay time at λ1 cm seems to be proportional to the intensity of the flares.

The tendency of short wavelength flaring first is also suggested by the increase of lags towards long wavelength based on an analysis of the the new VLA data at λ2, 1.3 and 0.7 cm (Bower *et al.* 2002). In addition, the strong X-ray flare of time scale of ~1 hr observed by Baganoff *et al.* (2001) was about 10 days earlier than a radio peak observed in all three VLA monitoring bands. During Flare 2 (July 2001), Chandra observed Sgr A* on July 14, 2001, a few days past the λ1 mm peak, showing no X-ray flares. The X-ray flux level was consistent with that of a quiescent state (Baganoff 2001, private communication).

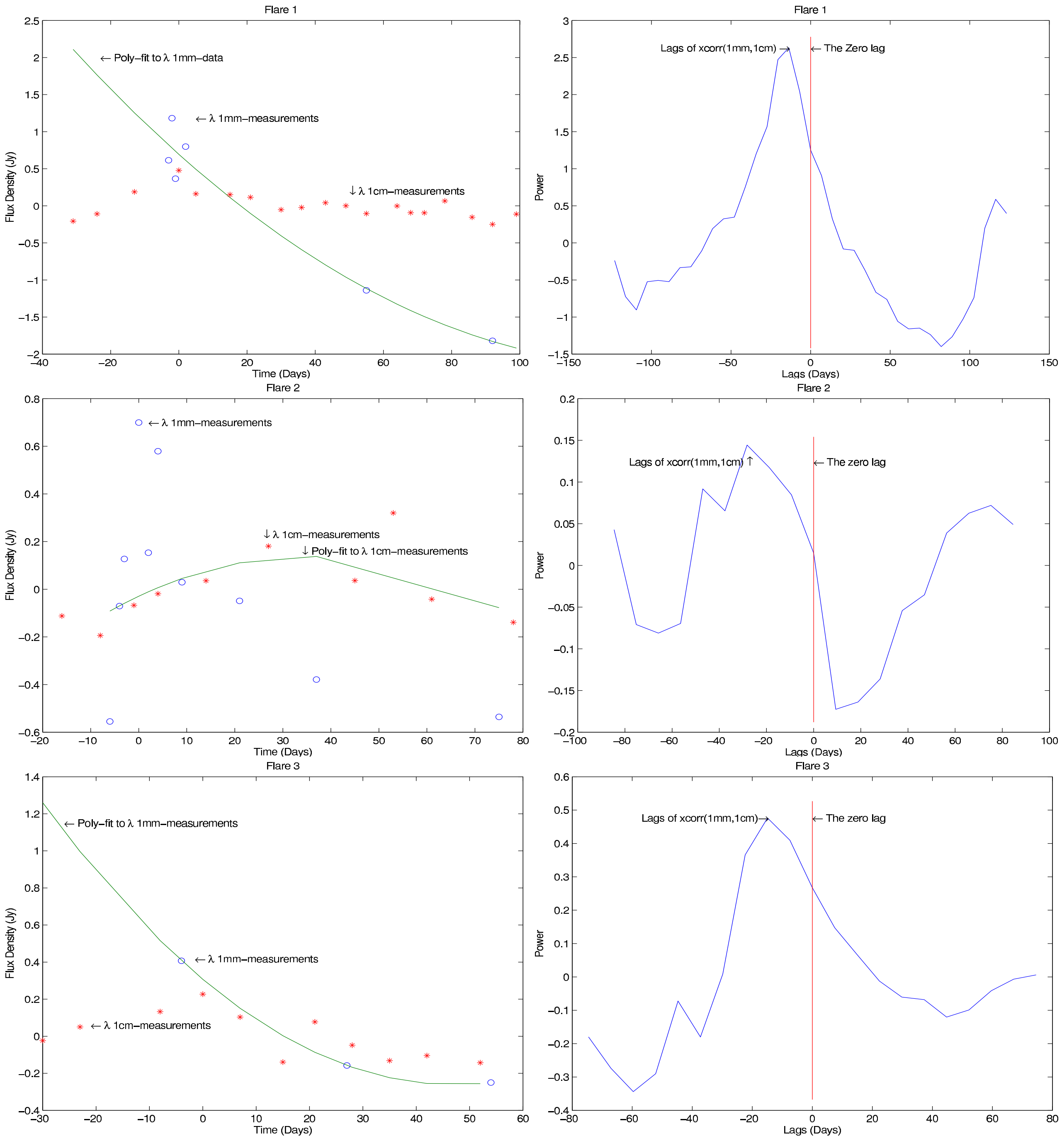


Figure 5: The left panels are the segmental light curves at λ1.3 mm (open circles) and λ1.3 cm (asterisks) of each observed "flares" (Flare 1, Flare 2, and Flare 3). The right panels are the cross-correlations (blue curve) of the SMA data at λ1.3 mm with the VLA data at λ1.3 cm. The vertical red line marks the zero lag. The lags are t_{lag}(Flare1) ~ -14 d, t_{lag}(Flare2) $= -24 \pm 8$ d, and t_{lag}(Flare3) ~ -15 d.

4. Discussion & Summary

The SMA observations have shown that Sgr A* varies significantly at $\lambda 1$ mm during the course of SMA monitoring in the past year. The derived lags from a cross-correlation analysis appear to be good evidence for that the flaring component is inside out starting from short wavelengths and then passing to long wavelengths. A recent work by Yuan, Markoff & Falcke (2002) provides a way to link a jet outflow (e.g. Falcke *et al.* 1993) with the ADAF (Narayan *et al.* 1998). The Jet-ADAF model appears to fit reasonably well to the overall spectrum of Sgr A* from radio, sub-millimeter, IR to the X-ray. In the Jet-ADAF model, the sub-millimeter excess is thought to be a result from a sum of the synchrotron radiation from both the ADAF and the nozzle of the jet.

On the other hand, from the observations with SMA and other interferometer arrays, further constraints on the models are discussed. Taking a mean delay time of 2 weeks and the source size of 40 R_{sc}, an expansion velocity, $v_{exp} \sim 200$ km s^{-1} or < 0.001 c, is inferred. The specific kinetic energy ($\frac{1}{2}v_{exp}^2 \sim 5 \times 10^{-5}$ c^2) in the outward bulk motion of the flaring plasma appears to be far below the gravitational potential energy ($\sim \left[\frac{GM}{r}\right]_{r=40R_{sc}} \sim 0.01c^2$) within the radius of 40 R_{sc} or the characteristic surface at $\lambda 3$ mm. The bulk kinetic energy appears to be too small to power a noticeable jet in Sgr A*. In addition, the break wavelength around $\lambda 3$ mm also indicates that a large fraction of the flaring plasma might well be confined within the characteristic radius at $\lambda 3$ mm although the possible outflow tends to expand to a larger scale.

The sparse SMA data is not sufficient to confirm the periodic/quasi-periodic fluctuation in flux density around $\lambda 1$ cm. The observed outburst rate ($\sim$ 3 times in a year) is consistent with that Sgr A* has been being regularly powered by the central engine.

The time scale (weeks) of $\lambda 1$ mm flares differs from the time scale (1 hr) of the X-ray flare (Baganoff, 2001). The fact of a lack of strong flares in a short time scale at $\lambda 1$ mm places a critical constraint on the hypothesis of the inverse Compton scattering as the emission mechanism for the short lived X-ray flares. Alternatively, the flares at sub-millimeter wavelengths might be a result of collective mass ejections associated with the X-ray flares.

Finally, the data obtained from the SMA monitoring program are critical to our diagnosis of the Sgr A* phenomenon and therefore to our understanding the accretion process and the active environment around a supermassive black hole in a low luminosity AGN.

I would like to thank the SMA staff from both SAO and ASIAA for supporting this monitoring program. In particular, I am very grateful to Ken (Taco) Young for his help and efforts in acquiring the SMA data.

References

Baganoff, F. K., Bautz, M. W. *et al.*, 2001, Nature 413, 45
Bower, G. C., McGary, R. S., Zhao, J.-H., & Goss, W. M., 2002, AAS Meeting 199, #85.08
Brown, R. L. & Lo, K. Y., 1982, ApJ, 253, 108
Doeleman, S. & Shen, Z., Rogers, A.E.E., *et al.*, 2001, AJ, 121, 2610
Eckart, A., & Genzel, R., 1997, MNRAS, 284, 576
Falcke, H., Mannheim, K., & Biermann, P. L. 1993, A&A, 278, L1
Falcke, H., Goss, W. M., Matsuo, H., Teuben, P., Zhao, J.-H., & Zylka, R., 1998, ApJ, 499, 731
Falcke, H., 1999, in ASP Conf. Ser. 186: The Central Parsecs of the Galaxy, ed. H. Falcke, A. Cotera, W. J. Duschl, F. Melia, and M.J. Rieke (San Francisco: Astronomical Society of the Pacific), p. 113
Ghez, A. M., Klein, B. L., Morris, M., and Becklin, E. E., 1998, ApJ, 509, 678
McGary, R. *et al.*, 2002, in preparation
Moran, J. M., 1998, in Proc. SPIE, Vol. 3357: Advanced Technology MMW, Radio & Terahertz Telescopes, ed. Thomas, G. Phillips, p. 208
Narayan, R., Mahadevan, R., Grindly, J. E., Popham, R., & Cammie, C., 1998, ApJ, 492, 554
Tsuboi, M., Miyazaki, A. & Tsutsumi, T., 1999, ASP Conf. Series 186, p105
Tsutsumi, T., Miyazaki, A. & Tsuboi, M., 2002, AAS Meeting 200, #44.09
Serabyn, E., Carlstrom, J., Lay. O., Lis, D. C., Hunter, T. R., & Lacy, J. H., 1997, ApJ, 490, L77
Wright, M. and Backer, D. C., 1993, ApJ, 417, 560
Yuan, F., Markoff, S., & Falcke, H., 2002, A&A, 383, 854
Zhao, J.-H., Ekers, R. D., Goss, W. M., K. Y. Lo & Narayan R., 1989, IAU Symp. 136, 535.
Zhao, J.-H., Goss, W. M., Lo, K. Y. and Ekers, R. D., 1992, ASP Conf. Series 31, 295
Zhao, J.-H. and Goss, W. M. 1993 Sub-arcsecond Radio Astronomy, R. J. Davis and R. S. Booth, Cambridge University Press, 38
Zhao, J.-H., Bower, G. C., Goss, W. M., 2001, ApJ, 547, L29
Zhao, J.-H., *et al.*, 2002, in preparation
Zylka, R., Mezger, P. G., & Lesch, H., 1992, A&A, 261, 119

Abstracts

X-ray Sources and Star Formation Activity in the Sgr B2 Cloud Observed with *Chandra*

Shin-ichiro Takagi, Hiroshi Murakami and Katsuji Koyama

(1) Department of Physics, Faculty of Science, Kyoto University, Sakyo-ku, Kyoto 606-8502, Japan; takagi9@cr.scphys.kyoto-u.ac.jp, hiro@cr.scphys.kyoto-u.ac.jp, koyama@cr.scphys.kyoto-u.ac.jp

We report the X-ray population study in the giant molecular cloud Sagittarius B2 (Sgr B2). More than a dozen of X-ray cloud members (and candidates) are discovered with *Chandra*. Two bright X-ray sources are located near Sgr B2 Main, the most copious complex of the ultra compact HII sources. The X-ray spectra are fitted with a thin thermal plasma model of 5–10 keV temperature. The intrinsic luminosity after correcting the absorption of $\sim 5 \times 10^{23}$ $H\ cm^{-2}$ is $\sim 10^{33}$ erg s^{-1}. Although these two X-ray sources are attributable to young stellar objects (YSOs) in the same HII complex, they are in sharp contrast; one at the center of the HII complex exhibits strong K-shell transition lines of iron, while the other near the east has only weak lines. The other HII complexes, Sgr B2 North and South, also show hard and highly absorbed X-ray emissions due possibly to the star formation activity. The composite X-ray spectrum of the other cloud member X-ray sources is fitted with a thin thermal plasma of ~10-keV temperature with the hydrogen column density (N_H) of 1.3×10^{23} $H\ cm^{-2}$, and the individual X-ray luminosity of a few times of 10^{31-32} erg s^{-1}. These are likely to be a single or cluster of YSO(s), but neither radio nor infrared counterpart is found. An alternative scenario of isolated white dwarfs powered by the Bondi-Hoyle accretion from the dense cloud gas is also discussed. The X-ray spectra exhibit an additional 6.4-keV line of neutral or low-ionization irons, which indicates that the environment gas is concentrated near at the sources.

Ref.: ApJ (2002), vol. 573 (July 1, 2002), in press
Email: takagi9@suzaku.scphys.kyoto-u.ac.jp
Eprint: astro-ph/0203035

The Dynamics of the Circumnuclear Disk and its environment in the Galactic Centre

B. Vollmer[1] *and W.J. Duschl*[2,1]

(1) Max-Planck-Institut für Radioastronomie, Auf dem Hügel 69, D-53121 Bonn, Germany. and Institut für Theoretische Astrophysik der Universität Heidelberg, Tiergartenstrae 15, 69121 Heidelberg, Germany.

We address the question of the dynamics in the inner 50 pc of the Galactic Centre. In a first step we investigate the cloud–cloud collision rate in the Circumnuclear Disk (CND) with the help of a three dimensional N–body code using gas particles that can have inelastic collisions. The CND might be a longer lived structure than previously assumed. The whole disk–like structure of the CND can thus survive for several million years. A realistic simulation of the CND shows the observed disk height structure. In a second step the environment of the CND is taken into account. Retrograde and prograde encounters of a cloud of several 10^4 $M_\odot$ falling onto an already existing nuclear disk using different energy loss rates per collision are simulated. The influence of the energy loss rate per collision on the evolution of the mass accretion and cloud collision rates is strongest for a prograde encounter. A composite data cube of two different snapshots of a prograde encounter together with the CND shows striking similarity with the observed Sgr A cloud complex. The current appearance of the Galactic Centre environment can thus be explained by at least two dynamically distinct features together with the CND. The current mass accretion rate within the CND ranges between 10^{-3} and 10^{-4} $M_\odot\,yr^{-1}$. It can rise up to several 10^{-2} $M_\odot\,yr^{-1}$ during massive accretion events.

Ref.: A&A, 2002, in press
Email: bvollmer@sun184.mpifr-bonn.mpg.de
Eprint: astro-ph/0203428

The Structure and Variability of Sagittarius A*: Zooming in to the Supermassive Black Hole at the Galactic Center

Feng Yuan[1], *Jun-Hui Zhao*[2]

(1) Max-Planck-Institut für Radioastronomie, Auf dem Hügel 69, D-53121 Bonn, Germany

(2) Harvard-Smithsonian Center for Astrophysics, 60 Garden Street, MS 78, Cambridge, MA 02138, USA

The Galactic center provides a unique astrophysical laboratory for us to study various astrophysical processes. In this paper, we review and outline the latest results from observations of Sgr A$*$ in terms of source structure and variations in flux density. Sgr A$*$ phenomenon represents a typical case of low radiative efficiency accretion flow surrounding a supermassive black hole in low luminosity AGNs. Many pending astrophysical problems found from observations of Sgr A$*$ have challenged the existing astrophysical theories. Current theoretical models of Sgr A$*$ are also reviewed.

Ref.: to appear in "Astronomy and Chinese Astronomy: Present and Future", Mainland and Overseas Young Chinese Astronomer Colloquium: Celebration of the 15th Anniversary of the National Science Foundation of China, Beijing, December 2001
Email: fyuan@mpifr-bonn.mpg.de
Eprint: astro-ph/0203050

Spatially Resolved Observations of the Galactic Center Source, IRS 21

A. Tanner(1), A. M. Ghez(1), M. Morris(1), E. E. Becklin(1) A. Cotera (2), M. Ressler, M. Werner (3) P. Wizinowich(4)

(1) UCLA Department of Physics and Astronomy, Los Angeles, CA 90095-1562 (2) Steward Observatory, University of Arizona, Tucson, AZ 85721 (3) Jet Propulsion Lab, 169-327, 4800 Oak Grove Drive, Pasadena, CA, 91109 (4) W.M. Keck Observatory, 65-1120 Mamalahoa Hwy., Kamuela, HI 96743

We present diffraction-limited 2-25 μm images obtained with the W. M. Keck 10-m telescopes that spatially resolve the cool source, IRS 21, one of a small group of enigmatic objects in the central parsec of our Galaxy that have eluded classification. Modeled as a Gaussian, the azimuthally-averaged intensity profile of IRS 21 has a half-width half-maximum (HWHM) size of 650$\pm$80 AU at 2.2 μm and an average HWHM size of 1600$\pm$200 AU at mid-infrared wavelengths. These large apparent sizes imply an extended distribution of dust. The mid-infrared color map indicates that IRS 21 is a self-luminous source rather than an externally heated dust clump as originally suggested. The spectral energy distribution has distinct near- and mid-infrared components. A simple radiative transfer code, which simultaneously fits the near- and mid- infrared photometry and intensity profiles, supports a model in which the near-infrared radiation is scattered and extincted light from an embedded central source, while the mid-infrared emission is from thermally re-radiating silicate dust. We argue that IRS 21 (and by analogy the other luminous sources along the Northern Arm) is a massive star experiencing rapid mass loss and plowing through the Northern Arm, thereby generating a bow shock, which is spatially resolved in our observations.

Ref.: ApJ, in press
Email: tanner@astro.ucla.edu
Eprint: astro-ph/0204372

Where have all the black holes gone?

T. Beckert (1), W. J. Duschl (2,1)

(1) Max-Planck-Institut fuer Radioastronomie, Auf dem Huegel 69, 53121 Bonn, Germany; (2) Institut fuer Theoretische Astrophysik, Universitaet Heidelberg, Tiergartenstr. 15, 69121 Heidelberg, Germany

We have calculated stationary models for accretion disks around super-massive black holes in galactic nuclei. Our models show that below a critical mass flow rate of 3 10^{-3} $\dot{M}_{Edd}$ advection will dominate the energy budget while above that rate all the viscously liberated energy is radiated. The radiation efficiency declines steeply below that critical rate. This leads to a clear dichotomy between AGN and normal galaxies which is not so much given by differences in the mass flow rate but by the radiation efficiency. At very low mass accretion rates below 5 10^{-5} $\dot{M}_{Edd}$ synchrotron emission and Bremsstrahlung dominate the SED, while above 2 10^{-4} $dotM_{Edd}$ the inverse Compton radiation from synchrotron seed photons produce flat to inverted SEDs from the radio to X-rays. Finally we discuss the implications of these findings for AGN duty cycles and the long-term AGN evolution.

Ref.: A&A, in press
Email: wjd@ita.uni-heidelberg.de
Eprint: astro-ph/0203489

Annihilation Radiation from a Dark Matter Spike at the Galactic Centre

Gianfranco Bertone (1,2), Guenter Sigl (2), Joseph Silk (1)

(1) Department of Astrophysics, University of Oxford; (2) Institut d'Astrophysique de Paris

We study annihilation radiation of neutralinos in the Galactic centre, assuming the existence of a 'spike' in the dark matter density profile, due to adiabatic accretion onto the massive black hole lying at the Galactic centre. Under this assumption we find that it is possible to reproduce the observed SgrA* emission at radio and gamma-ray frequencies in a consistent scenario with a magnetic field close to the equipartition strength and with values of γ (the density profile power law index) around 0.1.

Ref.: MNRAS, submitted
Email: bertone@iap.fr
Eprint: astro-ph/0203488

Adaptive Optics Near-Infrared Spectroscopy of the Sgr A* Cluster

S. Gezari, A.M. Ghez[a], E.E. Becklin, J. Larkin, I.S. McLean, M. Morris

[a]Also affiliated with UCLA's Institute of Geophysics and Planetary Physics.

(1) Department of Physics and Astronomy
University of California, at Los Angeles, CA 90095-1562

We present K-band $\lambda/\Delta\lambda \sim 2600$ spectroscopy of five stars (K $\sim$ 14 - 16 mag) within 0."5 of Sgr A*, the radio source associated with the compact massive object suspected to be a 2.6 x 10^6 $M_\odot$black hole at the center of our Galaxy. High spatial resolution of $\sim$ 0."09, and good strehl ratios of $\sim$ 0.2 achieved with adaptive optics on the 10-meter Keck telescope make it possible to measure moderate-resolution spectra of these stars individually for the first time. Two stars (S0-17 and S0-18) are identified as late-type stars by the detection of CO bandhead absorption in their spectra. Their absolute K magnitudes and CO bandhead absorption strengths are consistent with early K giants. Three stars (S0-1, S0-2, and S0-16), with $r_{proj} < 0.0075$ pc ($\sim$ 0."2) from Sgr A*, lack CO bandhead absorption, confirming the results of earlier lower spectral and lower spatial resolution observations that the majority of the stars in the Sgr A* Cluster are early-type stars. The absolute K magnitudes of the early-type stars suggest that they are late O - early B main sequence stars of ages < 20 Myr. The presence of young stars in the Sgr A* Cluster, so close to the central supermassive black hole, poses the intriguing problem of how these stars could have formed, or could have been brought, within its strong tidal field.

Ref.: ApJ, accepted
Email: suvi@aida.phys.columbia.edu
Eprint: astro-ph/0205186

Images of very high energy cosmic ray sources in the Galaxy I. A source towards the Galactic Centre

W. Bednarek, M. Giller and M. Zielińska

(1) Division of Experimental Physics, University of Łódź, ul. Pomorska 149/153, 90-236 Łódź, Poland

Recent analyses of the anisotropy of cosmic rays at 10^{18} eV (the AGASA and SUGAR data) show significant excesses from regions close to the Galactic Centre and Cygnus. Our aim is to check whether such anisotropies can be caused by single sources of charged particles. We investigate propagation of protons in two models of the Galactic regular magnetic field (with the irregular component included) assuming that the particles are injected by a short lived discrete source lying in the direction of the Galactic Centre. We show that apart from a prompt image of the source, the regular magnetic field may cause delayed images at quite large angular distances from the actual source direction. The image is strongly dependent on the time elapsed after ejection of particles and it is also very sensitive to their energy. For the most favourable conditions for particle acceleration by a young pulsar the predicted fluxes are two to four order of magnitudes higher than that observed. The particular numbers depend strongly on the Galactic magnetic field model adopted but it looks that a single pulsar in the Galactic Centre could be responsible for the observed excess.

Ref.: J.Phys. G, in press
Email: bednar@fizwe4.fic.uni.lodz.pl
Eprint: astro-ph/0205324

Spin-Induced Disk Precession in the Supermassive Black Hole at the Galactic Center

Siming Liu[1] and Fulvio Melia[1,2,3]

(1) Physics Department, The University of Arizona, Tucson, AZ 85721 (2) Steward Observatory, The University of Arizona, Tucson, AZ 85721 (3) Sir Thomas Lyle Fellow and Miegunyah Fellow.

Sgr A* is a compact radio source at the Galactic Center, thought to be the radiative manifestation of a $2.6 \times 10^6\ M_\odot$ supermassive black hole. At least a portion of its spectrum—notably the mm/sub-mm "bump"—appears to be produced within the inner portion ($r < 10\,r_S$) of a hot, magnetized Keplerian flow, whose characteristics are also consistent with the $\sim 10\%$ linear polarization detected from this source at mm wavelengths. (The Schwarzschild radius, r_S, for an object of this mass M is $2GM/c^2 \approx 7.7 \times 10^{11}$ cm, or roughly $1/20$ A.U.) The recent detection of a 106-day cycle in Sgr A*'s radio variability adds significant intrigue to this picture, since it may signal a precession of the disk induced by the spin a of the black hole. The dynamical time scale near the marginally stable orbit around an object with this mass is ≈ 20 mins. Thus, since the physical conditions associated with the disk around Sgr A* imply rigid-body rotation, a precession period of 106 days may be indicative of a small black hole spin if the circularized flow is confined to a region $\sim 30\,r_S$, for which $a \approx (M/10)\ (r_o/30\ r_S)^{5/2}$. The precession of a larger structure would require a bigger black hole spin. We note that a small value of a/M (< 0.1) would be favored if the non-thermal ($\sim 1-20$ cm) portion of Sgr A*'s spectrum is powered with energy extracted via a Blandford-Znajek type of process, for which the observed luminosity would correspond to an outer disk radius $r_o \sim 30\ r_S$. Such a small disk size is also suggested by earlier hydrodynamical simulations, and is implied by Sgr A*'s spectral and polarimetric characteristics.

Ref.: ApJ Letters in press
Email: liusm@blackhole.physics.arizona.edu
Eprint: astro-ph/0205487

NH3 in the Central 10 pc of the Galaxy. II. Determination of Opacity for Gas with Large Linewidths

Robeson S. McGary[1] and Paul T.P. Ho[1]

(1) Harvard-Smithsonian Center for Astrophysics, 60 Garden Street, Cambridge, MA 02138,

rmcgary@cfa.harvard.edu, pho@cfa.harvard.edu

The 23 GHz emission lines from the NH3 rotation inversion transitions are widely used to investigate the kinematics and physical conditions in dense molecular clouds. The line profile is composed of hyperfine components which can be used to calculate the opacity of the gas (Ho & Townes 1983). For intrinsic linewidths of a few km/s, the 18 magnetic hyperfine components blend together to form a line profile composed of five quadrupole hyperfine lines. If the intrinsic linewidth exceeds one half of the separation of these quadrupole hyperfine components ($\sim 5-10$ km/s) these five lines blend together and the observed linewidths greatly overestimate the intrinsic linewidths. If uncorrected, these artificially broad linewidths will lead to artificially high opacities. We have observed this effect in our NH3 data from the central 10 pc of the Galaxy where uncorrected NH3 (1,1) linewidths of ~ 30 km/s exaggerate the intrinsic linewidths by more than a factor of two (Genzel & Townes 1987). Models of the effect of blending on the line profile enable us to solve for the intrinsic linewidth and opacity of NH3 using the observed linewidth and intensity of two NH3 rotation inversion transitions. By using the observed linewidth instead of the entire line profile, our method may also be used to correct linewidths in historical data where detailed information on the shape of the line profile is no longer available. We present the result of the application of this method to our Galactic Center data. We successfully recover the intrinsic linewidth ($< v > \approx 15$ km/s) and opacity of the gas. Clouds close to the nucleus in projected distance as well as those that are being impacted by Sgr A East show the highest intrinsic linewidths. The cores of the "southern streamer" (Ho et al., 1991; Coil & Ho 1999,2000) and the "50 km/s" giant molecular cloud (GMC) have the highest opacities.

Ref.: ApJ (2002), in press
Email: rmcgary@iorek.harvard.edu
Eprint: astro-ph/0206077

Massive Stars and The Creation of our Galactic Center

Donald F. Figer

(1) STScI, 3700 San Martin Drive, Baltimore, MD 21218

JHU, 34th and Charles Street, Baltimore, MD 21218

Our Galactic Center hosts over 10% of the known massive stars in the Galaxy. The majority of these stars are located in three particularly massive clusters that formed within the past 5 Myr. While these clusters are extraordinary, their formation repesents about half of the total inferred star formation rate in the Galactic Center. There is mounting evidence that the clusters are just present-day examples of the hundreds of such similar clusters that must have been created in the past, and whose stars now comprise the bulk of all stars seen in the region. I discuss the massive stellar content in the Galactic Center and present a new analysis that suggests that effects of continuous star formation in the Galactic Center can be seen in the observed luminosity functions newly-obtained HST/NICMOS and Gemini AO data.

Ref.: proceedings of IAU212
Email: figer@stsci.edu
Eprint: astro-ph/0207300

GCNEWS is brought to you by

Angela Cotera
Steward Observatory Rm. 274
University of Arizona
Tucson, AZ, U.S.A. 85721
(cotera@as.arizona.edu)
+1 (602) 315-1899

Heino Falcke & Sera Markoff
Max-Planck-Institut für Radioastronomie
Auf dem Hügel 69
D-53121 Bonn, Germany
(hfalcke,smarkoff@mpifr-bonn.mpg.de)
+49 (228) 525-217, 525-425

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.