PROCEEDINGS OF SCIENCE

Sgr A*, the best-sampled of all AGN?

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In this essay, I will update my earlier talk on this Galactic source, given on Vulcano Island in spring 2012, [Kundt, 2013]. My conviction has not really changed since: that with Sgr A*, we deal with a Burning Disk (BD), rather than with a Supermassive Black Hole (SMBH), for an ever increasing number of reasons. Astrophysical disks give birth to stars, jets, planets, and moons when of stellar mass, and to galaxy-scale fountains and jets when distinctly more massive, as long as they contain enough nuclear fuel, including hydrogen. They re-eject their inspiralling matter explosively. Luckily, our present Universe turns out to be stable against the formation of Black Holes (BHs), and likewise of Naked Singularities (NSs).

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[*] Speaker.

1. Introduction

In this presentation, I will argue that our understanding of the Universe – based on observations with ever improving spatial and spectral resolution – can be consistently described by regular solutions of Einstein's GRT, without singularities, such as Black Holes (BHs), or Naked Singularities (NSs). Sgr A* is our best case. Matter approaching the center of our (Milky Way) Galaxy via spiral-in through its disk tends to be re-ejected to large distances, via its innermost, nuclear-burning portion, its 'Burning Disk' (BD), whose spectrum is remarkably broadband, and remarkably time-variable. This BD lies at the center of the (unresolved) point source Sgr A*.

I shall now present a series of maps centered on Sgr A*, with their resolution increasing six times by factors of 10, in figs.1 - 7. They will allow us to get a coarse understanding of the prevailing large-scale motions of matter in our Galaxy, a non-trivial task. Finally, fig.8 will prove consistency with our understanding of all the other galaxies in the Universe.

2. Reasons for, and against the occurrence of BHs in our cosmic neighbourhood

Why should we expect to encounter BHs anywhere in the Universe? Most of us have learned that BHs form an unavoidable last step in the compression of matter. Stars are stabilised by internal pressures exerted by the hot, burning plasma in their interiors; planets and moons are stabilised by the thermal, liquid and/or solid-state pressures of their gaseous atmospheres, liquid oceans, and solid continental crusts and cores; white dwarfs of mass below 1.4 $M_\odot$ are stabilised by the much stronger degeneracy pressure of crushed atomic or molecular matter (in which atoms lose their electrons); and neutron stars – unless too heavy ($\gtrsim 3M_\odot$) – are in addition stabilised by repulsive nuclear forces. But as soon as a (static) neutron star exceeds a mass of some $3M_\odot$, GRT has taught us that increasing its local pressures cannot extend its range of stability, because pressure has weight: The stability condition gets non-linear at high densities, with compressional forces increasing faster than their resisting pressure forces, and there is no longer a stable state for our (too) heavy neutron star; we conclude at its unhalted collapse, at the formation of a BH.

When considerations like this were first expressed – during the1960s and later – the doors opened to BH physics, and no way out seemed to exist. Roger Penrose's (1972) 'cosmic censorship' postulate then looked like a helpful constraint; but was it really required? The later result "BHs are of measure zero within the set of all collapse solutions" made BHs look like a rather unlikely phenomenon, cf. [Kundt, 2015a]. On the other hand, their generalisations – Naked Singularities – did not make us any happier either: Do we really live in a Universe which abounds of singular substructures??

There is another answer to neutron-star accretion which apparently, all of us have overlooked until now: angular momentum! All neutron stars spin, though not faster than at a (subrelativistic) period of 1.4 ms, and it is almost impossible to increase their mass quasi-statically, beyond their mass of birth: Matter falling down onto a neutron star accretes almost at the speed of light, and spins the star up, towards a compact disk, instead of squashing it. No BH forms in this way; nor in any other way that I am aware of. Instead, the centers of galaxies are all populated by BDs, by nuclear-burning (central) accretion disks, the nearest of which is Sgr A*.

Once we have become aware that we do not know a single mechanism for a BH to form, it may be useful to realise further reasons against their existence: A nearby BH would have destroyed (swallowed) our solar system, before life got started. BHs are not stationary objects, they are extremely active, (except inside of a perfect vacuum). They accrete all their surrounding matter, as fast as they can, and grow in mass unlimitedly. Whereas all other heavy bodies in the Universe blow winds, with which they hold back, and sweep away their ambient matter, BHs only attract, and swallow. Once heavy enough, they swallow at increasingly higher velocities, as long as there is enough ambient matter within reach – like inside galaxies – and even like beyond. Note that in particular, all the radiations, and all the cosmic rays fill almost all of our surrounding space, and do not mind entering BHs either. For instance, a SMBH near the center of our Milky Way Galaxy would not need longer than some 10^8yr for growing to a weight at which it attracts, and swallows our solar system, (whereby its most distant food falls in towards it at typical speeds of $\gtrsim 10\,\mathrm{km/s}$). The Sloan Digital Sky Survey (SDSS) plot of unresolved galactic-center masses, fig.8, assures us that there have been plenty of supermassive centers around in the past to pursue this job, in all the sampled galaxies, so that no humans could have evolved there either, according to our new insight. Which completes my second proof that BHs are absent in our present, surveyable Universe.

3. Our Galactic Twin-Jet

Not all galactic centers show twin-jets, but all the brightest ones do, and so does our Milky Way's center, if only at a presently low rate. In my understanding, based on [Kundt & Krishna, 2004] and [Kundt, 2015b], a twin-jet requires a heavy, fast-rotating magnet as its central engine, in interaction with some adjacent resistance that prevents the magnet from spinning freely. Such a resistance can be a low-mass surrounding disk, as exists in all stellar X-ray binaries with jets, or can be substructures of the central disk, as in all the twin-jets from AGN, but by no means a SMBH [Kundt, 2011]; (the latter would simply have swallowed the whole source, in the past). In our present case, the twin-jet from inside Sgr A* is fed, I think, by the pair-plasma created in vacuum discharges of the BD's corotating magnetosphere, in interaction with its anchoring plasma. Ever since [Kundt, 1996], I visualise this BD as the innermost portion of our Milky Way's disk, approximately as a flat star, of cylinder radius 10^{14}cm, height 10^{12}cm, which [Roxburgh, 1993] has shown to burn extremely chaoticly, due to its flat geometry, with a highly broadband, highly time-variable spectrum, ranging from radio frequencies $\lesssim$GHz up to PeV γ-rays, and variable on all timescales above 0.1 minute; the hardest and most-variable source in our whole Galaxy, whose sampled power $L \gtrsim 10^{38}$erg/s would even be $\gtrsim$100-fold larger, had it not thrusted out and expanded from very near the bottom of our Galaxy's deep gravitational potential well. This BD, inside of Sgr A*, has a present mass of $M \lesssim 10^{6.6} M_\odot$ (= $10^{39.9}$g). Note that because of its exceptional (central) location, its received 'specific power' L/M appears low: some 200 times weaker than that of our Sun: $(L/M)_\odot$ = 2 erg/g s.

This our Galactic twin-jet is not easy to recognise near its very source, on scales smaller than 1 lyr; see figs. 1-5, which home in roughly in steps of 'factor of 1/10'. (Note that ideal jets, i.e. stationary, straight jets through vacuum, perform strict **E** x **B**-drifts, hence do not radiate at all). The twin-jet may have been some 10^5 times brighter at X-rays only a century ago, as was found recently by spectral X-ray maps due to the superluminal light-echo effect, on length scales of 50 pc

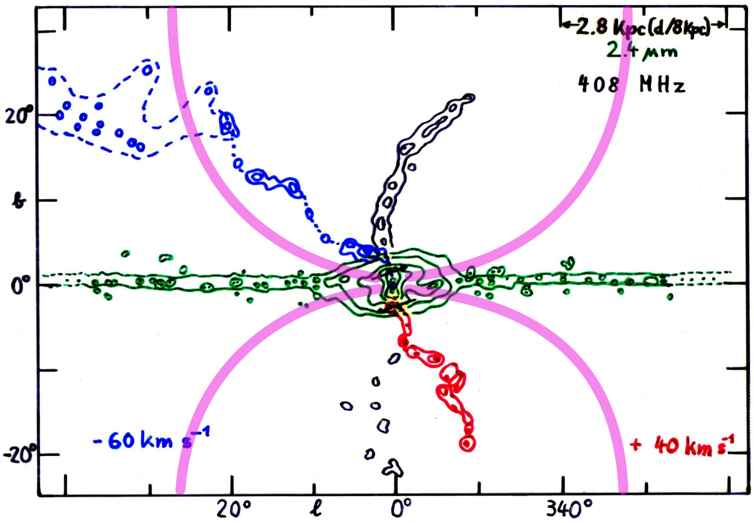

Figure 1: Simplified, joint IR, radio, and γ-ray map of our Galaxy seen from Earth, on the ten kpc scale, with all structures indicated which are likely powered by its central engine, the BD; after [Kundt, 1990], [Sofue et al, 1989, 2000, 2001], and [Bührke, 2011]. Blue and red colours denote blue- and red-shifts of the channel wall's HI gas, and the shapes of the (hard) Fermi bubbles are sketched in purple.

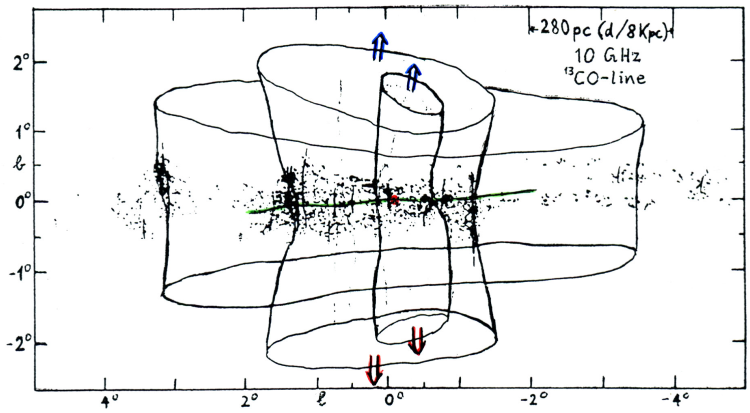

Figure 2: The same view as in fig.1, but narrowed in to the central kpc scale, according to [Kundt, 1996], suggesting time-varying feeding by our CE in the past.

[Ponti et al, 2010]; and it may even have been considerably brighter some 10^7yr ago, as has been suggested via radio maps at various frequencies, and via X-ray maps by [Sofue et al, 1989, 2000, 2001], which trace much wider (aged) channel widths of the innermost jet during past centuries, equally detected e.g. in the neighbouring galaxies M 83, NGC 1808, NGC 253, NGC 4258, M 82, and NGC 3079. Most galactic twin-jets are faint, and rapidly time-variable near their centers, due to interactions with ambient matter.

More in detail, fig.1 shows the innermost 10 kpc of the slowly decaying channel walls of our Galactic twin-jet: approaching us – i.e. blueshifted – in the northern hemisphere, and receding from us in the southern hemisphere, and branching already after $\approx$ one kpc in both hemispheres, where

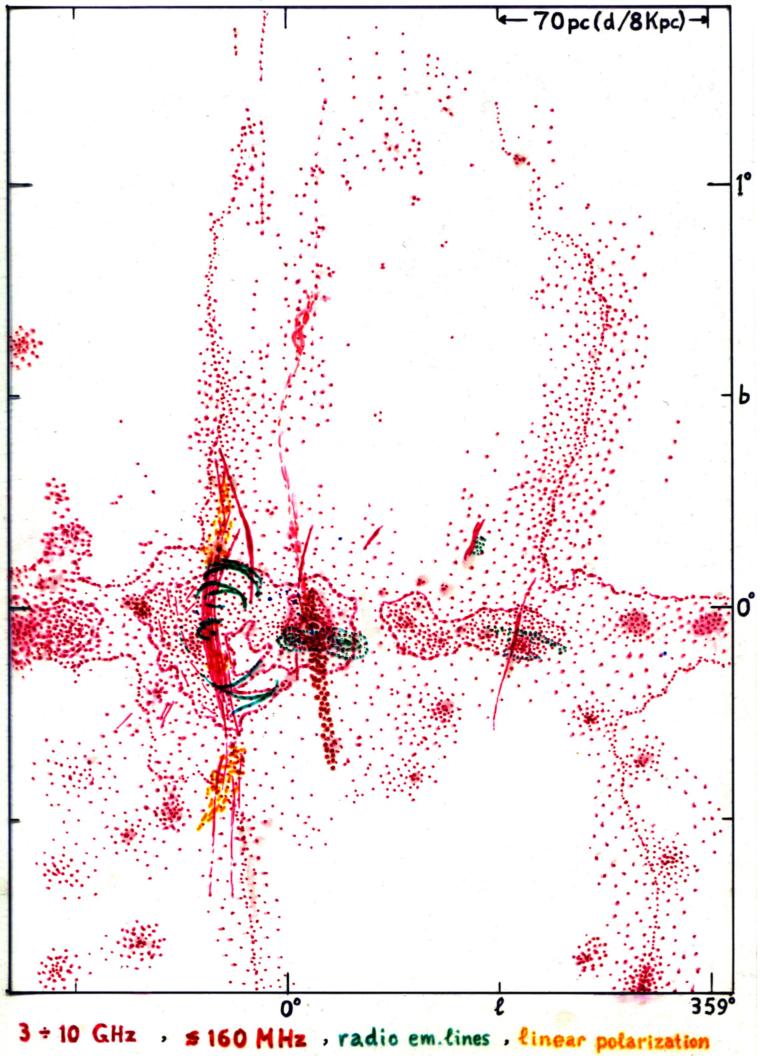

Figure 3: Again the same view, this time focussed on the innermost 0.1 kpc with the (almost straight) "chimney" – revealing its inner jet structure – from [Kassim et al, 1987], [Yusef-Zadeh et al, 1986], [Kundt,1990].

a new (younger) channel has been found in the northern hemisphere, whose relative velocity w.r.t. us cannot be measured, due to its lack of emitted spectral lines. (Note that some 30 yr ago, these "decaying channel walls" used to be called "falling hydrogen clouds"). On this same scale, the (high-frequency) "hypershells" found by the Fermi mission [Bührke, 2011] are sketched in purple, as the outer edges of two X-ray and gamma-ray bubbles likewise fed by the BD at the Galactic center, and extending to heights of 20 kpc on either side. In other words: the BD, inside of Sgr A*, feeds not only the twin-jets with pair plasma, but also the pair of (embedding) Fermi bubbles with high-energy cosmic rays.

None of this could be achieved by a SMBH. The boosting requires a) creators of hard pair plasma – I put my money on relativistic $e^{\pm}$ pair plasma, created via magnetic reconnections, and post-accelerated by the low-frequency magnetic waves emitted by the disk, (as is known for the

Crab nebula) – and b) particle boosters for the CRs – I put my money on middle-aged Galactic neutron stars. – Hell is loose inside of a BD, inside of Sgr A*, the core of our Galactic disk! It is a powerful engine, driven by a) kinetic energy from spiral-in motion, b) magnetic fields, anchored in the convected plasma, and c) nuclear burning. All the nearby, well-studied active galactic nuclei avail of these three forms of energy, with which they reverse their infalling accretion flows.

Figs.2 and 3 cover the inner parts of the Galactic twin-jet, on scales of $\lesssim$ kpc and $\lesssim$0.1 kpc respectively, where both jets propagate essentially in the direction of decreasing gravity, at right angles to the Galactic disk. Only on the latter, smaller scale, have trails of the 2 jets been clearly mapped during the past 30 years, at IR (in the north), and at low radio frequencies and X-rays (in the south) respectively. Again, these two jets must have been much more energetic in the past. They clearly sprang forth from inside of Sgr A East.

Fig. 4, on the scale of $\lesssim$10pc, maps essentially Sgr A East, a long-known, variable, broad-band source which has often been mistaken for a SNR. It differs from a typical SNR, however, by being too energetic – by a factor of 10^2 – and too small – by a factor of $10^{-1.5}$ – also by being in a preferred position, and even more clearly so by being surrounded by an enclosing 'membrane' inside of which it houses $\geq$4 small HII-regions. Sgr A East encloses part of the innermost Galactic disk, in the shape of Sgr A West, and is clearly more extended than Sgr A West; whereby the very center of our Milky-Way disk, Sgr A*, looks pointlike on this map, and is located near the center of Sgr A West, in between its 3 spiral arms. I interpret Sgr A East as a storage bubble for all the CRs listed above, which have been created and/or post-accelerated inside of Sgr A*, and pour into Sgr A East from inside of Sgr A*, blown by its central engine, the BD.

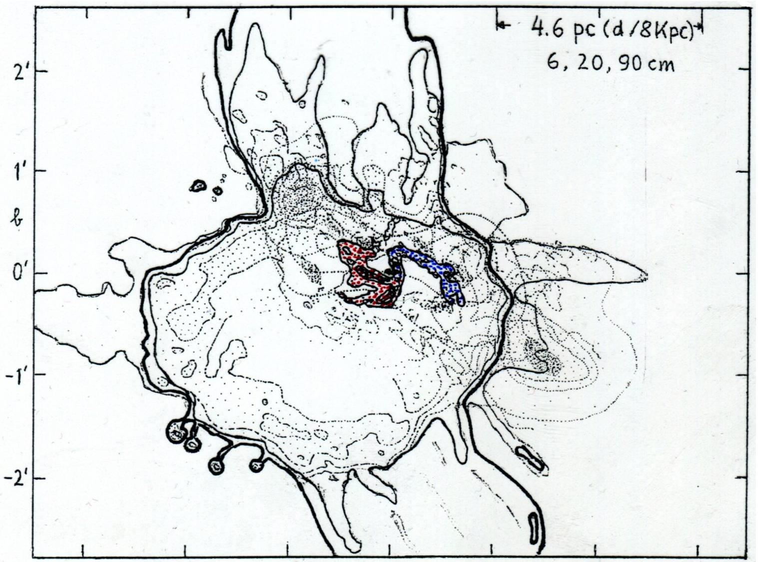

Figure 4: Composite map of the innermost 10 pc, taken from [Kundt, 1996], with blue- and red-shifts marking the motions inside of Sgr A West, the centralmost part of our Galactic disk. It is contained inside of Sgr A East, the large storage bubble which discharges to the North and South into the central chimney. The jet proper cannot be recognised on this scale, but has been mapped by [Baganoff et al, 2003] at X-rays, projecting onto Sgr A West, to the South of Sgr A*, as a 0.3 pc-long straight-line segment; cf. fig.5.

Fig.5, for a change, maps the innermost $\lesssim 3$ lightyears of our Galaxy at various IR and radio frequencies. It shows the central storm field, blue- and red-shifted on both sides of the (central) BD, and co-aligned with the central twin-jet. The latter has been detected more recently by [Baganoff et al, 2003] at X-rays, and added in purple (by us), as a thin, straight, radial feature passing through Sgr A* (at the center), almost vertically in Galactic coordinates, of length one lyr, starting at a distance of one lyr from Sgr A*. It has the expected position, orientation, width (of order 1%), and length of a central jet launched from the rotation center of our Galaxy, together with a plausible brightness. On 3-times larger maps, its straight-line connection with SGR A* passes in addition through both the NE and SW (X-ray) 'Clump', and it passes also through IRS 16, properties which strengthen this interpretation. In my understanding, it completes our search for the southern twin launched presently by the center of our Milky Way, towards its southern hemisphere.

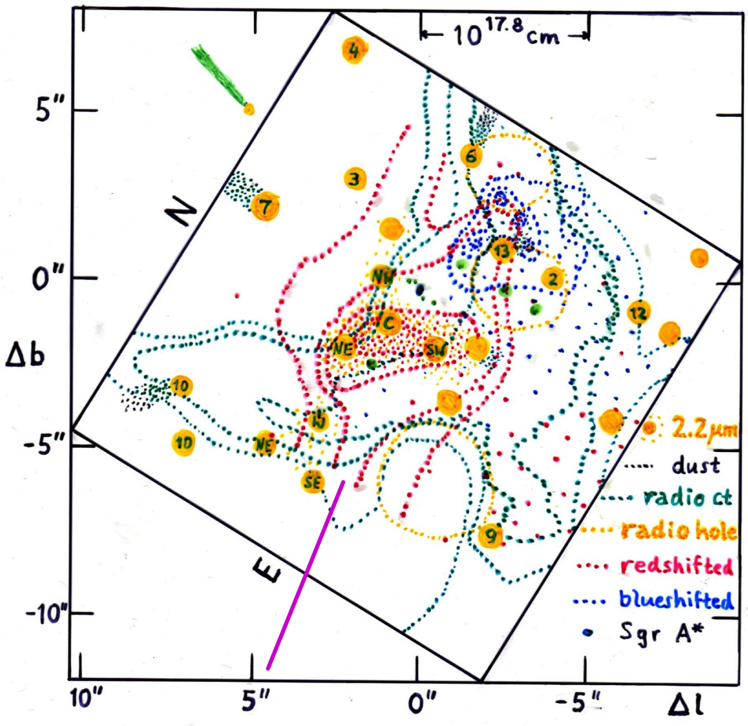

Figure 5: Multifrequency view of the CE of our Galaxy, on the scale of 1 pc, with an ecliptic (rectangular) grid drawn in (called 'N', 'E'), which identifies the $\lesssim 16$ brightest central stars with a few of their radial windhoses drawn in green. The central storm field can be recognised – at right angles to the central disk – by its blue- and red-shifted emissions, as well as Baganoff's (2003) receding jet segment (seen at X-rays, drawn in purple), of length 1 lyr.

Remain figs.6 and 7 of our hierarchy of maps centered on Sgr A*, with decreasing opening angles. Figure 6 – from the Keck/UCLA Galactic Center Group – shows the highly excentric (when seen from Earth) – orbits around Sgr A*, of 10 innermost stars monitored between 1995 and 2016 (at IR frequencies), on the scale of 0.1 lyr, and Figure 7 – from [Gillessen et al, 2006] – shows six small angular offsets of the innermost star S2 during its periastron passage in April 2002, on the scale of 0.01 lyr, which I understand as caused by the fata morgana effect. Note that this periastron passage happened at a distance of (only) 10^2a.u.! Up to now, no higher-resolution maps have been published of our Galactic center, though in particular fig.7 of [Ott et al, 2003] resolves as close in as $10^{-5.5}$pc, and is consistent with a BD of radial extent 10 a.u.(=$10^{-4.5}$pc), called 'flat star cluster' by them.

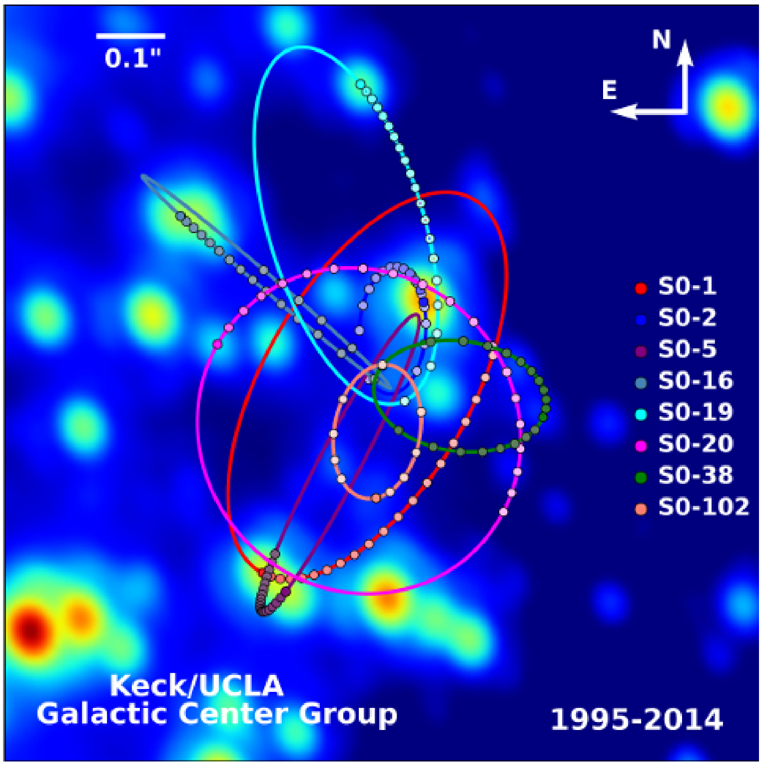

Figure 6: IR map of the monitored orbits of 10 centralmost stars, including S2 and S102 (of periods 15.8 and 11.5 yr) around Sgr A*, on the scale of 0.1 pc, from [Website Keck/UCLA Galactic Center Group, 2016]. Their deviations from Keplerian shape yield estimates of the massive extent of Sgr A*.

4. Sgr A*, the unique point source at our Galactic Center

Sgr A* is the brightest, hardest, most strongly variable point source in our Galaxy, and is located at the rotation center of its disk. At the same time, we have just seen that it lies at the center of the Galactic twin-jet, and at the center of a giant outflow of cosmic rays, the Fermi bubbles. It contains the Burning Disk as its powering engine. A further, non-relativistic outflow from Sgr A* has not yet been mentioned: the central storm field, shown in fig.5, at right angles to the central disk (near the center of Sgr A West), which blows windhoses off the windzones of at least 8 bright stars within 1 lyr from it, from both sides of the BD. Its velocity structure – the BLR of our Galaxy – has been traced by the spectral lines Br α , Br γ, He I, and [Ne II], [Kundt, 2013]. The storm blows at speeds of $\lesssim 10^3$km/s, with a mass rate $\dot{M}_{out} = 10^{-2.5\pm1} M_\odot$/yr which has been shown by [Collin-Souffrin,1993] to equal the mass infall rate $\dot{M}_{in}$ through the disk. This observed mass-flow continuity through the central portion of our Galaxy argues strongly against the presence of any

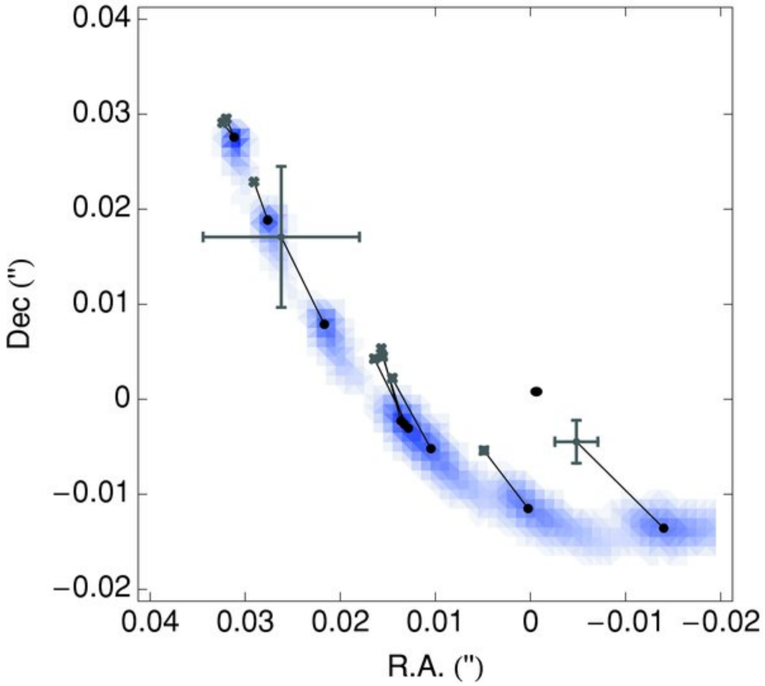

Figure 7: Orbit anomalies of star S2 near peri-astron passage, on the scale of 0.05" $\simeq 10^{15.7}$cm ($\lesssim$0.01pc), measured in April 2002, from [Gillessen et al, 2009]. I like to interpret the orbit irregularities – both their angular offsets, and the flaring brightness of S2 – as a fata morgana at IR frequencies.

BH thereabouts. The re-ejection requires a large energy input – apparently via nuclear burning – consistent with the strong observed outflowing spectral lines by highly ionised iron.

Remarkable about the spectrum of Sgr A* are also its high pair formation rate, $\dot{N} \lesssim 10^{43}\mathrm{s}^{-1}$, and its repeated pair annihilation rate, of comparable power, a spectrum unique of a central Galactic disk, including its hardness, up to PeV photon energies [Aharonian et al, 2004]. Unique were likewise its gigantic X-ray flares in the past, during hours, or even centuries. And most puzzling of all: Why does this active, broadband point source Sgr A* – of typical emitted power $\gtrsim 10^{38}$erg/s – not outshine the windzones of all its surrounding bright stars at IR frequencies, by factors of hundreds? This seemingly modest behaviour has intrigued its observers for decades. I see only one way to explain it: The radiation of the BD has to climb out, and expand from inside of one of the world's deepest potential wells, jointly with its dense, expanding windzone. Its storm escapes strongly redshifted. Our telescopes are screened by it against the powerful radiation from the central BD.

5. Inferences drawn from the orbits of a few central-most stars in our Galaxy

We have learned a lot from plotting the orbits of a few central-most stars around our Galactic center, preferentially from their innermost bright one, S2, of orbital period P = 15.8 yr, though likewise from the somewhat fainter star S102, of P = 11.5 yr (figs. 6 and 7), and from dozens of other stars [Gillessen et al, 2017], which deviate slightly from Newtonian behaviour. In particular, when deriving the mass M, and distance d of its orbital center Sgr A* from the orbit of star S2, during the years between 2001 and 2007, I noticed that their values rose monotonicly during increasing approach – from $10^{6.41}M_\odot$ to $10^{6.63}M_\odot$, and from 8.0 kpc to 8.33 kpc respectively – and stayed constant thereafter, e.g. when re-evaluated in November 2016. This seeming deviation from Newtonian dynamics was expected for a non-pointlike SgrA* – in particular for a BD – approximated by a Mac Laurin ellipsoid.

A third, striking deviation from Newtonian dynamics of S2 (around a central point source) was found by Frank Eisenhauer, and reported by him in his Bonn colloquium on 16 November 2007: He told us that its orbit had precessed through some 3° during one revolution. And [Gillessen et al, 2009] reported that S2 flared during its periastron passage in April 2002, by half a magnitude, and that six successive measurement points were offset towards Sgr A* through up to 10 marcsec in angle, reminiscent of a fata morgana at IR frequencies, see fig.7. These latter two facts are consistent with a (high) local plasma density n of some 10^{12}cm^{-3}, as expected around a BD.

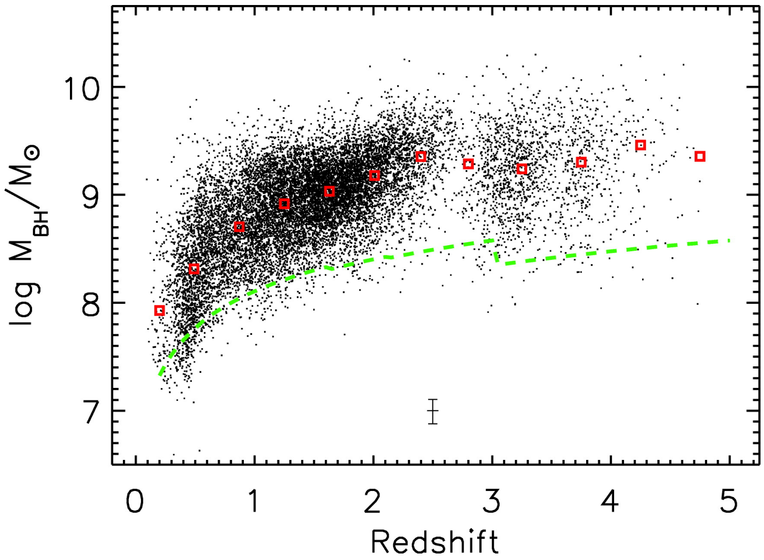

Figure 8: SDSS collection of unresolved core masses of some 14584 galaxies, plotted as functions of their redshifts z (∈(0.2, 4.5)). Statistically, their masses decrease monotonicly with time, starting with average values near $10^{9.5}M_\odot$ at high redshifts, and dropping to $\lesssim 10^7 M_\odot$ today, inversely to what would be expected from (swallowing) SMBHs, [Kormendy & Bender, 2011].

A further, remarkable property of the central-most stars in our Galaxy is their very existence: Why were they not torn apart by the (strong) tidal forces of its pointlike CE [Perets and Gualandris, 2010]? This problem disappears for an extended BD, of $\gtrsim 10^2$-times larger extent.

6. How different are all the other galactic centers?

Let us start this section with a glance at the famous plot by the SDSS, fig.8, which shows us that the masses of the unresolved centers of some 15000 galaxies started out extreme – $M_{CE} \lesssim 10^{10}M_\odot$ – at redshifts $z \geq 4.5$, implying innermost Kepler velocities $\lesssim c$ for these galaxies – and dropped statistically ever since, to the typical low values $\gtrsim 10^6 M_\odot$ shared by our present Milky Way. All these CEs therefore behave like BDs, not like SMBHs. There helps no “downsizing”, no reference to “antihierarchical behaviour”, or “co-evolution” with other structures, such as “feedback from SNe and AGN” – as once proposed by Günther Hasinger for their interpretation.

More individually, during the past two years, the journal NATURE contained several detailed observations of both nearby, and even (bright) distant galaxies which their observers liked to interpret as powered by SMBHs, i.e. with even stronger, and faster ejections from their centers than our Milky Way, which convinced me that quite similar processes take place in them, i.e. that our Galaxy can serve as a modest, but nevertheless typical example, not as a worst case. They are the galaxies NGC 3842, 4889, 1600 [NATURE 532, p.340 (2016)], Mrk 1018 [NATURE 540, p.48 (2016)], IRAS 13224-3809 [NATURE 543, p.318 (2017)], and the more distant sources JO201, 204, 100, 206, 135, and JO194 [NATURE 548, p.304 (2017)]. In the extreme case IRAS 13224-3809, the storm from its center reaches its outskirts at almost luminal speeds: of $\beta \leq 0.236$, $\beta :=$ v/c. A gigantic engine blows at its center!

7. Summary

In this presentation of our present knowledge on the functioning of our Galactic center, some 30 reasons have been collected which argue in favour of Sgr A* being essentially powered by the central, nuclear-burning part of our Galactic disk, a BD. They began in section 2 with the recent insight that BHs are neither required, nor consistent, with the presence of a SMBH at the center of our Galaxy. Or even more distinctly: BHs were introduced into modern astrophysics during the early 1970s, when we had insufficient insight into cosmic processes at extreme compactness. Now, at second thought, we notice that they are no longer wanted, that they are inconsistent with our existence. They would even have swallowed us. We better do without them.

Returning to our Galaxy in section 3, its twin-jet is shown, in at least five of the eight figures, at increasing enlargements. But “BHs cannot blow jets” was shown in [Kundt, 2011]: Jets require sophisticated engines for their formation and maintenance, not swallowing monsters. They belong to the most sophisticated structures encountered in the non-animated Universe, without a (detectable) creator, or building plan; they evolve, so to speak, by themselves, by chance: in a reconstructable manner, which must avoid a SMBH. Of basic importance appeared also the funnelling, SNR-like-looking storage bubble Sgr A East of fig.4.

Section 4 concentrated on the crucial central source of our Galaxy, Sgr A*, whose modest appearance has tolerated a decades-long interpretation as a SMBH, inconsistent with reality. Observers have been shy of trying a more conservative model, in analogy to star-forming disks.

Then we considered the kinematics of the innermost bright stars in our Galaxy, in section 5, and encountered four indications that their attractice center, Sgr A*, does not behave like a (gravitating) point source, rather like an extended source, (on the scale of its Schwarzschild radius). And so is its extremely broadband, extremely variable, and extremely underluminous spectrum, dimmed by having climbed out of the deepest potential well of the Milky Way. Already the early paper by [Ott et al, 2003] came close to deriving it.

In my BD approach pursued in this paper, [Kundt, 2013], I felt reassured in the interpretation of our Galactic Central Engine by Susy Collin’s [1993] continuity relation $\mathrm{M}^*_{\mathrm{in}} = \mathrm{M}^*_{\mathrm{out}}$ of the mass flow through the center-most portion of our disk, (which has to be reaccelerated!); also by the Magorrian relation [Kormendy & Bender, 2011] which finds a direct proportionality of the masses of the CEs and of the central bulges of their host galaxies (though not beyond), also by the halo-sized FERMI bubbles [Su et al, 2012] which are likewise powered by Sgr A*, and by the healthy survival of 'clouds' G2 and G1, of masses $\lesssim 3\ M_\odot$, during pericenter passage beginning in February 2013, against their observers' expectation! A more recent, striking observation in the field of pulsar statistics is the complete absence of pulsars in the central 20 pc – with the exception of one magnetar (of distinctly higher magnetic field in its emission region) – whilst some thousand of them are expected (by continuity): In my understanding, the local plasma pressure is too high in this region for them to blow cavities for their windzones, (inside which they emit their coherent radio pulses).

Finally, in section 6, I interpret the SDSS plot (in fig.8) and a number of original publications in NATURE as proving inconsistency with the SMBH model, of our knowledge about all the sampled, bright galaxies, whilst apparently functioning rather similarly.

Acknowledgements

This presentation has strongly profited from repeated interaction with and help by Ole Marggraf.

DISCUSSION

Pieter Meintjes: Have you made some calculations to see whether a large-scale magnetic funnel that can confine the electron-positron outflow (jet) can be sustained, since large-scale reconnection will probably destroy any magnetic structure built in the disk that can confine the outflow?

Wolfgang Kundt: A deep question, thank you, Pieter! Well, I did make a few stability calculations, for my 2004 universal jet model with Gopal Krishna: Its guiding magnetic field is toroidal, perpendicular to the jet axis, anchored in the overall neutral, though (weakly) alternatingly charged **E** x **B**-drifting pair plasma. Apparently, this toroidal **B**-field survives even in the longest cosmic jets, of lengths reaching the scale of Mpc.

References

[1] Aharonian, Felix, et al (100 authors): *Astron. Astrophys.* **425**, L13-L17, 2004

[2] Baganoff, Frederick, et al (12 authors): *Ap.J.* **591**, 891-915, 2003. See also "CHANDRA PHOTO ALBUM": http://www.chandra.harvard.edu/photo/2003/02031 ong/more.

[3] Bührke, Thomas: *Sterne und Weltraum*, Januar, 26-27, 2011

[4] Collin-Souffrin, S., *Lecture Notes in Physics* **413**, 97-152, 1993

[5] Gillessen, Stefan, Eisenhauer, F., Trippe, S., Alexander, T., Genzel, R., Martins, F., Ott, T.: *Ap. J.* **692**, 1075-1109, 2009

[6] Gillessen, S., et al.(11 authors): An update on Monitoring Stellar Orbits in the Galactic Center, *The Astrophysical Journal* **837**:30, 2017

[7] Kassim, Namir, Erickson, W., La Rosa, Th., in: The Galactic Center, *IAP*, **155**, 196-200, 1987

PoS(MULTIF2017)050

[8] Kormendy, John, Bender, Rolf: *Nature* **469**, 374-379, 2011.

[9] Kundt, W.: Our Galaxy - a former Seyfert?, *Astrophys. & Space Sci*. **129**, 195-201, 1987

[10] Kundt, W.: The Galactic Centre, *Astrophys. & Space Sci*. **172**, 109-134, 1990

[11] Kundt, W.: in: *Jets from Stars and Galactic Nuclei*, Lecture Notes in Physics **471**, 265-270, 1996

[12] Kundt, W.: in: *The Physics of Galactic Halos*, eds. H. Lesch, R.-J. Dettmar, U. Mebold, R. Schlickeiser, Akademie Verlag, 255-259, 1997

[13] Kundt, W.: *Astrophysics, A New Approach*, Springer, 147-152, 2004

[14] Kundt, W.: Black Holes cannot blow Jets, in: *COSMOLOGY AND GRAVITATION,* XIVth Brazilian School of Cosmology and Gravitation, Mangaratiba 2010, eds. Mario Novello & Santiago E.Perez Bergliaffa, *Cambridge Scientific Publishers*, pp.109-118, 2011

[15] Kundt, W.: Our Galactic Center – the nearest Burning Disk, ACTA POLYTECHNICA **53**, Supplement 2013, pp.506-512, 2013

[16] Kundt, W.: A brief Observational History of the Black-Hole Spacetimes, *Advances in Mathematical Physics*, vol.2015, Article ID 617128, 4 pp., 2015a

[17] Kundt, W.: A Uniform Description of all the Astrophysical Jets, *PoS(FRAWS 2014)025*, pp.1-9, 2015b

[18] Kundt, W., Krishna, G.: The Physics of **E** x **B**-drifting Jets, *J. Astrophys. Astron*. 25, 115-127, 2004

[19] Kundt, W., Marggraf, Ole: Physikalische Mythen auf dem Prüfstand, *Springer*, 445 S., 2014

[20] Ott, T., Schödel, R., Genzel, R., Eckart, A., et al (24 more), *The Messenger* No.**111**, pp. 1-8, March 2003

[21] Perets, Hagai, Gualandris, Alessia: *Ap. J.* **719**, 220-228, 2010

[22] Ponti, G., Terrier, R., Goldwurm, A., Belanger, G., Trap, G.: *ApJ*. **714**, 732-747, 2010

[23] Sofue, Yoshiaki, Reich, W., Reich, P.: *Ap.J*. **341**, L47-L49, 1989

[24] Sofue, Yoshiaki: *Ap.J*. **540**, 224-235, 2000

[25] Sofue, Yoshiaki, Vogler, A.: *Astron. Astrophys*. **370**, 53-64, 2001

[26] Su, Meng, Finkbeiner, Douglas P.: *Ap. J*. **753**, 61, 13 pp., 2012

[27] Yusef-Zadeh, Farhad, Morris, M., Slee, O.B., Nelson, G.J.: *Ap. J.* **300**, L47-L50, 1986