Newsletter – December 2020

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New members

Betti Hartmann has joined the RTG as Scientific coordinator on 10 August 2020.

News

- The RTG has been extended until the end of 2021.
- The DFG has approved our Covid-based application for 3 additional months for 9 PhD students and 1 postdoc.
- Jose Luis Blázquez-Salcedo has been appointed Assistant Professor in the Theoretical Physics Department of the Universidad Complutense de Madrid, Spain. Congratulations!

Testing the foundations of cosmology with the radio sky

Thilo Siewert

For many centuries, the place of our Earth and the Solar system in the Universe has been an open question and triggered multiple models and measurements from all perspectives of astronomy. The Cosmic Microwave Background, which is at first sight isotropic and obeys a nearly perfect black-body spectrum at a temperature of roughly 2.7 K, is nowadays accepted to be a perfect probe to define an absolute rest-frame of the Universe. At second sight, the temperature of the CMB reveals a prominent dipole anisotropy of order 10^{-3}, which is accepted to be caused by the proper motion of our Solar system. Based on the assumption of the Cosmological principle, the proper motion of our Solar system should also affect measurements at radio frequencies, known as Cosmic Radio Dipole. This Cosmic Radio Dipole is typically measured by means of source counts of extragalactic radio sources. Recent measurements report, with respect to the CMB dipole, a significantly increased dipole amplitude of order 10^{-2}. In contrast to the well established and precisely measured CMB dipole, the measurements of the Cosmic Radio Dipole are affected by several systematic contributions. Fractional sky coverages and poorer statistics of radio continuum surveys, as well as contributions from local structures to the observed source counts complicate the analysis of the Cosmic Radio Dipole. During the course of my PhD research, we studied the Cosmic Radio Dipole and the underlying radio source distribution in more detail, as well as how to measure it with existing and upcoming radio continuum surveys. My first research project covered therefore the question if we are able to distinguish the kinematic dipole from the mean density of observed source counts and statistical fluctuations of existing radio surveys. In order to measure the Cosmic Radio dipole, we introduce a quadratic estimator and find it to be unbiased from systematic contributions of incomplete sky coverages and low source densities. Moreover, we estimate for the first time the Cosmic Radio Dipole consistently from four different radio surveys. Additionally, one of the surveys is used for the first time to explore the Cosmic Radio Dipole. We find for the four radio surveys dipole amplitudes, which are a factor of five to ten times larger than the amplitude of the CMB dipole. In general, these measurements are in good agreement to results of previous studies. However, based on the consistent estimation for the four radio surveys, which cover a decade of frequency, we find indications for a frequency dependent dipole amplitude. Assuming this frequency dependence to be significant, the assumption of a purely kinematic origin of the Cosmic Radio Dipole can be neglected. Contributions to the dipole, like local structures and individual systematics in the radio source distributions can not be ruled out with these existing surveys. Therefore, we analysed simulated source count maps for survey specifications of the upcoming Square Kilometre Array (SKA), which are based on the best-fit cosmology of Planck 2018 and include large-scale structures. Using these simulations, which are boosted with a kinematic dipole, we are able to identify contributions of local structures within $z \leq 0.5$ to the observed dipole amplitudes and directions. In general, with upcoming surveys of the SKA, we are statistically able to measure the Cosmic Radio Dipole within absolute accuracies of better than 10^{-3} in terms of the dipole amplitude and one degree in terms of the dipole direction. While the SKA is still in the planning process, we analysed a first data release of the LOFAR Two-metre Sky Survey (LoTSS-DR1) in terms of data quality and first cosmological measurements. While the spatial number counts of radio sources are usually assumed to be described by a Poisson distribution, we find an improved fit to a Compound Poisson distribution, which can be motivated by localised groups of radio sources and/or components. However, we can confirm with measurements of the angular two-point correlation function that the observed radio sky of the LoTSS-DR1 is statistically isotropic at better than one per cent above angular separations of one degree. Additionally, we find good agreement to expectations from the best-fit cosmology of Planck 2018 below angular scales of 6 degrees.

My Postdoc years in Oldenburg

Jose Luis Blázquez-Salcedo

I have been a postdoc in the University of Oldenburg from September 2014 to October 2020. Since October 2020, I am an Assistant Professor (Profesor Ayudante Doctor) in the Theoretical Physics Department of the Universidad Complutense de Madrid (Facultad de Ciencias Físicas). It has been a privilege to work in the Oldenburg Field Theory Group and the RTG “Models of Gravity”. During my Postdoc, one of the most important scientific events that occurred to me was the announcement of the first detection of a gravitational wave from a black hole merger. The last few years have seen the birth of gravitational wave astronomy, opening a completely new window to the observable universe.

My main research interest is on the analysis of the properties of gravitational waves emitted from compact objects in alternative theories of gravity. In particular, during the ring-down phase of a merger event, the emission is characterized by a spectrum of frequencies and damping times that is described by the quasinormal modes. Alternative theories of gravity modify this spectrum with respect to General Relativity, and hence it could be possible to look for signatures of these other theories on the ring-down phase of the gravitational waves. In the coming years, these signatures may become observable in the detected signals by LIGO/VIRGO.

Over all these years, I have been developing all the necessary methods and techniques that were needed in order to study, in a consistent way, the quasi-normal modes of different classes of compact objects. Our focus has been, mainly, on theories that introduce gravitating scalar fields.

Together with the Oldenburg group, but also many international collaborators, I have studied the properties of black holes (in scalar-Einstein-Gauss-Bonnet-Gravity and Einstein-Maxwell-scalar theory), neutron stars (in scalar-tensor theories, R2 gravity, and different subclasses of Horndeski theory), and also wormholes with phantom scalar. These studies typically involve: the detailed construction and analysis of the static configurations (most of the times, with semi-analytical and numerical techniques); the study of non-radial perturbations (resulting in some cases in the determination of their mode-stability); the analysis of the quasi-normal mode spectrum and its properties, comparing always with the well-known results of General Relativity. This research line is still ongoing, and there are many ramifications (other theories, objects, settings, etc.) that we have only started exploring.

On the other hand, I am also interested in higher dimensional black holes and solitons. The Oldenburg group has a world-wide renowned expertise in this area. Black holes in higher dimensional gravitational theories have several interesting applications, related to Supergravity, the AdS/CFT correspondence, black hole thermodynamics, etc.

Publications

J. L. Blázquez-Salcedo, D. D. Doneva, S. Kahlen, J. Kunz, P. Nedkova and S. S. Yazadjiev, *Polar quasinormal modes of the scalarized Einstein-Gauss-Bonnet black holes* Phys. Rev. D 102, 024086 (2020)

E. Boffo and P. Schupp, Dual gravity with *R* flux from graded Poisson algebra PoS **CORFU2019** (2020), 140

M. Fennen and D. Giulini, *Lie sphere geometry in lattice cosmology* Class. Quant. Grav. 37 (2020) 065007

J. L. Blázquez-Salcedo, F. S. Khoo and J. Kunz, *Ultra long lived quasi-normal modes of neutron stars in R2 gravity* Eur. Phys. Lett. 130, 50002 (2020)

J. L. Blázquez-Salcedo and C. Knoll, *Constructing spherically symmetric Einstein-Dirac systems with multiple spinors: Ansatz, wormholes and other analytical solutions* Eur. Phys. J. C 80, 174 (2020)

J. C. Drawer and S. Grunau, *Geodesic motion around a supersymmetric AdS5 black hole* Eur. Phys. J. C 80, no.6, 536 (2020)

A. Trova, E. Hackmann, V. Karas, K. Schroven, J. Kovář and P. Slaný, *Influence of test charge and uniform magnetic field on charged fluid equilibrium structures* Phys. Rev. D 101, no.8, 083027 (2020)

D. Philipp, E. Hackmann, C. Lämmerzahl, and J. Müller, *Relativistic geoid: Gravity potential and relativistic effects* Phys. Rev. D 101, no.6, 064032 (2020)

J. C. Drawer and S. Grunau, *Geodesic motion around a supersymmetric AdS5 black hole* Eur. Phys. J. C 80, no.6, 536 (2020)

S. Grunau and M. Kruse, *Motion of charged particles around a scalarized black hole in Kaluza-Klein theory* Phys. Rev. D 101, no.2, 024051 (2020)

Publications (contd.)

R. Tanzi and D. Giulini, *Asymptotic symmetries of Yang-Mills fields in Hamiltonian formulation* JHEP 20 (2020) 94

E. Deligianni, J. Kunz and P. Nedkova *Quasi-periodic oscillations from the accretion disk around distorted black holes* Phys. Rev. D 102, 064023 (2020)

D. Stock, *The Hawking Energy on the past-lightcone in cosmology* Class. Quan. Grav. 37 (2020) 215005

J. L. Blázquez-Salcedo, S. Kahlen and J. Kunz *Critical solutions of scalarized black holes* Symmetry **12** (2020), 2057

J. L. Blázquez-Salcedo, C. A. R. Herdeiro, S. Kahlen, J. Kunz, A. M. Pombo and E. Radu *Quasinormal modes of hot, cold and bald Einstein-Maxwell-scalar black holes* arXiv:2008.11744 [gr-qc]

M. C. Teodoro, L. G. Collodel and J. Kunz, *Retrograde Polish Doughnuts around Boson Stars* arXiv:2011.10288 [gr-qc]

We have investigated the space of solutions and the properties of black holes and solitons in different versions of Einstein-Maxwell-Chern-Simons theory. In particular, extremal solutions, which possess an amazingly rich and interesting branch structure (radially excited black holes, solitonic limits, supersymmetric limits, etc).

In Oldenburg I had the opportunity to be the advisor of Dr. Christian Knoll (for both his Master Thesis and PhD Thesis). We studied quasi-normal modes of Dirac fields on the background of black holes in four and higher dimensions (somewhat in between the previous two lines of research). Later, all the experience we developed allowed us to study Dirac solitons in higher dimensions, and finally to construct the first example of a wormhole supported purely by Dirac fields.

In Oldenburg, I also had the opportunity to be the Master Thesis Advisor of Kevin Eickhoff (on quasi-normal modes of neutron stars in a subsector of Horndeski theory) and Merik Juljan Niemeyer (on the near-horizon formalism). And in addition, I have collaborated with many other students of the RTG group, namely, Fech Scen Khoo, Xiao Yan Chew, Sindy Mojica, Zahra Altaha, and recently with Sarah Kahlen. As a member of the RTG group, the opportunity of collaborating and assisting the "Models of Gravity" students has been, for me, one of the most important and enriching life experiences during my Postdoc years. It has always resulted in excellent scientific discussions, results and, of course, ongoing collaborations. With "Models of Gravity", I have had the opportunity to collaborate with researchers all over the world. All the support I have received has been crucial in allowing me to travel to international conferences, meetings and schools, and also making very fruitful scientific visits. In addition, I had the opportunity to participate in the many amazing colloquia, workshops and events that the "Models of Gravity" group has organized over these years. Top researchers were often invited to report on state-of-the-art results and discoveries. These events were always incredibly enlightening. I am very grateful for all the support I have received from the RTG group all these years and specially, from Prof. Dr. Jutta Kunz. Collaborating with her has been an honour, a pleasure and an inspiration. I am sure that the continued collaboration with her, and also, with all the very brilliant students and alumni of the "Models of Gravity" group, will go on to produce excellent results.

The Nobel prize in physics 2020

Betti Hartmann, Jutta Kunz, Claus Lämmerzahl

Half of this year's Nobel prize in Physics has been awarded to Sir Roger Penrose "for the discovery that black hole formation is a robust prediction of the general theory of relativity" , while the other half is shared by Reinhard Genzel and Andrea Ghez "for the discovery of a supermassive compact object at the centre of our galaxy."

Roger Penrose, who was born in Colchester (UK) in 1931, received his PhD from the University of Cambridge in 1957 working on tensor methods in algebraic geometry. After a number of appointments in the USA and the UK, he became Rouse Ball professor of Mathematics at the University of Oxford in 1973, from which he is now Emeritus Professor since 1998. During his career, he has made ground-breaking contributions to mathematics and physics some of which carry his name such as twistor theory, Penrose tiling, the Penrose triangle, the Penrose stairs, the Penrose process, the Penrose diagram as well as the Penrose–Hawking singularity theorems. For his outstanding contributions he has been knighted in 1994 and is one of only twenty living recipients of the honor Order of Merit. He is also a Fellow of the Royal Society since 1972 and received numerous prizes for his research, including the Wolf prize for physics in 1988, which he shared with Stephen Hawking for their joint work on singularities in General Relativity.

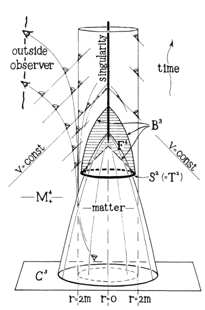

Figure 1: From [1]

The Nobel prize has been awarded to him for his invaluable work on exactly this aforementioned area, and, in particular, for his 1965 publication "Gravitational Collapse and Space-Time Singularities" [1], a two and a half page paper that contains only one figure – the now famous drawing of a gravitational collapse shown in Fig. 1.

After Albert Einstein presented his Theory of General Relativity in 1915 and Karl Schwarzschild found a spherically symmetric, static solution to the vacuum Einstein equation in 1916, it was widely believed before Penrose's work that a situation mathematically described by the Schwarzschild solution, in which the radius of a body of mass M would be equal to its Schwarzschild radius $r_s = 2GM/c^2$ and possesss a physical singularity at its center, could not occur in the real physical world. Although Oppenheimer and Snyder had demonstrated in 1939 that a sufficiently massive star that has exhausted its nuclear energy would eventually collapse to such an object [2], it was believed that the conditions used (a spherically symmetric, pressureless dust cloud as a model for the star) were too specific to be realized in nature. However, at the end of the 1950s, quasars had been discovered and re-newed interest in the foundations of General Relativity and its solutions appeared. As a consequence, Penrose invented new mathematical tools to get a better understanding of the Schwarzschild space-time and its "singularities". One of the key ingredients in the development of singularity theorems was the so-called *convergence condition* for time-like and null-like geodesics, respectively, which itself is a consequence of the Raychaudhuri equation. Assuming a $(-+++)$ signature of the metric, the condition reads: $R_{\mu\nu}v^\mu v^\nu \geq 0$, where v^μ is a hypersurface-orthogonal vector field that determines a time-like or null-like geodesic congruence and $R_{\mu\nu}$ is the Ricci tensor, which – via the Einstein equation – can be related to the energy-momentum content of the space-time. Raychaudhuri and Komar showed that the energy-density of a non-rotating perfect fluid diverges along any time-like geodesic if this condition is fulfilled [3]. This theorem hence already predicts the existence of a space-time singularity as the point at which the energy density diverges, has, however, the disadvantage that it is restricted to situations without acceleration and rotation. Penrose's contribution, which gained him the Nobel prize, was to show that singularities do, indeed, form in more general situations. He demonstrated in his singularity theorem that *if the convergence condition holds for null-like vectors and an initial Cauchy surface C^3 together with its future development M_4^+ (see Fig. 1) as well as a future-trapped surface (T^2 in Fig. 1) exist in the space-time, then null geodesics exist that are future incomplete.* Within this theorem he introduced new notions that revolutionized the understanding of General Relativity and paved the way for accepting the existence of black holes as real physical objects. The key new concept is that of a *trapped surface*. An example of such a trapped surface is the 2-sphere $S^2 (= T^2)$ in Fig. 1. Using the convergence condition mentioned above Penrose defined a trapped surface as a closed, spacelike 2-surface with the property that the two systems of null-like geodesics meeting it orthogonally all converge initially at this surface. Penrose [1] and later Hawking and Penrose [4] provided theorems that demonstrated that the presence of such a trapped surface in a given space-time *always* implies the presence of (some form of) a space-time singularity. The nature of this space-time singularity is not as clear as it is in the singularity theorems by Raychaudhuri and Komar since the proof relies on another new concept that Penrose introduced, namely that of *geodesic incompleteness*. Note that the latter is now the established tool to describe a space-time singularity and means that geodesics cannot be extended indefinitely to arbitrarily large values of their affine parameter. The assumptions of Penrose are so general and do not use symmetry or special conditions that his paper [1] has often been said to be "the major contribution to the development of General Relativity after Albert Einstein's original work 50 years earlier". It not only marked the beginning of black hole physics, but also introduced profound mathematical techniques to study the evolution of the universe. In fact, Hawking used Penrose's theorem to demonstrate that in a spatially flat, isotropic and expanding universe geodesic incompleteness appears if a trapped surface is present [5]. While in Penrose's gravitational collapse scenario, the trapped surface appears in the future, Hawking used a passed trapped surface to demonstrate that the universe has its origin in a past singularity - a singularity that we now often refer to as the "Big Bang".

To this day, progress in the understanding of our universe and its content would be unthinkable without Roger Penrose's contributions. They paved the way for the acceptance of black holes as more than just mathematical solutions to Einstein's equation, and consequently the quest to observe and study these objects. One of the ground-breaking observations of black holes has been done by the two recipients of the second half of year's Nobel prize, Andrea Ghez and Reinhard Genzel.

Andrea Ghez is only the fourth female scientist to be awarded the nobel prize in physics, after Donna Strickland (2018), Maria Goeppert-Mayer (1963) and Marie Curie (1903). Andrea Ghez and Reinhard Genzel shared already the Crafoord-Preis in 2012, when Andrea Ghez was the first female scientist to receive this prize.

After receiving a B.S. in Physics from MIT Andrea Ghez went to Caltech to obtain her master and her PhD (1992). Under the guidance of her advisor Gerry Neugebauer, a pioneer of infrared astronomy, Andrea Ghez used the 5m Hale telescope on Mount Palomar to study young stars in binary and multiple systems, for which high angular resolution could be achieved via speckle imaging. After her PhD Andrea Ghez went to the Steward Observatory of the University of Arizona, where she was a Hubble Research Fellow (1992/1993). Then she returned to California, becoming a professor of astronomy at UCLA (1994), where she continued her work on young stars.

Based at UCLA Andrea Ghez now did her observations at Mauna Kea, Hawaii, where she used one of the 10m telescopes of the Keck Observatory. However, she first decided to modify the Keck facility near-infrared camera (NIRC) in order to use it for speckle-imaging experiments and reach an angular resolution of 50 milliarcseconds [6]. With this superior instrument Andrea Ghez turned her attention also towards the region of SgrA* at the galactic center, where a supermassive black hole was surmised. With the newly gained resolution of 0.”05 the (1996) images of the UCLA group were in general agreement with earlier images of the Genzel group. However, they could resolve much of the extended emission seen by the Genzel group with a resolution of only 0.”15 into point sources [7].

Andrea Ghez and her group then conducted a two year study of the proper motion of stars in the vicinity of SgrA* [8]. Following earlier work of the Genzel group, they doubled the number of stars with proper motion measurement in the central 25 arcsec^2 of the Galaxy, and improved the accuracy of the velocity measurements in the central 1 arcsec^2 by a factor of 4. Inferring a large central density of at least $10^{12} M_\odot \mathrm{pc}^{-3}$ they concluded that the Milky Way harbors a supermassive black hole at its center. Moreover they pointed out that “The significance of a central black hole in our normal inactive Galaxy is the implication that massive black holes might be found at the centers of almost all galaxies” [8]. To obtain more precise information about the mass and the location of the black hole, Ghez and her team then determined the accelerations of stars orbiting the galactic center [9]. This allowed for the first time to perform excellent fits to the orbits of the stars S0-1 and S0-2 (in their nomenclature), suggesting that S0-2 could have an orbit as short as 15 years, a value very close to the current value of 16 years.

The next big step forward was the implementation of adaptive optics at the Keck telescope, leading to still higher angular resolution (0.”022 and 0.”040 at 0.85 and 1.65 μm wavelengths) [10]. Adaptive optics made it now possible to perform the first spectroscopic observations of individual stars in the galactic center, providing the important third dimension as well as the rotational velocity of the stars and their spectral type [11]. For the star S0-2 this lead to the surprising conclusion that it most probably represents a young (less than 10 Myr) main-sequence star of about 15 $M_\odot$. Since the presence of such a young star in the close vicinity of a supermassive black hole is highly challenging to explain, Ghez and her team coined the phrase ‘paradox of youth’ for this circumstance. At the same time the uncertainties in the orbital parameters of S0-2 were reduced by a factor 2-3, and the new estimate or the mass of the supermassive black hole yielded $4.1(\pm 0.6) \times 10^6 (D/8\ \mathrm{kpc})^3$, assuming a distance of 8 kpc to the galactic center.

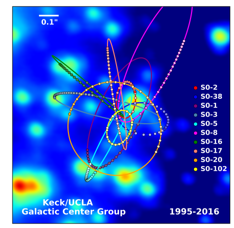

Figure 2: Stellar Orbits in the Central Arcsec

A source of uncertainty at the time was, that the precise location of SgrA* was only known for radio emission, whereas measurements of the stars’ orbits were made in the infrared. Therefore the detection of infrared emission from the supermassive black hole was needed, and both competing teams focused on this issue. A few weeks after the respective submission from the Genzel group, also the Ghez group announced the detection of infrared emission from SgrA* [12]. Subsquently, collecting results from about 10 years of observations at the Keck telescope, Andrea Ghez’ group then analyzed simultaneously the orbits of seven stars around SgrA* in order to further constrain the mass of the central black hole [13], see also Fig. 2. In the determination of the mass of $3.7(\pm 0.2) \times 10^6 (D/8\ \mathrm{kpc})^3$ the distance to the galactic center now represented the limiting source of uncertainty (see also [14]). Further observations with constantly improving accuracy have kept increasing the scientific evidence for a supermassive black hole at our galactic center ever since.

Reinhard Genzel studied Physics at the University of Freiburg and the University of Bonn where he also received his Diploma in physics in 1975. Three years later he did his PhD at the University of Bonn and The Max Planck Institute for Radio Astronomy in Bonn. Then he went to the US and first held a Postdoc position at the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts, and then went to Berkeley where he got a full professor position in 1985. One year later he was appointed as Director of the Max-Planck-Institute for Extraterrestrial Physics in Garching together with a Honorary Professor Position at the Ludwig-Maximilians-University in Munich.

Reinhard Genzel was mainly working in the physics of the center of galaxies, their evolution, in the physics of the evolution of stars, in the interstellar medium, and in extragalactic astrophysics. He is experimental astronomer and his main experimental tool is high resolution infrared and submillimeter astronomy. He is one of the world leading experts in this technology. For his research he received, among many other awards, the Otto-Hahn-Medal of the Max-Planck-Society, the Gottfried-Wilhelm-Leibniz-Price of the German Research Foundation (DFG), The Stern-Gerlach-Medal for Experimental Physics of the German Physical Society (DPG), the Karl-Schwarzschild Price of the Astronomical Society, the Tycho-Brahe-Price of the European Astronomical Society, the Herschel-Medal of the Royal Astronomical Society London and furthermore the Order Pour le Mérite (OPLM), the "Großes Verdienstkreuz mit Stern des Verdienstordens der Bundesrepublik Deutschland", and a Honorary Doctorate from the Observatoire de Paris.

Reinhard Genzel and his collaborators first used the New Technology Telescope (NTT) of the European Southern Observators (ESO) in Chile. With this they observed at 2.2 μm the velocity of stars near to the center of our Milky Way. They found that near to the galactic center the mean velocities of stars vary with the inverse of the square root of the distance to the center. This is characteristic for a central massive body and not for a continuous mass distribution. This were the first papers of Genzel together with Andreas Eckart hinting towards the existence of a Black Hole [15, 16]. These papers were also mentioned by the Swedish Academy of Science as justification of the Nobel Price. These measurement then have been confirmed and refined by Area Ghez with measurements at the Keck observatory. He and his coworkers also started observing the motion of a number of single stars. Here, in particular the star S2 has to be mentioned. The observation of this star started in 1992 and by today this star almost completed two orbits around the SgrA* [17, 18]. A 2010 review can be found in [19].

Lateron Reinhard Genzel and his coworkers used for his discoveries the Very Large Telescope (VLT) of ESO in Chile which started observation in 2000. The VLT uses adaptive optics: a laser beam is sent to sky, is reflected back to gound at a height of approx. 100 km. On ground one measueres the deformation of the wave front of the reflected light what is due to atmospheric turbulences. This deformation then will be corrected in the light waves arriving from distant stars, thus leading to a much better resolution. A further devlopment has been proposed already in the late 1980s by Pierre Léna, Fritz Merkle and others, namely interferometry [20] combining all four telescopes of the VLT, called VLTI. The VLTI observed its "first light" in 2001. Several interferometry instruments have been used. In 2016 a new one, GRAVITY with Frank Eisenhauer as PI, connecting all four telescopes, was started and which is dedicated to measure astrometric distances with an accuracy of approx. 10 μas and to produce pictures in the near infrared [21]. Another instrument, MATISSE, working since 2018, will provide pictures and spectra in the thermal infrared.

With all these instruments Genzel and his coworkers now could prove

- from star motion that the central compact object has a mass of approx. $4 \cdot 10^6\ M_\odot$ and is confined to a region of less than 50 AU.
- from observation of flares that the central compact object should be smaller than 0.1 AU [22].
- the peribothron shift of stars of $12.1'$ per orbit [23].
- the gravitational redshift near to the Black Hole [24].
- the universality of the gravitional redshift [25].

As a consequence all observations support the model of a Black Hole in the center of our galaxy. This has been further supported by an analysis of Broderick and coworkers who showed that assuming a sort of a surface of this compact object should lead to thermal radiation of a certain intensity which has not been observed [26]. This might be completed by a new analysis of Cardoso and Pani who showed that the existance of a surface slightly above the Schwarzschild radius will lead to gravitational wave echoes of the quasinormal modes of the ringdown of Black Holes [27]. A further support of the existence of Black Holes comes from the observation of the shadow of the compact object within M87 which comprises approx. $6 \cdot 10^6\ M_\odot$ [28]. More discussions on why the central object in SgrA* should be a Black hole can be found in [29].

Congratulations to Roger Penrose, Andrea Ghez and Reinhard Genzel for their groundbreaking work!

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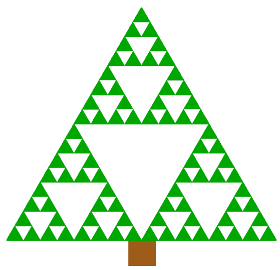

We wish you a happy Christmas time and a good start to the New Year!