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CENTRE FOR ASTRO-PARTICLE PHYSICS

NEWSLETTER OF THE CENTRE FOR ASTRO-PARTICLE PHYSICS

UNIVERSITY OF JOHANNESBURG

NINTH EDITION

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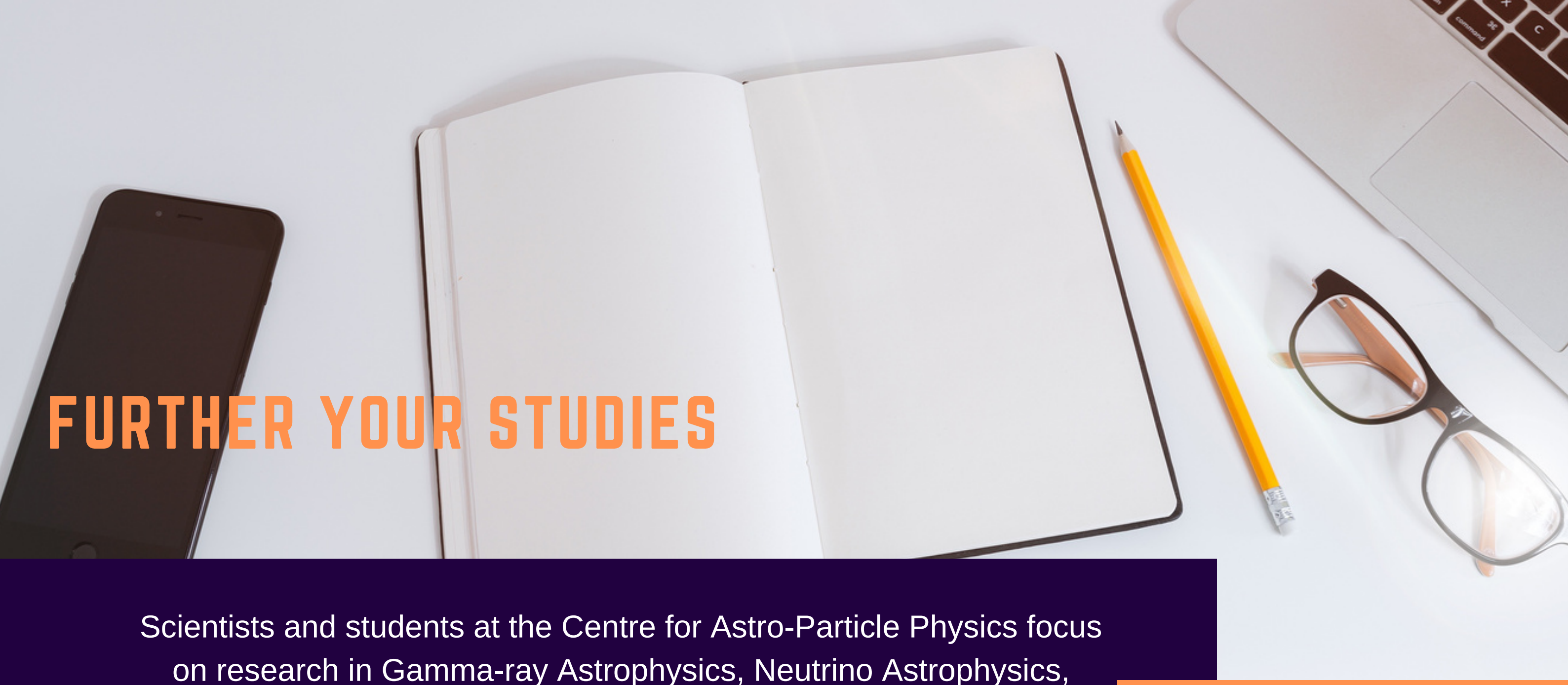
Designed by Jessica-Sheay Verrall

Centre for Astro-Particle Physics
UJ CAPP

UNIVERSITY OF JOHANNESBURG



FURTHER YOUR STUDIES

Scientists and students at the Centre for Astro-Particle Physics focus on research in Gamma-ray Astrophysics, Neutrino Astrophysics, Neutrino Physics and Gravitational Wave Physics. We perform theoretical studies as well as data analysis and modelling. All three experimental facilities that we are involved in, namely the Fermi Gamma-ray Space Telescope; the Cherenkov Telescope Array and the KM3NeT Neutrino Telescope, perform cutting edge research. Thus, working at CAPP can provide students and postdoctoral fellows opportunities to get involved in the science of these state of the art experiments, learn the latest techniques and interpret data collected with various instruments..

Cutting edge research by CAPP group members.

Research in Astro-Particle Physics requires strong background in Physics, Mathematics and computer programming. Although some theoretical studies are still done on papers with pencils, numerical computations and simulations on computers are the main tools to make theoretical predictions these days. Data analysis and modeling also require significant computer skills and learning specialised software.

Students who would like to pursue postgraduate studies in Astro-Particle Physics should choose Physics and Mathematics for their BSc degree. The BSc Honours programme at the Department of Physics offer a wide range of advanced courses, including Astrophysics courses, that can prepare students for future MSc and PhD research in Astro-Particle Physics. Honours students also get a taste of research by doing a project that helps them to prepare for MSc and PhD studies.

A limited number of top-up bursaries are available for Honours, MSc and PhD students from the CAPP. Interested students should contact Ms Jessica-Sheay Verrall (capp@uj.ac.za) with their academic transcripts.

FOLLOW US

WEBSITE	You can view our website to see events, the latest news, images, and info regarding the research of our group members as they happen and when they happen. *www.uj.ac.za/capp*
INSTAGRAM	You can follow us on Instagram @ ujcapp.
FACEBOOK	Centre for Astro-Particle Physics
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LINKEDIN	UJ CAPP. Centre for Astro-Particle Physics
FOR MORE INFORMATION	Email: capp@uj.ac.za

We now have a Facebook and Instagram page. Please help us grow by following us and sharing the news.

Farewell to two of our CAPP members

Dr. Feraol Dirirsa

Feraol Fana Dirirsa studied his Ph.D. from 2015 to 2019 under the supervision of Prof. Soebur Razzaque, at the Centre for Astro-Particle Physics (CAPP), Department of Physics, the University of Johannesburg (UJ). The title of his thesis was "Gamma-ray bursts as probes of cosmological parameters at high redshifts". His research related to modeling radiation from GRBs (Gamma-Ray Bursts) and standardizing these objects as cosmological standard candles through phenomenology correlation, like supernovae (SNe) Type Ia. He has employed the data of these GRBs from onboard the Fermi Gamma-ray Burst Monitor (GBM) and Large Area Telescope (LAT) launched by NASA in June 2008 as well as from Swift observatory. As a member of the Fermi-LAT collaboration since 2015, he has been actively involved in the alert follow-up of the LAT and gravitational-wave (GW) as a burst advocate (BA) and deputy shifter and the LAT Data Quality Monitoring.

He is currently a postdoctorate research fellow in the department and doing research related to his Ph.D. program under the mentorship of Prof. Soebur Razzaque.

After five and half years of his academic journey at UJ, Dr. Dirirsa will join the National Centre for Scientific Research of the Laboratoire d'Annecy-le-Vieux de Physique des Particules (LAPP) research team in France as a postdoctorate research associate. His work at LAPP will focus on the study of GRBs with the High Energy Stereoscopic System (H.E.S.S.) and the future generation ground-based Cherenkov Telescope Array (CTA), and GW alert follow-up optimization process with Virgo/LIGO. In particular, Dr. Dirirsa will work with the Virgo group to optimize the strategy for monitoring alerts. In the event of a successful follow-up of a GW alert, he will assume a leading role in the discussion between the collaborations.

Farewell to two of our CAPP members

Dr. Salvador Miranda-Palacios

Dr. Salvador Miranda-Palacios started his postdoctoral position in May of 2017 and his contract finishes October 2020. He has been working at UJ for 3 years and 5 months.

His research focused on the SBL (Short Baseline), and atmospheric neutrino experiment, which involves the study of neutrino oscillations including the extra neutrino on different mass mixing schemes to find constraints on the number of neutrino flavors. Results show an anomaly with respect to the three active neutrinos. One possible solution is the proposal of an extra sterile neutrino that affects the neutrino oscillations.

His second postdoc position will be at the University of Hong Kong, with the plan to begin working there at the beginning of 2021.

His research will be focused on the propagation of cosmic rays and dark matter.

Set your Goals High
and always Dream Big.
Because you're only
as big as the dreams
you dare to Live.

Happy Farewell!

2021

January

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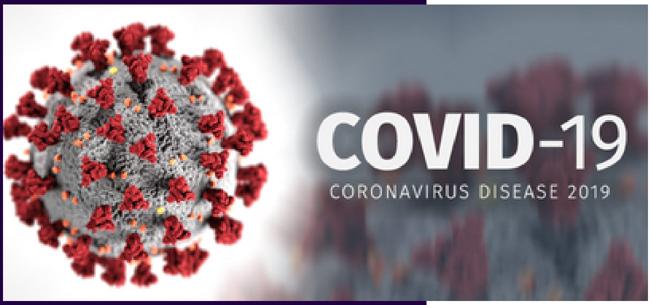
New dates of the 9th International Fermi Symposium

COVID-19 PANDEMIC

Due to the COVID-19 we have postponed the 9th International Fermi Symposium. The new dates for the symposium are **12-16 April 2021**.

We are closely monitoring the COVID-19 development, however, any further change will be communicated as soon as possible.



The latest news and discoveries

The construction of a new observatory which will taste Neutrino’s flavours

Xin, L., 2020. Powerful New Observatory Will Taste Neutrinos&Rsquo; Flavors. [online] Scientific American. Available at: <https://www.scientificamerican.com/article/powerful-new-observatory-will-taste-neutrinos-flavors/> [Accessed 13 October 2020].

The flow of time distinguishing music from noise using physics

Padavic-Callaghan, K., 2020. Time&Rsquo;S Arrow Flies Through 500 Years Of Classical Music, Physicists Say. [online] Scientific American. Available at: <https://www.scientificamerican.com/article/times-arrow-flies-through-500-years-of-classical-music-physicists-say/> [Accessed 13 October 2020].

Evolution of the black hole image

Davide Castelvecchi, N., 2020. The First Ever Image Of A Black Hole Is Now A Movie. [online] Scientific American. Available at: <https://www.scientificamerican.com/article/the-first-ever-image-of-a-black-hole-is-now-a-movie/> [Accessed 13 October 2020].

The beating heart of a black hole

Neutrinos are everywhere, the are pouring in from the Sun, deep space, and Earth, zipping through our bodies by the trillions every second. These particles are extremely elusive and difficult to find due to them seldomly interacting with anything because of their small size. Neutrinos come in different types (known as flavours); they also have the ability to switch from one type to another as they travel close to the speed of light.

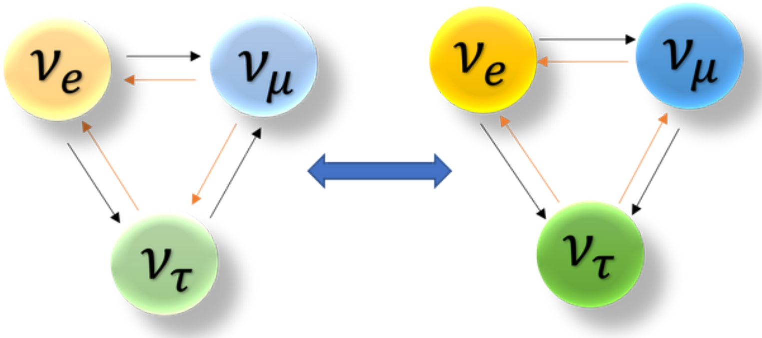
Credit: Liu Dawei Alamy

After almost six years of excavation a new neutrino observatory is taking shape in the underground of southern China. The Jiangmen Underground Neutrino Observatory (JUNO) will be one of the world's most powerful neutrino experiments, along with the Hyper-Kamiokande (Hyper-K) in Japan and the Deep Underground Neutrino Experiment (DUNE) in the USA. Two nearby nuclear power plants will be used as neutrino sources.

The main goal of this research is to answer the fundamental question of how the masses of the three known types of neutrinos compare with one another. The answer to this question can help scientists better estimate the total mass of neutrinos in the universe and therefore, determine how they have influenced the formation of the cosmos and the distribution of galaxies. Later 2020 or early 2021 researchers will start assembling the experiment's 13-story-tall spherical detector. The inside will be covered by a total of 43 000 light-detecting phototubes and it will be filled with 20 000 metric tons of specially formulated liquid. The detector will be 700 meters below the ground and once in a blue moon an electron antineutrino (from the nuclear reactor) will bump into a proton and trigger a reaction in the liquid, which will result in two flashes of light which are less than a millisecond apart. This will count as a reactor neutrino signal.

As the neutrinos arrive at the detector from the nuclear power plant, only roughly 30 percent of them will remain in their original identity, while the rest will have switched to other flavours. The observatory will have the ability to measure this percentage with great precision. Once the observatory is operational, JUNO expects to see approximately 60 such signals a day. JUNO can also catch what is called the geoneutrinos from below the Earth's surface, where radioactive elements such as uranium 238 and thorium 232 go through natural decay. At this point in time, studying geoneutrinos is the only effective way to learn how much chemical energy is left down there to drive our planet. JUNO should detect more than 400 geoneutrinos annually, whereas other existing detectors in Japan, Europe and Canada combined can only see about 20 events per year.

Neutrino osscilation diagram



The flow of time distinguishing music from noise using physics

What, exactly, makes music to the ears?

Noise can sound the same played forwards or backwards in time, but composed music sounds dramatically different in those two time directions.

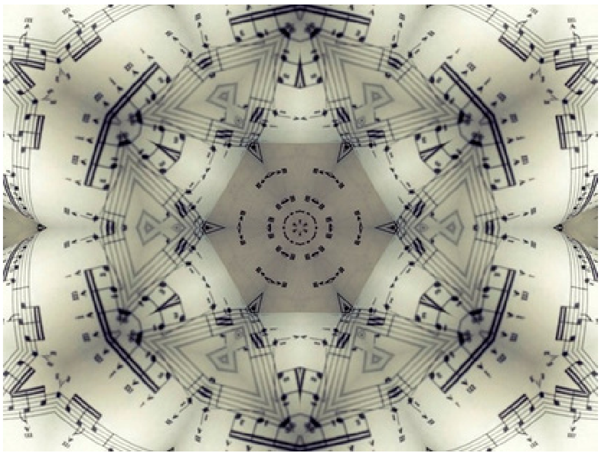
Using techniques derived from statistical mechanics, which is typically used to study large groups of particles, a team of physicists have mathematically measured the “time irreversibility” of more than 8 000 pieces of Western classical music.

“Time irreversibility” is a concept drawn from fundamental physics. It is possible to see the concept in action over, for example, a breakfast: Think of the implausibility of unscrambling an egg and returning it to a pristinely pieced-back-together shell.

Compared with systems which are made of millions of particles, a typical musical composition consisting of thousands of notes is relatively short.

Counterintuitively, that brevity makes statistically studying most music much more difficult, akin to determining the precise trajectory of a massive landslide based solely on the motions of a few tumbling grains of sand.

By translating sequences of sounds from any given composition into a specific type of diagram or graph, the researchers were able to marshal the power of graph theory to calculate time irreversibility.



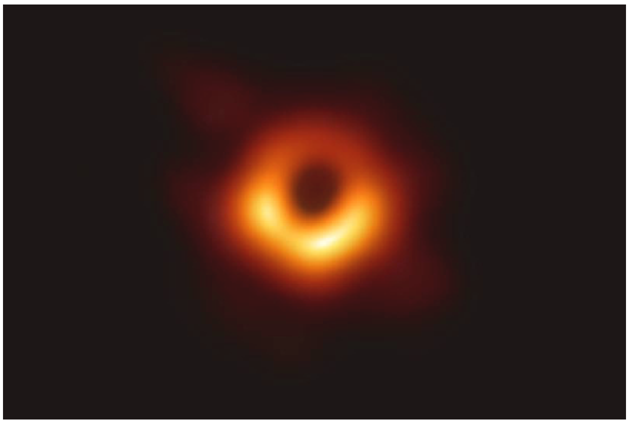
Credit: Getty Images

This is, however, far from being the first statistical study of music. Systems that are time-reversible, under statistical analysis, seem to be the same when the arrow of time is flipped. The unstructured static hiss of white noise is one example. A different kind of noise prevalent in biological systems, so-called “pink noise”, is also time-reversible and by certain statistical measures, it is almost indistinguishable from music. Consequently, music has been accepted to be a type of pink noise.

This new study challenges this association, demonstrating that despite such basic similarities, music has more structure than pink noise, and that this structure is meaningful. Time irreversibility is also found to be related to a measure of disorder that, in physics, is called entropy. The composition having the most entropy would be strictly random shuffle of sounds. It would also look the same-fully disordered- in all time directions, therefore, displaying no arrow of time. Conversely, the most time-irreversible composition would be one that is the least random, possessing the least amount of entropy and therefore, the most structured.

In this sense, measuring time irreversibility might reflect how singular a particular composer’s style is. Scientists wonder whether the time irreversibility scores their analysis assigned to each composer, could accurately reflect the aesthetic properties of that composer’s music. To be enjoyable, it seems, music must strike a balance of predictability and surprise (a property pink noise is considered to possess). Using the statistical mechanics methods, it was found that its rules emerge at the middle ground between dissonance and complexity. In a time-irreversible music piece, the sense of directionality in time may help the listener generate expectations. We would then think that the most compelling compositions would be those that balance between breaking those expectations and fulfilling them.

Evolution of the black hole image

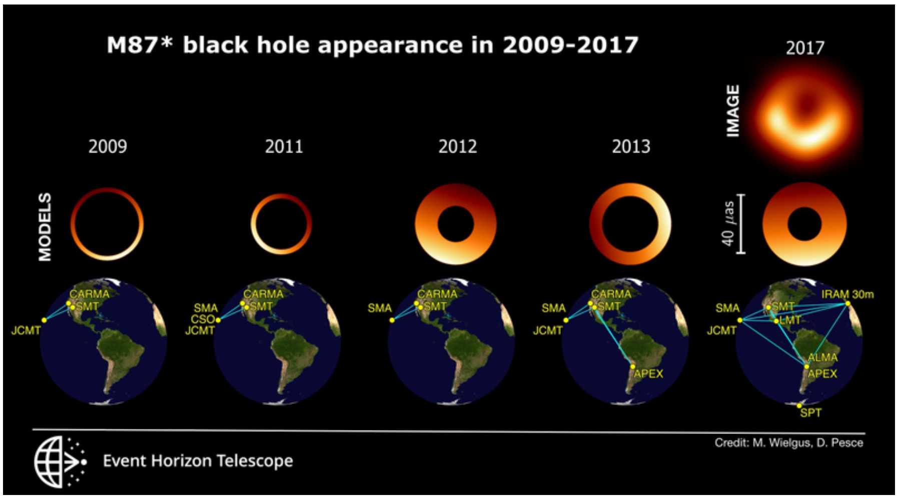


The historic first image of a black hole which was unveiled last year.

Credit: EVENT HORIZON TELESCOPE COLLABORATION

The sequences of models above show how the appearance of the black hole's surroundings changed over the years, as its gravity influences the material around it. The images show light swirling around the supermassive black hole at the centre of the galaxy M87. Event Horizon Telescope (EHT) collaboration exhumed old data on the black hole and combined these with a mathematical model based on the image released in April 2019. Based on the models it can be seen that the ring wobbles with time, this is due to the flow of matter which falls into the black hole being turbulent.

Although the actual image of the black hole is blurry, it does match the predictions made by Albert Einstein on the general theory of relativity, for what the immediate neighborhood of a black hole should look like. We see that one side of the ring appeared brighter; this was expected owing to the combination of effects in the complex dynamics around the black hole. This appearance is due to the accretion disk (matter falling into the void spiralling at a high velocity outside the black hole's equator), one side of the disk rotates towards the observer while the other side rotates away. This lopsided look is in part due to the Doppler Effect.



Credit: M. Wielgus, D. Pesce & the EHT Collaboration

Scientists went back to the older data from EHT to see whether the data could be reinterpreted using 2017's picture as a guide. Initially in 2009 M87* was being observed by telescopes in only three locations, but as more observatories were added the quality of the observations improved.

Once the old data was reanalyzed it was found to be consistent with the results of the 2017 campaign, including the presence of a dark disk and a bright ring.

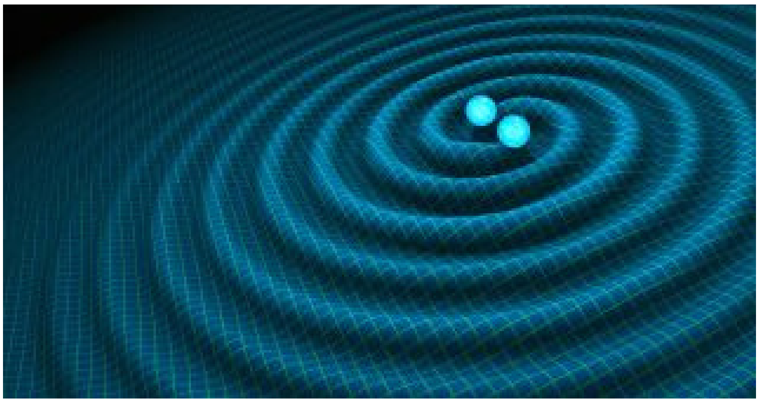
It needs to be mentioned that even though the old data did not have sufficient resolution to produce an image, the team was able to generate synthetic images for each of the years.

Research from our Centre

Lutendo Nyadzani -Masters student

Gravitational waves (GWs) are one of the key predictions of Einstein's theory of general relativity (GR). Scientists have been looking for evidence of GWs since their prediction by Einstein in 1916.

The first direct detection was achieved by the Laser Interferometric Gravitational-Wave Observatory (LIGO) in 2015, approximately 100 years after prediction, from merging of two black holes in a binary into a single black hole.

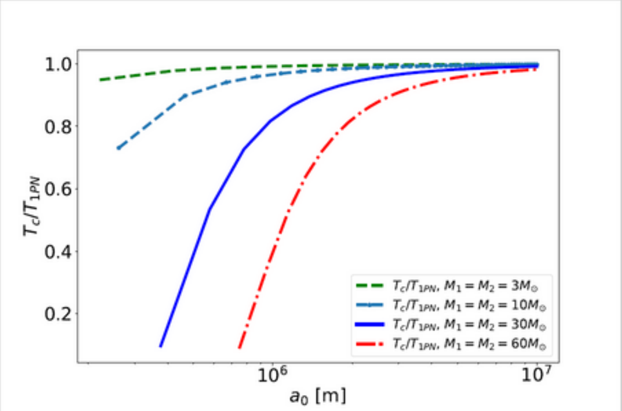


2020. Neutron Star Gravitational Wave. [image] Available at: <http://data:image/jpeg;base64,/9j/4AAQSkZJRgA... [Accessed 6 October 2020].

Here we study GWs generated by compact binary objects such as binary Neutron stars (NS-NS) systems and binary Neutron star-White dwarf (NS-WD) systems.

These compact binary systems coalesce over time due to radiation of gravitational waves, following the field equations of GR. Conservation of energy and angular momentum gives a mathematical description for the evolution of separation between the orbiting objects and eccentricity (e) of the orbit. Here we develop an improved analytical solution to the merger time for a circular binary system with an arbitrary semi-major axis (a), to the first post-Newtonian (1PN) accuracy. The results from the quadruple approximation and 1PN approximation are compared for a circular orbit (e = 0). These results show that the quadruple formula underestimates the merger time of binary systems.

We also study the polarization of GWs generated by massive binaries, which according to GR have two independent polarization states. We compute the power radiated and the strain of GW along the two polarization states from a compact binary system with its general orbital properties. We estimate the merger rates of NS-NS and NS-WD binary systems in the Milky Way using samples of 9 known NS-NS systems and 4 known NS-WD systems. We also calculate expected detection rates of these mergers by the advanced LIGO detector.



The ratio of the coalescence time scales in the quadruple approximation (Tc) to the 1PN approximation (T1P N) versus the initial semi-major axis (a0) for a circular binary system emitting GWs. Different lines are for different (equal) masses (3M , 10M , 30M and 60M) in the binary. The quadruple approximation increasingly underestimates the coalescence time compared to the 1PN approximation with increasing binary mass and decreasing semi-major axis.

The Anatomy of Ultrahigh Energy Cosmic Rays

By Prof. Razzaque

View full article : physics.aps.org | © 2020 American Physical Society | September 16, 2020 | Physics 13, 145 | DOI: 10.1103/Physics.13.145

The most energetic subatomic particles in nature with energies of 1018 eV and above are our ultrahigh-energy cosmic rays (UHECRs). The immense energy of UHECRs begs the question of how and where they are produced. The origin and chemical composition if UHECRs are still unknown, even though the UHECRs were discovered about 60 years ago.

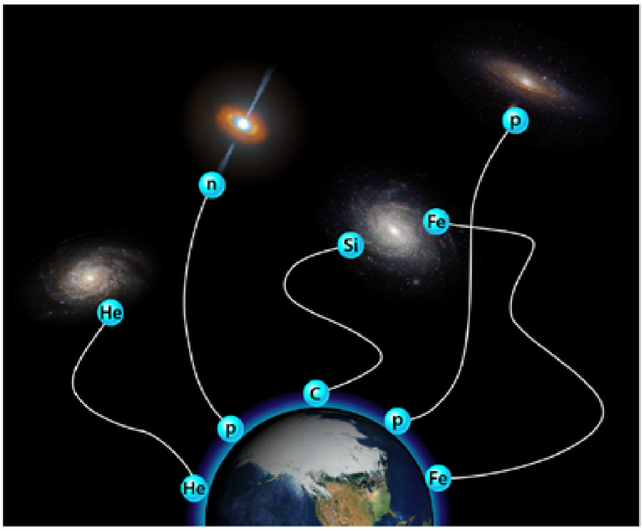


Figure 1: The latest data from the Pierre Auger Observatory suggest that ultrahigh-energy cosmic rays are a mix of nuclei that arrive from a large collection of galaxies spread evenly over the sky.
Credit: APS/Alan Stonebraker (galaxy images from NASA)

The latest data from the Pierre Auger Observatory provide the largest sample of UHECRs, with over 215 000 events. The data shows that UHECRs arrive uniformly over the sky. These results suggest that energetic star factories, called starburst galaxies, might be the most favourable source for UHECRs. The Pierre Auger Observatory in Argentina and the telescope Array in the US are the two largest cosmic-ray detectors currently operational. They cover 3000 and 700 square kilometers of instrumented areas, and such large areas are required to detect UHECRs. These UHECRs reach Earth with a flux of only about a hundred per square kilometer per year. At Ultrahigh energies, the cosmic rays break up in the atmosphere by interacting with the air molecules, creating approximately a billion or more secondary particles, which shower down on the Earth's surface. This event is called an extended air shower (EAS). See diagram.

So back to the composition of the UHECRs, at lower energies, satellite and balloon-borne experiments directly measure the primary cosmic rays, allowing them to determine the composition as predominantly protons and nuclei with heavier masses like that of Iron. Whereas, at higher energies, ground-based arrays must use computer simulations to decipher which primary particle likely produced an EAS. The collaboration has complied all their events above 2.5 x 1018 eV into a spectrum, which they find is better characterized by a four-component power-law fit than the previously used three-component fit. The new feature is a steepening or softening of the spectrum. The softening of spectrum in this intermediate region could be a hint that the mass composition of UHECRs is changing from light to heavy. Such an interpretation assumes that the UHECRs spectrum is dominated by different elements at different energies.

This type of model requires that the UHECR sources accelerate particles with an extremely flat spectrum, and that the number of these sources either remains the same over cosmic time or was even fewer at earlier times. Either way, both of these requirements are at odds with our knowledge of luminous astrophysical sources from observations in radio to gamma rays.

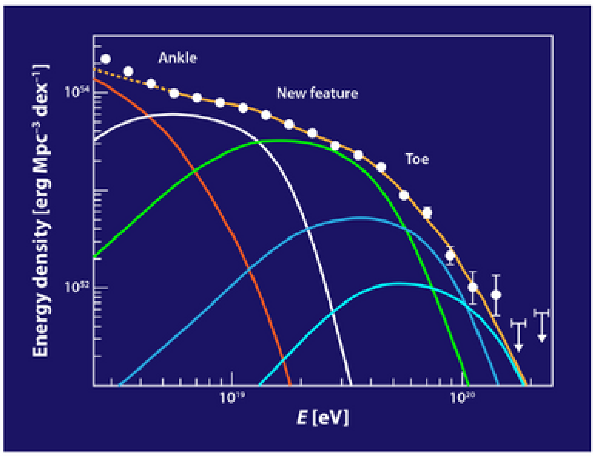
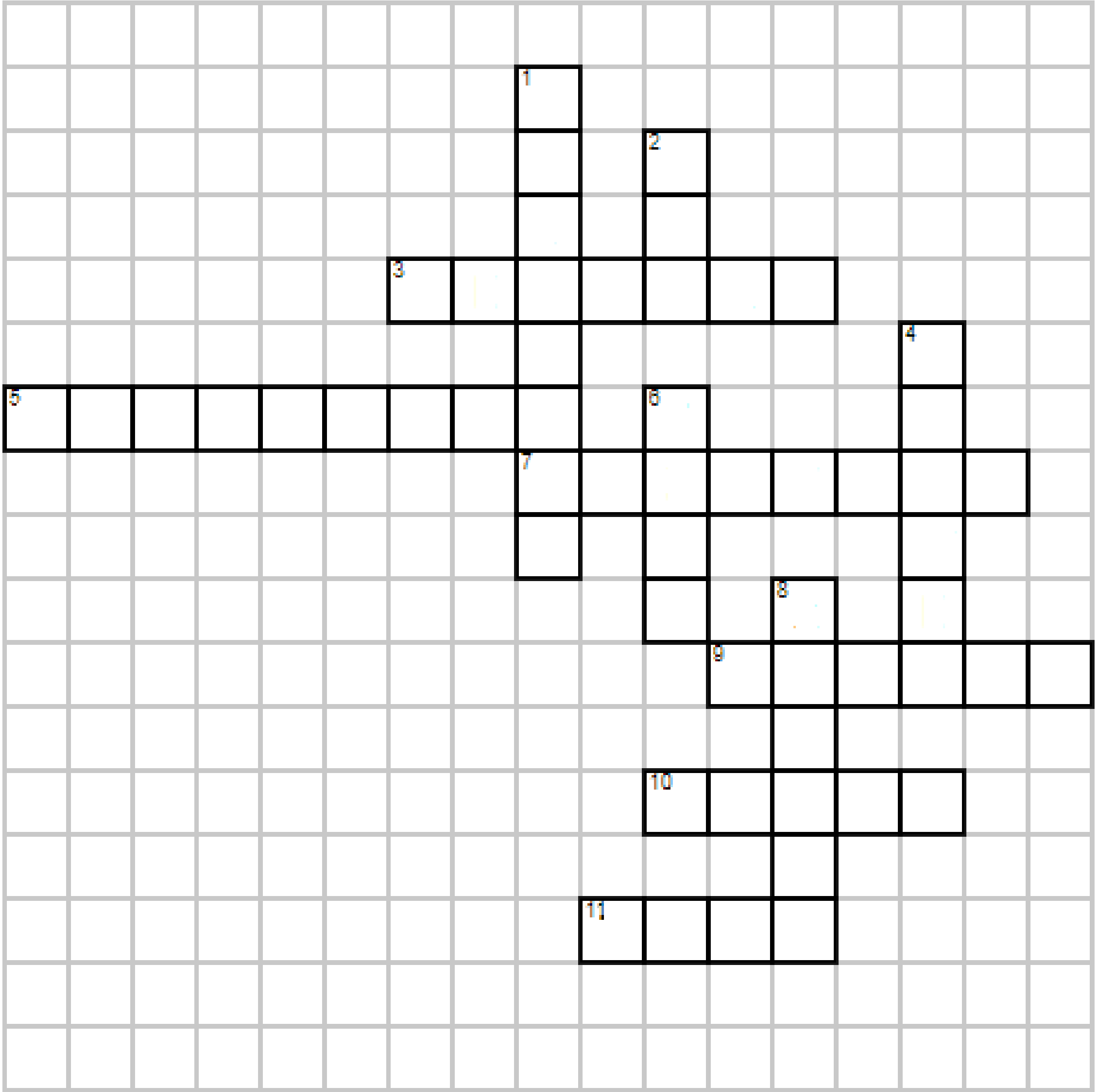


Figure 2: The UHECR spectrum compiled from the latest Auger data is shown here in terms of the energy density. The observations reveal a new feature at 13 ⍰ 1018 eV, where the spectrum steepens slightly. This break in the power-law fit occurs between two other breaks: an ankle and a toe. The shape of the spectrum suggests that different nuclei (shown in colors) contribute at different energies.
Credit: APS/Alan Stonebraker

ASTROPHYSICS THEMED WORD SEARCH

Have a go at our new astrophysics themed word search.



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CLUES:

Across

3 What planet is closest to the Sun?

5 The red-light shift is proof that our universe is....?

7 An elementary particle of half-integer spin

9 Protons and Neutrons consist of?

10 A subatomic particle, such as a photon, which has zero or integral spin

11 What space agency was founded in 1958

Down

1 What is the most abundant atom in the Universe and what is it's percentage?

2 A type of Lepton

4 According to Einstein's Theory of Special Relativity, the faster you go, the ..... time goes?

6 What is the spin of the radion?

8 The first person in space was from which country?

Across:
3- MERCURY
5- EXPANDING
7- ELECTRON
9- QUARKS
10- BOSON
11- NASA

Down:
1- HYDROGEN
2- TAU
4- SLOWER
6- ZERO
8- RUSSIA

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