Register Number:
Date:

ST. JOSEPH'S COLLEGE (AUTONOMOUS), BANGALORE- 27
III SEMESTER B.A/B.Sc -END SEMESTER EXAM - OCTOBER 2019
GENERAL ENGLISH (NSA - SPECIAL COURSE/EJP/CPE) - GE 413

TIME: $2^{1/2}$ HRS **MAX. MARKS: 70**

INSTRUCTIONS

1. **This paper is meant for students of NSA-SPECIAL Course and for IIISem CPE/EJP.**
2. This paper contains SIX printed pages and THREE sections.
3. Please indicate your stream clearly on the front page of your answer booklet.
4. You will lose marks for exceeding word limits.
5. You are permitted to use a dictionary during the exam.
6. Answer all questions.

I. Read Sam Sholtis' article 'How many Earth-like planets are around sun-like stars?'

A new study provides the most accurate estimate of the frequency that planets that are similar to Earth in size and in distance from their host star occur around stars similar to our Sun. Knowing the rate that these potentially habitable planets occur will be important for designing future astronomical missions to characterize nearby rocky planets around sun-like stars that could support life. A paper describing the model appears August 14, 2019 in *The Astronomical Journal*.

Thousands of planets have been discovered by NASA's Kepler space telescope. Kepler, which was launched in 2009 and retired by NASA in 2018 when it exhausted its fuel supply, observed hundreds of thousands of stars and identified planets outside of our solar system -- exoplanets -- by documenting transit events. Transits events occur when a planet's orbit passes between its star and the telescope, blocking some of the star's light so that it appears to dim. By measuring the amount of dimming and the duration between transits and using information about the star's properties astronomers characterize the size of the planet and the distance between the planet and its host star.

"Kepler discovered planets with a wide variety of sizes, compositions and orbits," said Eric B. Ford, professor of astronomy and astrophysics at Penn State and one of the leaders of the research team. "We want to use those discoveries to improve our understanding of planet formation and to plan future missions to search for planets that might be habitable. However, simply counting exoplanets of a given size or orbital distance is misleading, since it's much harder to find small planets far from their star than to find large planets close to their star."

To overcome that hurdle, the researchers designed a new method to infer the occurrence rate of planets across a wide range of sizes and orbital distances. The new model simulates 'universes' of stars and planets and then 'observes' these simulated universes to determine how many of the planets would have been discovered by Kepler in each 'universe.'

"We used the final catalog of planets identified by Kepler and improved star properties from the European Space Agency's Gaia spacecraft to build our simulations," said Danley Hsu, a graduate student at Penn State and the first author of the paper. "By comparing the results to the planets cataloged by Kepler, we characterized the rate of planets per star and how that depends on planet size and orbital distance. Our novel approach allowed the team to account for several effects that have not been included in previous studies."

The results of this study are particularly relevant for planning future space missions to characterize potentially Earth-like planets. While the Kepler mission discovered thousands of small planets, most are so far away that it is difficult for astronomers to learn details about their composition and atmospheres.

"Scientists are particularly interested in searching for biomarkers -- molecules indicative of life -- in the atmospheres of roughly Earth-size planets that orbit in the 'habitable-zone' of Sun-like stars," said Ford. "The habitable zone is a range of orbital distances at which the planets could support liquid water on their surfaces. Searching for evidence of life on Earth-size planets in the habitable zone of sun-like stars will require a large new space mission."

How large that mission needs to be will depend on the abundance of Earth-size planets. NASA and the National Academies of Science are currently exploring mission concepts that differ substantially in size and their capabilities. If Earth-size planets are rare, then the nearest Earth-like planets are farther away and a large, ambitious mission will be required to search for evidence of life on potentially Earth-like planets. On the other hand, if Earth-size planets are common, then there will be Earth-size exoplanets orbiting stars that are close to the sun and a relatively small observatory may be able to study their atmospheres.

"While most of the stars that Kepler observed are typically thousands of light years away from the Sun, Kepler observed a large enough sample of stars that we can perform a rigorous statistical analysis to estimate of the rate of Earth-size planets in the habitable zone of nearby sun-like stars." said Hsu.

Based on their simulations, the researchers estimate that planets very close to Earth in size, from three-quarters to one-and-a-half times the size of earth, with orbital periods ranging from 237 to 500 days, occur around approximately one in four stars. Importantly, their model quantifies the uncertainty in that estimate. They recommend that future planet-finding missions plan for a true rate that ranges from as low about one planet for every 33 stars to as high as nearly one planet for every two stars.

"Knowing how often we should expect to find planets of a given size and orbital period is extremely helpful for optimize surveys for exoplanets and the design of upcoming space missions to maximize their chance of success," said Ford. "Penn State is a leader in brining state-of-the-art statistical and computational methods to the analysis of astronomical observations to address these sorts of questions. Our Institute for CyberScience (ICS) and Center for Astrostatistics (CASt) provide infrastructure and support that makes these types of projects possible."

The Center for Exoplanets and Habitable Worlds at Penn State includes faculty and students who are involved in the full spectrum of extrasolar planet research. A Penn State team built the Habitable Zone Planet Finder, an instrument to search for low-mass planets around cool stars, which recently began science operations at the Hobby-Eberly Telescope, of which Penn State is a founding partner. A second Penn State-built spectrograph is in being tested before it begins a complementary survey to discover and measure the masses of low-mass planets around sun-like stars. This study makes predictions for what such planet surveys will find and will help provide context for interpreting their results.

I.A. Answer ANY TWO of the following questions in about 100words each: (2x5=10)

1. What is your understanding of “exoplanets”, “transit events” and “biomarkers”? Is this article scientific enough? How would a layperson relate to this? Explain.

2. Faculty and students of The Center for Exoplanets and Habitable Worlds at Penn State are involved in the full spectrum of extrasolar planet research.Don’t you think this research is a waste of human resource, infrastructure and economy? Justify with reasons.

3. Prof. Eric Ford’s statement, "We want to use those discoveries to improve our understanding of planet formation and to plan future missions to search for planets that might be habitable” seems very ironic in the light of how we are destroying our habitable planet Earth. What is your response to this? Put your argument across with relevant examples.

II. Read Neel V. Patel’s article ‘Stephen Hawking’s final scientific paper explores the mysteries of the multiverse—but it’s not a big deal.’

Stephen Hawking's death in March incited us all take a moment and think about the famed physicist's impact on the scientific world, and the myriad ways his research affected the way we think about the universe. As it turns out, he wasn't exactly done. Hawking's final paper was finally published Wednesday, in the *Journal of High Energy Physics*, and while it's not exactly the science-shattering work many outlets are reporting it to be, it still puts a pretty interesting, Hawking-esque spin on one of theoretical physics' most discussed concepts: the multiverse.

The idea that multiple parallel universes exist originates out of inflation, the incredibly rapid expansion of the universe right after the Big Bang, over repeated bursts at speeds faster than light. Many scientists think during these bursts, the smallest blips in energy at the quantum level swelled into larger pockets of space-time—effectively entire individual universes which are possibly, conceivably found everywhere, within an ever-expanding larger multiverse that houses them.

Subscribing to that view essentially means assuming that, if the multiverse continues to inflate, individual universes are being created ad infinitum. For some, that's a tough pill to swallow. And you can count Hawking and his co-author, Thomas Hertog from the University of Leuven in Belgium, among those skeptics.

So Hawking and Hertog created a framework for a simpler model of the multiverse that limits how many new universes could form, and ensures they adhere to the same laws of physics as our known universe. As opposed to older theories of multiverse that called for universes empty and full, volatile and boring, dead in an instant or with long lives ahead of them, these would be truer to the layman's conception of parallel universes.

The new paper is sort of an update of the "no-boundary" proposal, something Hawking and American physicist James Hartle worked on in the 1980s. Using new mathematics derived from string theory that weren't available in the 80s, Hawking and Hertog reach the conclusion our own universe is compatible with this idea, and that our multiverse is smaller than what we might expect from eternal inflation.

"Our model fits in nicely with the theory of inflation that says our universe underwent a very rapid period of expansion in its earliest stages," says Hertog. "But our model goes radically against the prevailing extrapolation of inflation that led to a multiverse."

It's a pretty neat idea! It's just not as exceptional as one outside the field might think at first glance. For one, it remains a theoretical paper; there's no real way to test it out or make any sort of observations of this cosmology. In practical terms, it's not practical at all. The original "no-boundary" proposal is speculative, and by extension so are these latest conclusions.

"The main conclusion of the paper is a conjecture and not proven mathematically," says Avi Loeb, a theoretical physicist at Harvard University and a noted skeptic of inflation theory. "It is a stimulating but not revolutionary paper."

Moreover, it's not exactly a bombshell of a framework. "This paper is rather the culmination of a line of research we had been pursuing for a number of years driven to a large extent by the problems associated with the multiverse," says Hertog. It's not a flashbulb epiphany that just appeared in the authors' brains in an instant, but rather an example of the slow burn of theoretical physics.

Like Loeb, Andrei Linde, a theoretical physicist based at Stanford University and a pioneer of inflation theory, thinks it's important to frame the findings as conjecture, not a final statement. But he does say they "may still be very significant, and, as many prolific statements made by Hawking, it may initiate productive work in this direction. This is an extremely complicated field of research, so it is very important to know Stephen Hawking's thoughts on that."

Loeb also finds it encouraging that the paper tampers down on the multiverse theory's "problematic" suggestion that everything that can happen will happen an infinite number of times. "This theory is not falsifiable, because everything is possible," he says. "The virtue of traditional physics is that its theories could be falsified by experiments. Science is a learning experience. If

we give up on the possibility of falsifying our ideas, then we will not learn anything from experiments."

But of course, Hawking and Hertog's theory is also not falsifiable.

Instead, the excitement over this paper might really just be the fact that it's Hawking's last paper. The paper was long-available to the physics community to read and discuss, and only was only submitted to JHEP and accepted for publication on April 20. This new spike in interest is really just among the public, eager to see the last thing Hawking wrote. That certainly doesn't diminish its impact, but it would be a bit foolish to make it out to be larger than it is.

It's a bummer Hawking is no longer around to deliver something more exceptional. "Of course I have enormously enjoyed my collaboration with Hawking," said Hertog. "But I am sad Stephen is no longer with us today to celebrate the publication of this paper and to participate in our future adventures in cosmology." He's certainly far from the only one.

II.A. Answer ANY THREE of the following questions in about 150-200 words each: (3x15=45)

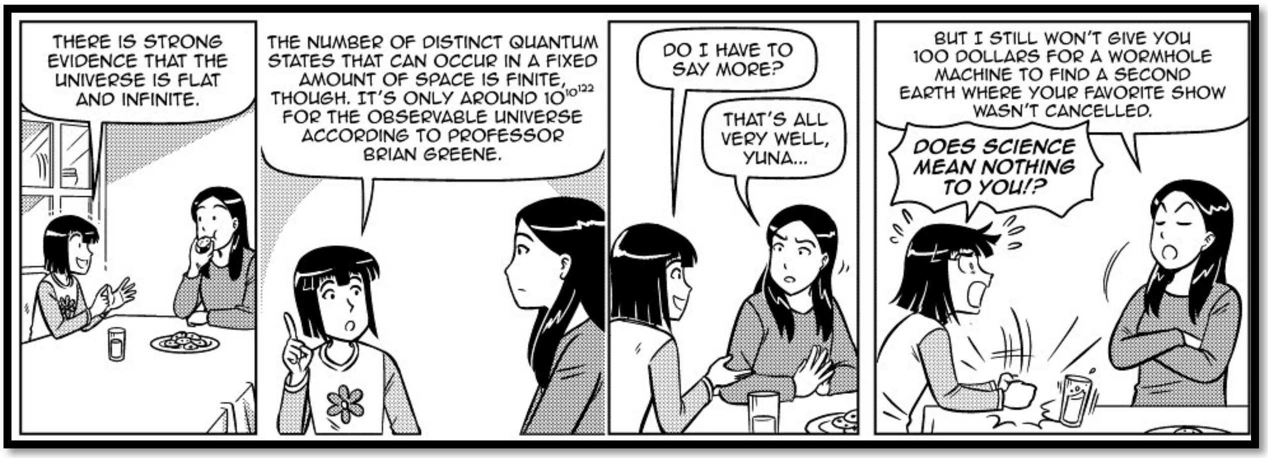
4. "Stephen Hawking's posthumous paper is more like a ruminative twist on multiverse theory, but that's just fine." How do you comprehend this statement in the light of Neel Patel's article that you read? Explain.

5. According to Andrei Linde, a theoretical physicist based at Stanford University and a pioneer of inflation theory, "it is important to frame the findings (of Stephen Hawking) as conjecture, not a final statement."Do you agree with this viewpoint? Why?

6. "Ifwe give up on the possibility of falsifying our ideas, then we will not learn anything from experiments." Why should a theory be falsifiable? Justify your answer with relevant examples.

7. What are some of the interesting things that you read/ listened to/ watched during this semester that helped you in framing better arguments both verbally and through writing? Were there any areas of contention that you encountered? Recall.

III. Read the following comic strip and respond in about 200-250 words: (1x15=15)



[Panel 1: YUNA: THERE IS STRONG EVIDENCE THAT THE UNIVERSE IS FLAT AND INFINITE.

Panel 2: YUNA: THE NUMBER OF DISTINCT QUANTUM STATES THAT CAN OCCUR IN A FIXED AMOUNT OF SPACE IS FINITE THOUGH. IT'S ONLY AROUND 10 TO THE POWER OF 10 TO THE POWER OF 122 FOR THE OBSERVABLE UNIVERSE ACCORDING TO PROFESSOR BRIAN GREENE.

Panel 3: YUNA: DO I HAVE TO SAY MORE? ADULT: THAT'S ALL VERY WELL, YUNA . . .

Panel 4: ADULT: BUT I STILL WON'T GIVE YOU 100 DOLLARS FOR A WORMHOLE MACHINE TO FIND A SECOND EARTH WHERE YOUR FAVORITE SHOW WASN'T CANCELLED. YUNA: DOES SCIENCE MEAN NOTHING TO YOU!?]

8. Is the above comic strip about science? Explain. What are your other observations of the comic strip? Identify the tone of the comic strip.

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