Can computer bridge between the gap between ideal and fact?

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The universe exhibits a very extreme environment in several aspects.

The temperature in interstellar matter is around minus 200 degrees Celsius, contrasting with several billions of degrees Celsius in Supernovae. As for density, If you take an atom-size cube from the neutron star, it weighs the cube as thick as human hair taken from the Earth and the size of Mt.Fuji extracted from the very sparse universe! This extraordinary variety of environments in the universe is exceedingly interesting to me. My primary interest lies in high-energy astrophysics, where I investigate the origin of extremely energetic phenomena such as gamma-ray bursts, which are the most energetic events in the current universe, and the mergers of neutron stars or black holes, both of which are highly dense celestial objects. These extreme phenomena cannot be explained from the viewpoint of our knowledge of physics on the Earth and that attracts me very much. I believe it not only challenges our understanding but also provides insights into the fundamental principles governing the universe. The natural sciences rely on observing phenomena, formulating hypotheses, and verifying them through experiments or observations. Yet, there sometimes are gaps among these processes. A well-known and instructive example is Einstein's general relativity and the resulting gravitational wave. About 100 years ago, Einstein devised general relativity and predicted that a gravitational wave must break out when enormous objects collide with each other through a gravitational field, analogous to light traveling through the electromagnetic field. I was impressed to hear this episode and thought about how powerful and beautiful theoretical physics is when I determined my major.

Bridging the gap between hypothesis and observation often requires combining theory, observation, and simulation. A significant challenge in astrophysics is the shortage of observational data. The universe's hierarchical structure, from the Earth to galaxy clusters, requires various telescopes and satellites to capture its scales. However, the cost of developing new telescopes and technology limits our capabilities. Computational simulation has emerged as a third approach alongside experiments and theory. It allows us to gather a lot of novel information, such as imaging faint and distant stars or studying past eras beyond direct observation. Despite its advantages, many papers present simulation results without deep consideration or insights that can be inferred from those results. My work focuses on bridging the gap between numerical and analytical approaches and integrating simulations with observational results. I do not think each of them has to mean itself, and by combining these three approaches, we can understand the universe, physics, and ultimately, how we were born.

However, when I was a high school student, it never occurred to me that I would study astrophysics. The universe seemed irrelevant to daily life, and I doubted the significance of studying it. The vast distances and extreme conditions of space felt disconnected from the immediate concerns of everyday life, like school, relationships, and future career choices. My attitude changed through interactions with university friends and teachers. Conversations and lectures helped me understand that while basic sciences may not directly affect our daily lives, they support most technologies and applied sciences. Progress in these fields may seem subtle or indirect but often brings unexpected benefits. For instance, elementary particle physicists at CERN invented the World Wide Web to manage vast amounts of data, revolutionizing global communication and information sharing. This realization that basic science drives technological innovation and societal progress was pivotal in changing my perspective. Also, one of my friends who majored in mathematics was asked for advice by an AI start-up company even though he majored in pure mathematics, and this kind of logical thinking ability and expertise can be useful in areas not necessarily related to research.

Studying basic sciences helps us understand the world around us and lays the groundwork for technological advancements. For instance, the principles of quantum mechanics, once considered purely theoretical, now underpin technologies like semiconductors, lasers, and magnetic resonance imaging (MRI). Similarly, research in electromagnetism in the 19th century led to the development of electric power, telecommunications, and modern electronics.

One of the benefits of studying astrophysics is realizing Earth's peculiarity and understanding our origins by combining insights from extreme environments in the universe. This fundamental question has intrigued humanity since ancient times and fuels my interest. The Large Hadron Collider (LHC) at CERN, designed to study fundamental particles, led to the invention of the World Wide Web. These unexpected benefits highlight the far-reaching impacts of basic science research.

By understanding the universe through extreme environments, we can inspire the next generation to engage with science. These extreme conditions not only challenge our understanding but also spark our curiosity and drive us to seek answers. Studying basic sciences helps us learn how to think critically and live our lives based on evidence and logical analysis. As we continue to explore the cosmos, the insights gained from these studies will undoubtedly lead to new technologies and discoveries that benefit all of humanity.

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