Relativity and Concluding Activities

Dr. Sarah's Differential Geometry

Welcoming Environment: Actively listen to others and encourage everyone to participate! Keep an open mind as you engage in our class activities, explore consensus and employ collective thinking across barriers. Maintain a professional tone, show respect and courtesy, and make your contributions matter.

Try to help each other! Discuss and keep track of any questions your group has. Feel free to ask me questions during group work time as well as when I bring us back together.

1. Discuss and review how did curvature arise in the curves section?

2. Discuss and review how did various curvatures arise in the surface section?

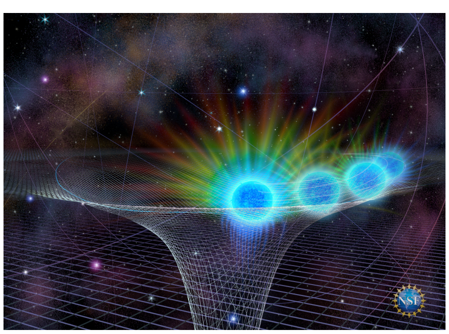
3. Discuss and review how do various curvatures relate to spacetime and relativity?

4. Mercury was known to behave differently than predicted by Newtonian equations modeling elliptical orbits of planets. Mercury's orbit is approximately an ellipse, but the closest point to the sun, called a perihelion, advances slowly. This advance is called a precession. In Richard L Faber's section on orbits in general relativity from *Differential Geometry and Relativity Theory* [pp. 223–230], Faber calculates the orbit of a planet under the assumption of general relativity. Following Albert Einstein's 1916 paper on general relativity, Faber assumes a planet follows a timelike geodesic. Faber considers the Schwarzschild metric to obtain an elliptical orbital equation and an equation for the amount of precession, measured in seconds per century. Faber then compares theoretical predictions to observational data for Mercury, Venus, Earth and the asteroid Icarus:

planet	general relativity	observed
Earth	3.8	5.0 ± 1.2
Icarus	10.3	$9.8 \pm .8$
Mercury	43.03	$43.11 \pm .45$
Venus	8.6	8.4 ± 4.8

Do the theoretical predictions mesh with the observational data? Mercury provided the first empirical evidence in support of the theory of relativity!

5. Here is a different image, but with some similar elements as I showed you on the very first day of class from the artist's rendering of S0-2 and supermassive black hole by Nicolle Fuller/National Science Foundation:



The title of the research news article is "Astronomers see evidence of Einstein's theories in star orbiting massive black hole." The star is known as S0-2, which is the blue and green object. It orbits the supermassive black hole at the heart of our Milky Way galaxy once every 16 years. After 24 years of observations over time that measured the star's precise positions and the wavelengths of its light, astronomers have compared it to Einstein's theory of relativity. S0-2 made its closest approach to the supermassive black hole in 2018. Read the following, which appeared in the article:

> More than 100 years ago, Albert Einstein predicted that light is deflected by extremely massive objects, but there is no way to test such powerful effects on Earth. Instead, astronomers turn their attention to where the action happens, such as stars orbiting black holes.
>
> The star S0-2 is a perfect test candidate, as it orbits the supermassive black hole at the heart of our Milky Way galaxy once every 16 years. After 24 years of observations that measured the star's precise positions and the wavelengths of its light, astronomers have shown Einstein's predictions, once again, hold up.
>
> An international team of astronomers co-led by UCLA professor Andrea Ghez published the results of the study in *Science*.
>
> "Einstein's right, at least for now," said Ghez. "Our observations are consistent with Einstein's theory of general relativity. However, his theory is definitely showing vulnerability. It cannot fully explain gravity inside a black hole, and at some point we will need to move beyond Einstein's theory to a more comprehensive theory of gravity that explains what a black hole is."
>
> ... Ghez and her collaborators have verified with a high level of confidence Einstein's idea about strong gravity.

In 2020, Ghez became the fourth woman to be awarded the Nobel Prize in Physics. Einstein won in 1921. Consider the above as well as the curves and surfaces represented in the image and discuss.

6. Search `news.google.com` for general relativity and take a bit of time to look through and find a title that interests you.

7. Discuss a title from the news with your group.

8. Discuss what most interested you in the curves section of the class.

9. Discuss what most interested you in the surfaces section of the class.

10. Discuss what most interested you in the geometry of spacetime and relativity section of the class.

11. In our catalog description

    > This is an introductory course in the differential geometry of curves and surfaces in space, presenting both theoretical and computational components, intrinsic and extrinsic viewpoints, and numerous applications. The geometry of space-time will also be considered.

    the wording of "introductory course" is intentional as there are so many directions we could extend related content, both theoretically and in applications. If you have the time and the opportunity to do so in the future, what topic related to differential geometry are you most interested in learning more about? Discuss with your group.

12. Consider the remaining items in and out of class and ask me any questions you have!

	Class Monday	Between Classes (by just before 3pm Wed.)	Class Wednesday	Between Classes (by just before 3pm Mon.)
				-course survey -course evaluations -re-engage 13
4/29–5/1	work on final project or optional revisions	-complete any open items	stand up & share final project idea or title	-final project video
5/6	turn in video presentation on ASULearn by the beginning of our 2pm assigned time during the assigned time 2–4:30, conduct 4 video project peer reviews and a self-evaluation (optional) revise and reflect on one in-class assessment, one of the first three projects			