How to Travel on an Interstellar Adventure

Exploring Light Intensity and Distance

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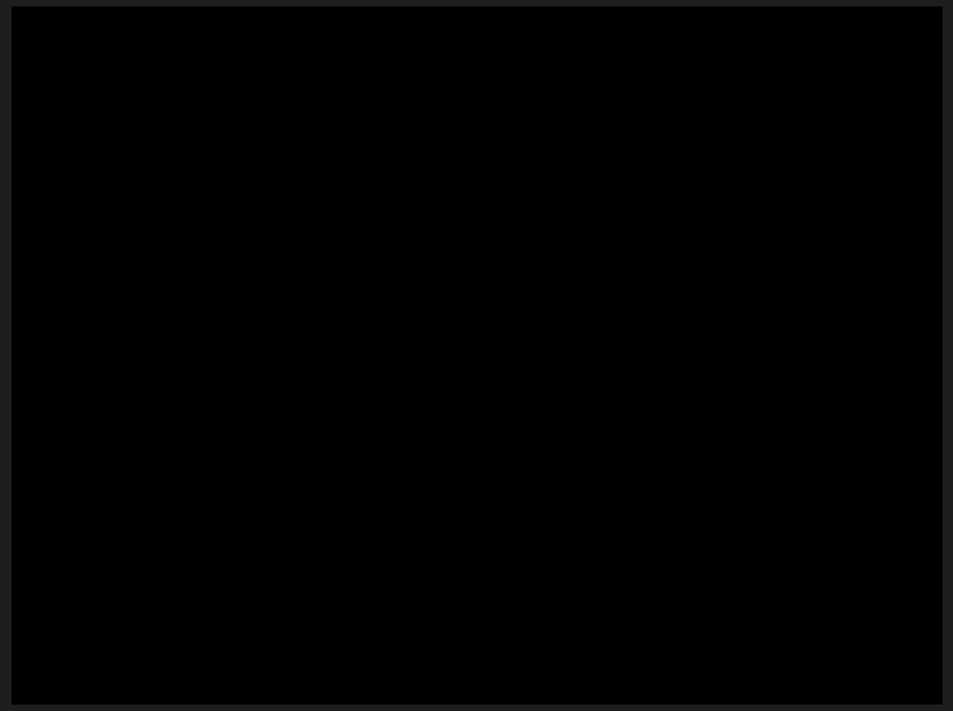
Agenda

Chemical Propulsion
Types of Propulsion Methods
Sound Demo
Light Intensity Lab Investigation
Data Analysis
Extensions
Questions??

Chemical Propulsion Methods

Current chemical propulsion technology can not get us past Mars.



Chemical Propulsion Methods

DEMO:

Take your strongest pointer finger and tap it on the table as fast as you can. OK, go faster. Nope, you're going to have to go faster…

Hmm, there seems to be a limit to how fast one finger can go. Let's try adding the pointer finger of your other hand. Now, with those two fingers, can you tap the table faster?

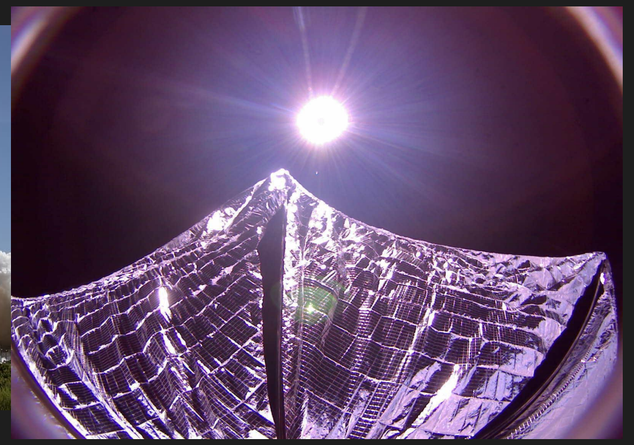
Types of Propulsion Methods

Chemical

using chemical reactions to produce thrust to push a spacecraft forward

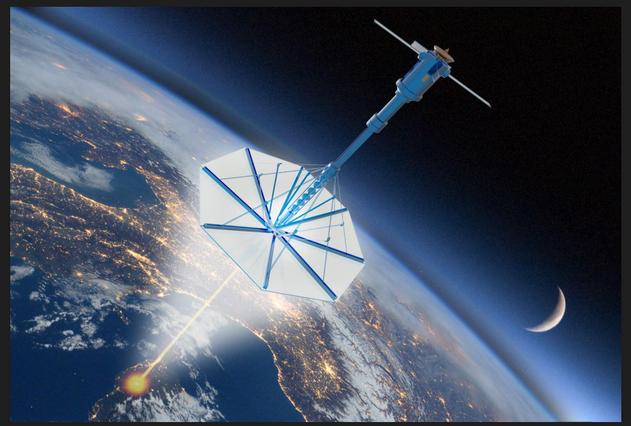
Light

using photons to generate thrust



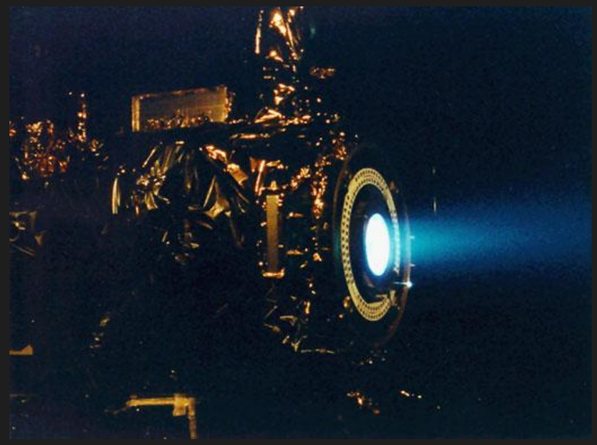
Laser

using laser beams to generate thrust

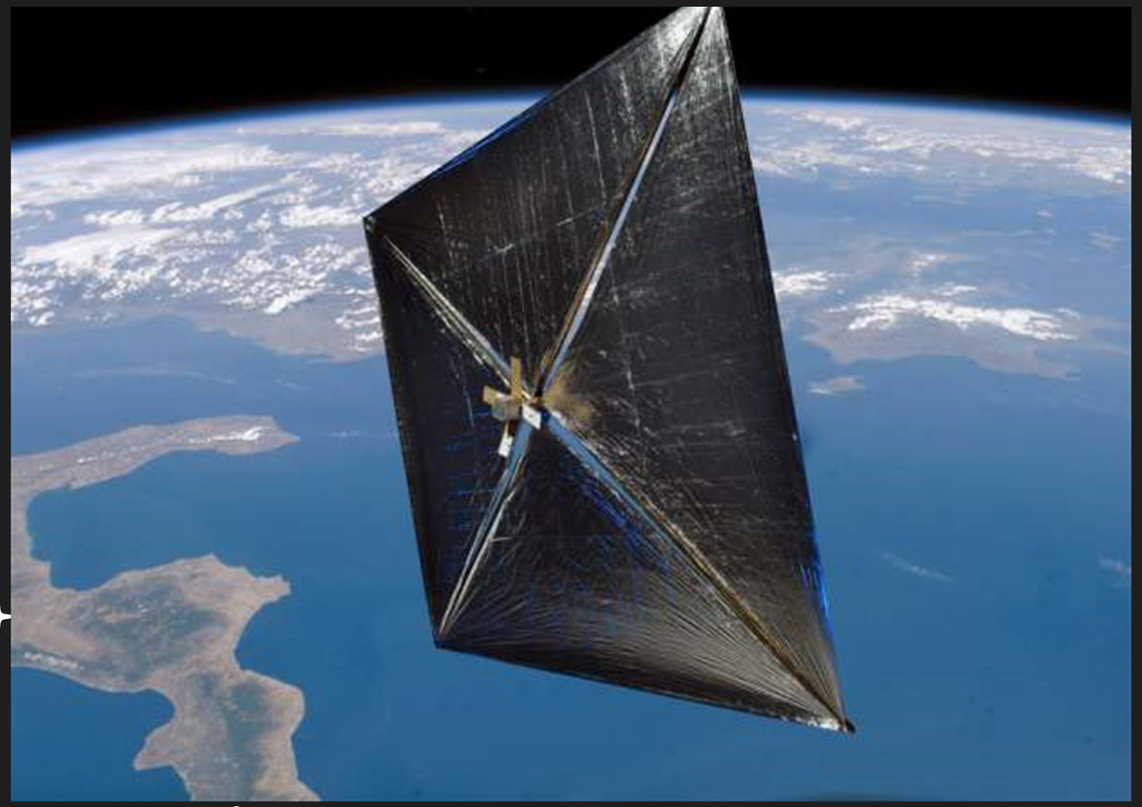


Ion

using electrically charged particles to create thrust



Solar Sails

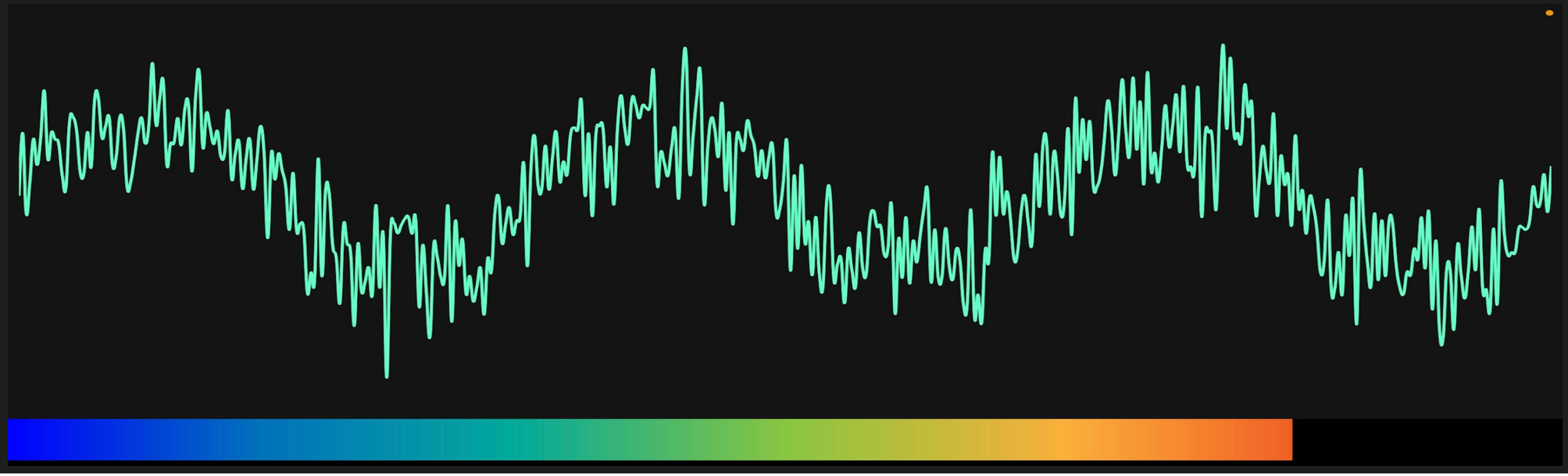


We can harness light to power our spacecraft with solar sails.

But what happens as you get further away from the sun?

Sound Demo

- Have someone sing or play a song.
- As musician moves farther away, what happens to the sound?
- If this is what happens to sound waves, what do you think would happen with light ?



Investigating Light and Distance

Materials

- Flashlight, various types of light bulbs, lasers
- Measuring tape or ruler
- PocketLab Voyager Sensor and Computer (or another method of measuring light intensity)

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Procedure

1. Record your hypothesis to predict what will happen to the intensity of light as distance from the light source increases.

2. Place the light source on a flat surface.

3. Measure and mark every 0.2 meters (20 cm) with tape. The PocketLab will be moved to measure the light intensity at different distances from the light source.

Procedure

4. Connect a PocketLab.

5. Set the graph to record light intensity and rangefinder. Click record.

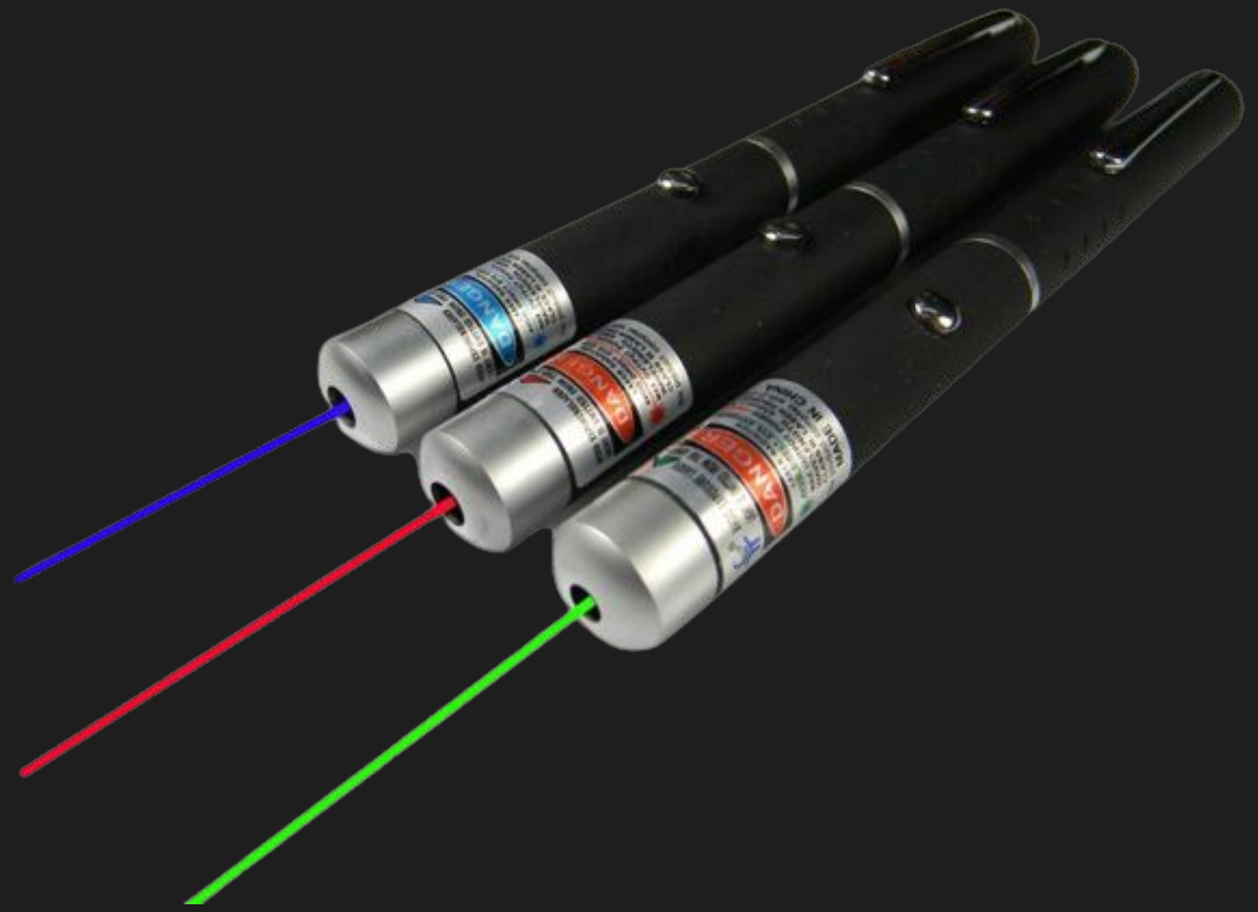
6. Turn on the light and place the PocketLab at the closest tape to the light source.

7. Every few seconds, move the PocketLab back a line.

8. After gathering all measurements, save the data.

Procedure

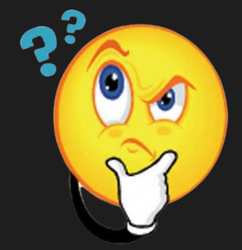
Repeat the same procedure with different colored lasers



Data Collection and Analysis

1. What do you observe?
2. Record the distance from the light source and the corresponding light intensity
3. Graph the values showing the relationship between the distance (x) and light intensity (y).

Analysis



1. What happened to the light intensity as the distance increased? Was it different for the different types of light?

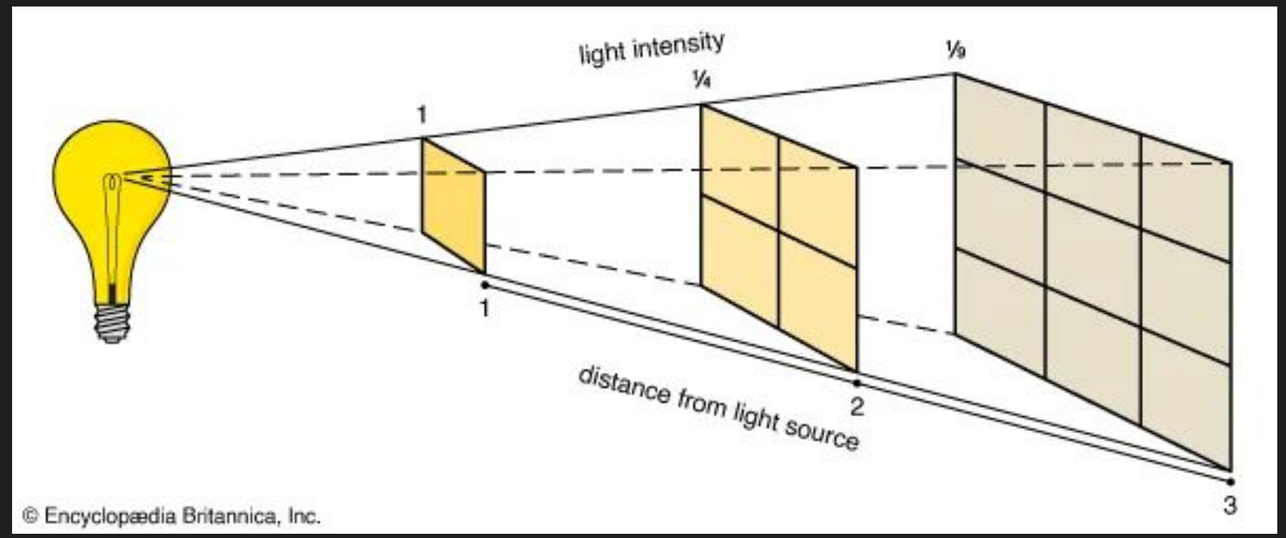
2. How did your results compare to your hypothesis?

3. How would this relationship affect spacecraft propelled by solar sails?

4. What would be the advantage of using lasers for propulsion instead?

Inverse Square Law

- A spacecraft with solar panels and a Solar Sail both require energy from the sun
- The inverse square law is a mathematical relationship between distance and the intensity (brightness) of the light.
- The further away a spacecraft is from the sun, the less light energy is available
- How will this impact a spacecraft traveling away from the sun?



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Laser Propulsion Demo

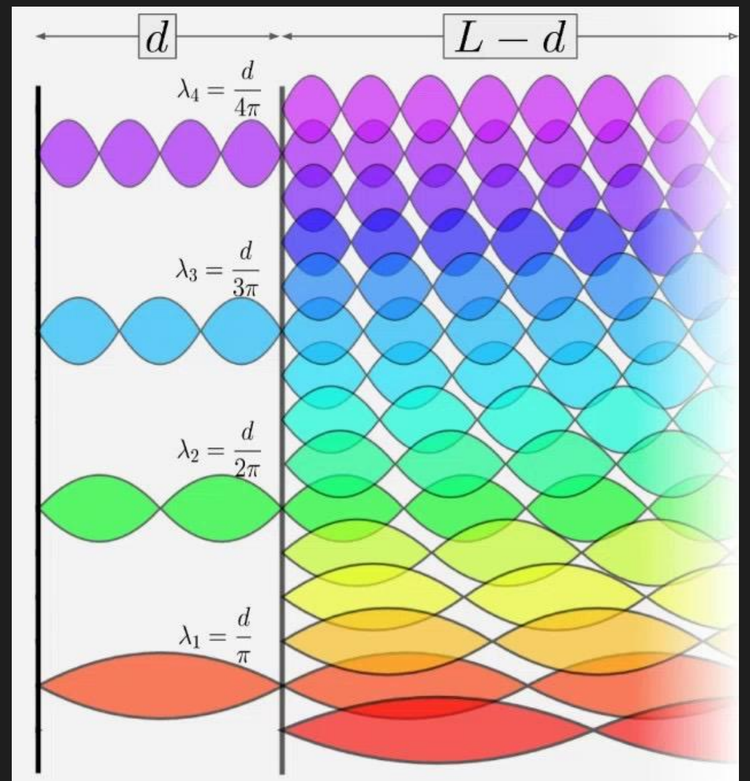
Is light energy powerful enough?

Let’s look at what light can do!

Materials needed:

- Black balloons
- White balloon
- Powerful laser light

Embracing the Unknown- Casimir Effect



(Fig.1) K. Kingsbury "The Casimir Effect: A Comprehensive Exercise" (2009)

- When 2 conductive metal plates are extremely close (approx. 10 nanometers) in a vacuum
- Quantum fluctuations cause photons to pop into the space around the plates (no one is sure why this happens yet!)
- Because only certain wavelengths are allowed between the plates, the pressure outside is greater than the pressure inside
- This energy and pressure difference causes the plates to push together

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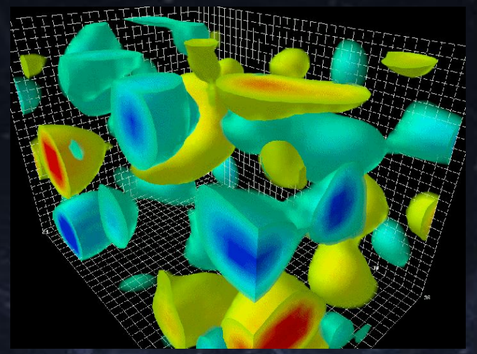
Quantum Vacuum: Empty Space Isn't Empty…

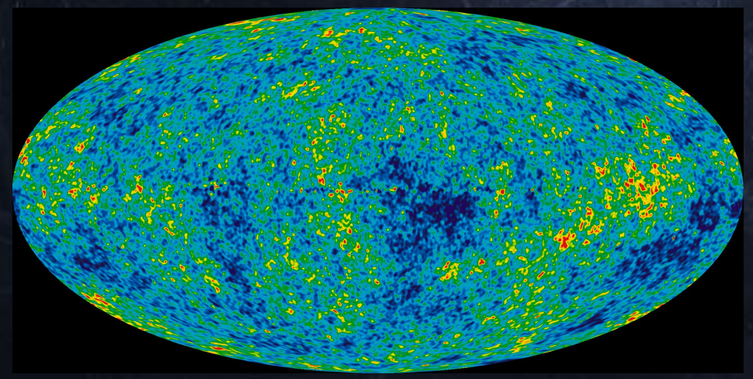
$$\Delta x \Delta p \geq \frac{\hbar}{2}$$

Heisenberg's uncertainty principle

computer simulation of "nothing"



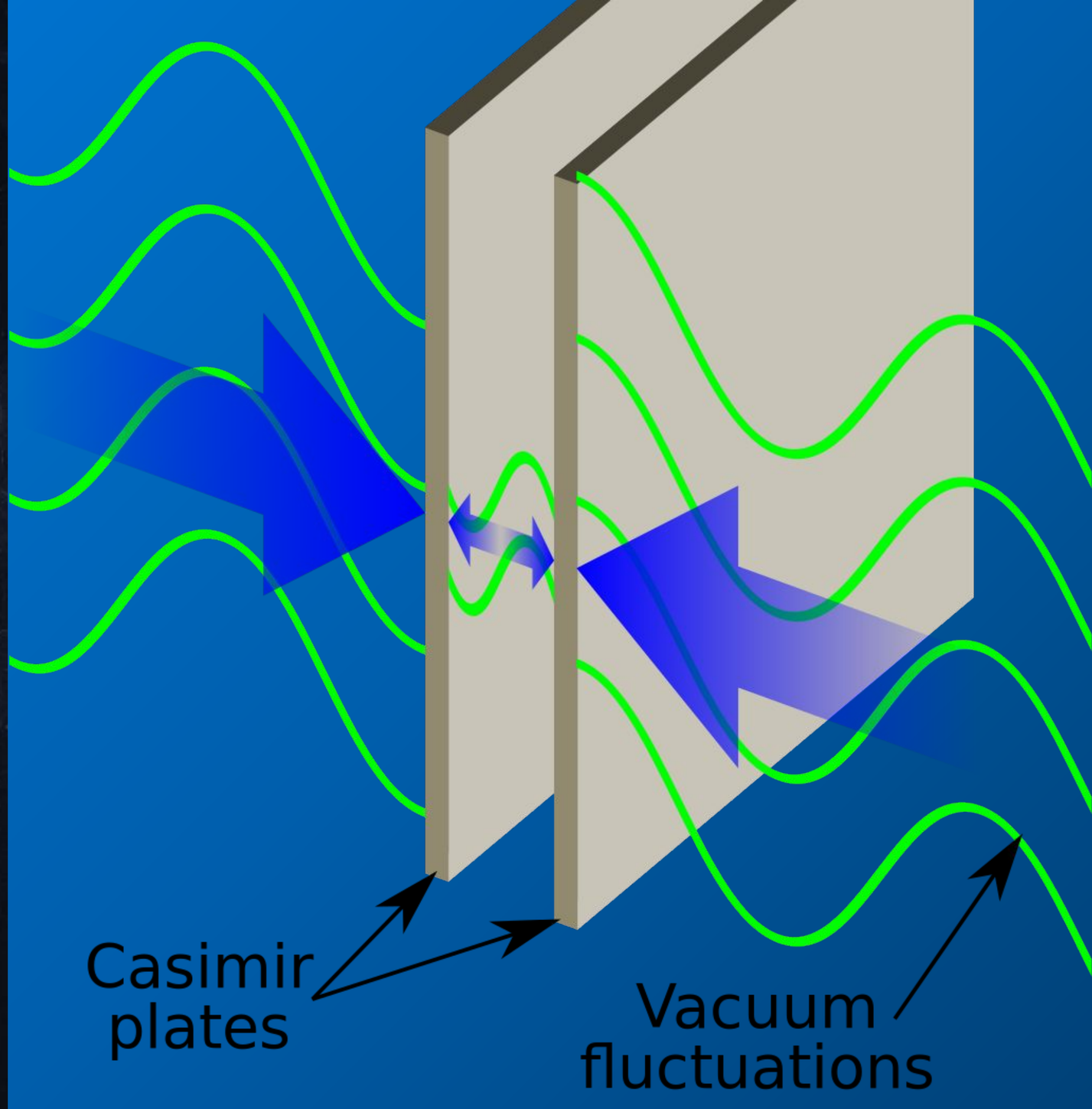
"empty" space filled with sea of virtual particle/photon pairs that pop into and out of existence.



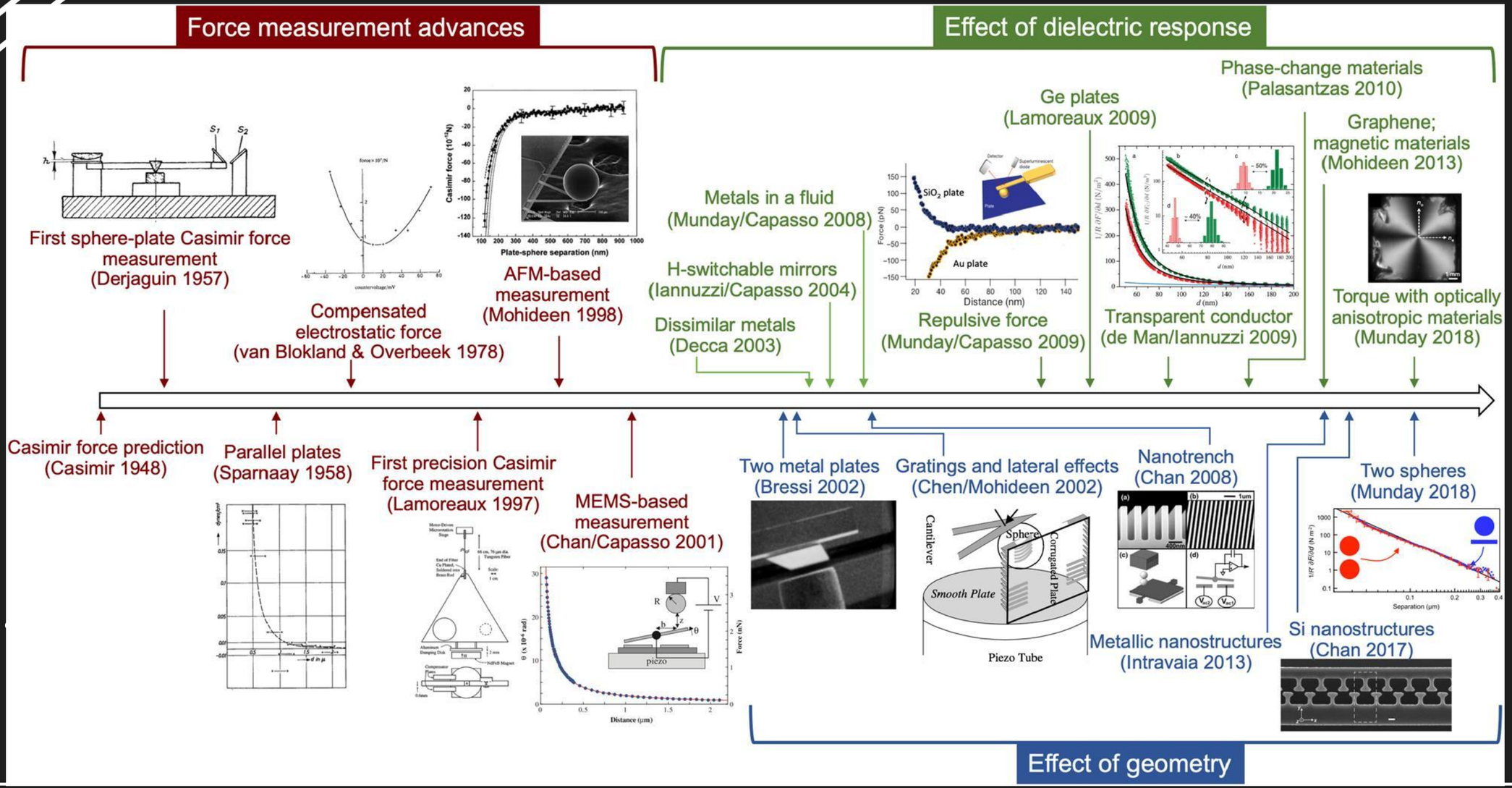
13.77 billion year old temperature fluctuations in infant universe (WMAP data)

$$\frac{F_c}{A} = \frac{\hbar c \pi^2}{240 a^4}$$

Casimir Force



A Brief History of Casimir Force Measurement



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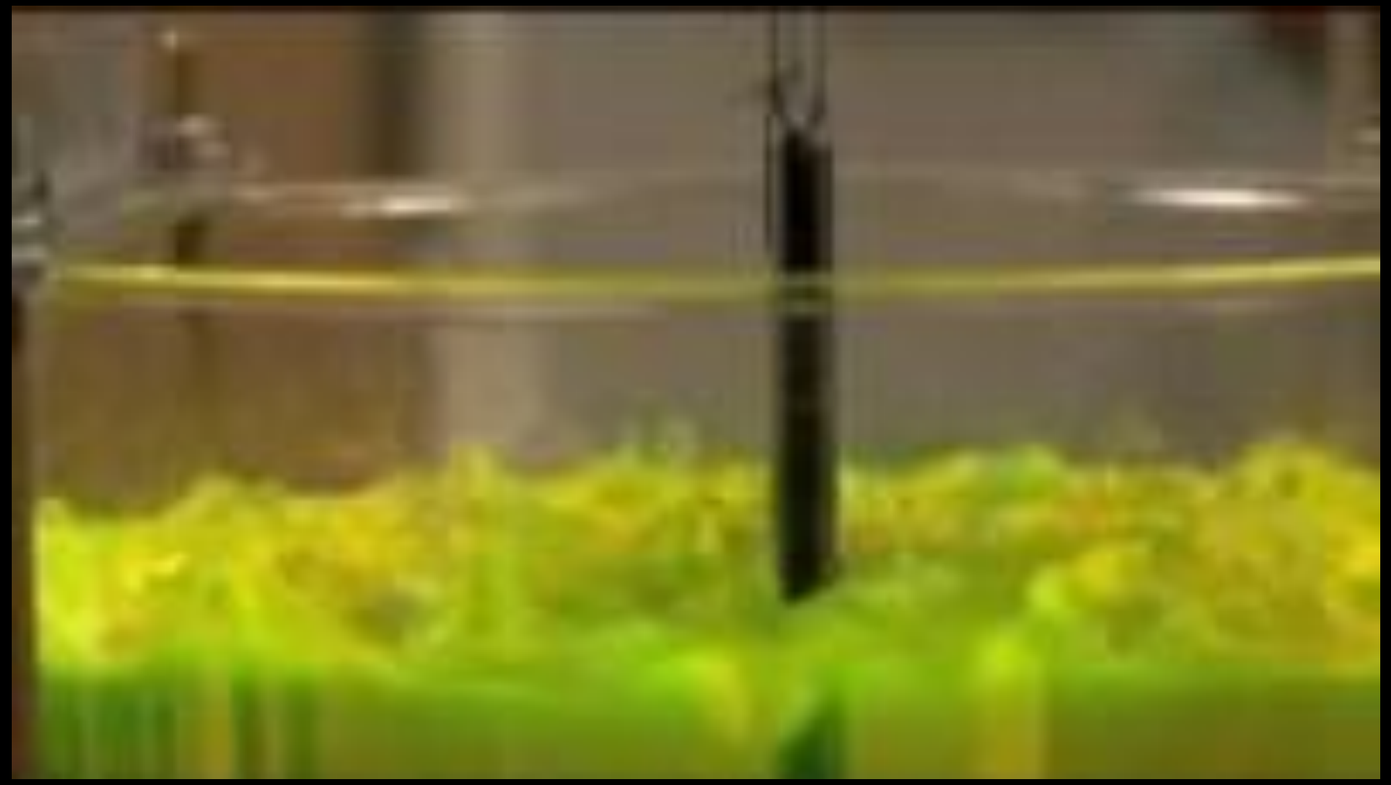
Water Wave Analog of Casimir Effect



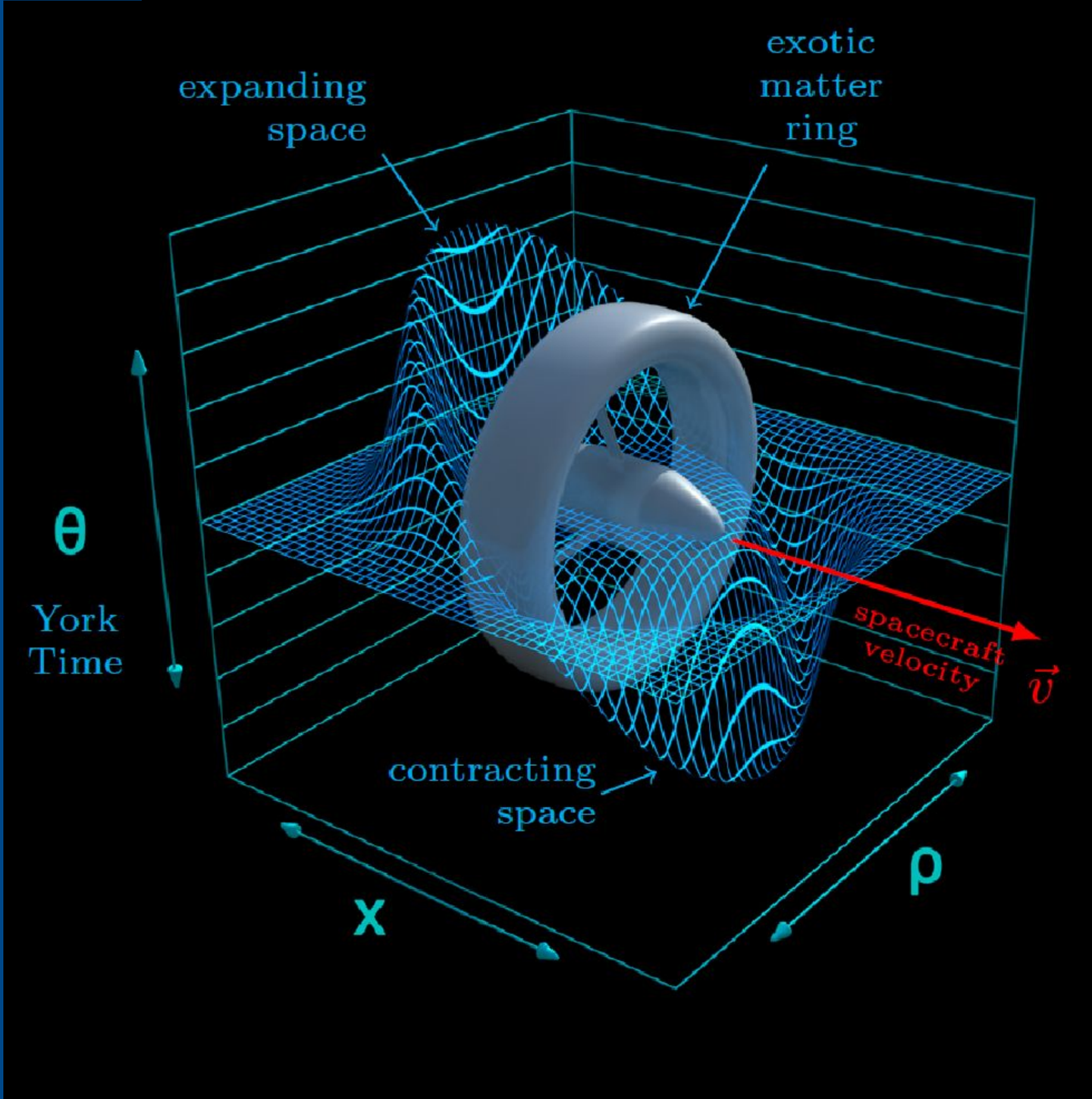
https://www.youtube.com/watch?v=H-GnwnEnLCA

Inflation: Alcubierre Metric

- First physics model published in 1994
  - Concept uses expansion and contraction of space to implement trick
  - Requires ring of exotic matter around central spacecraft

- Terrestrial analog: travelator at an airport

Image by Trougnouf - own work, CC BY 4.0, https://commons.wikimedia.org/w/index.php?curid=71365118



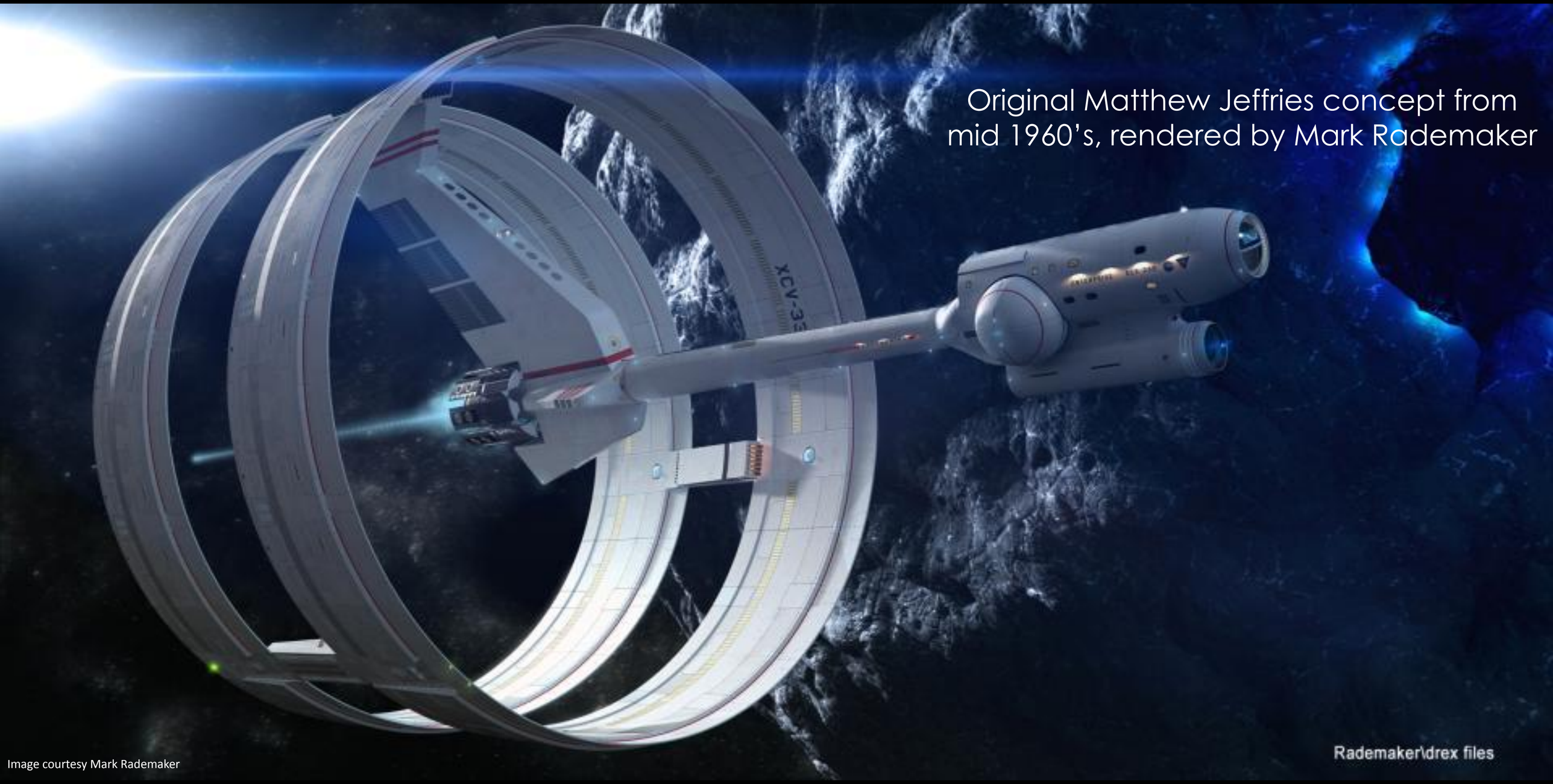
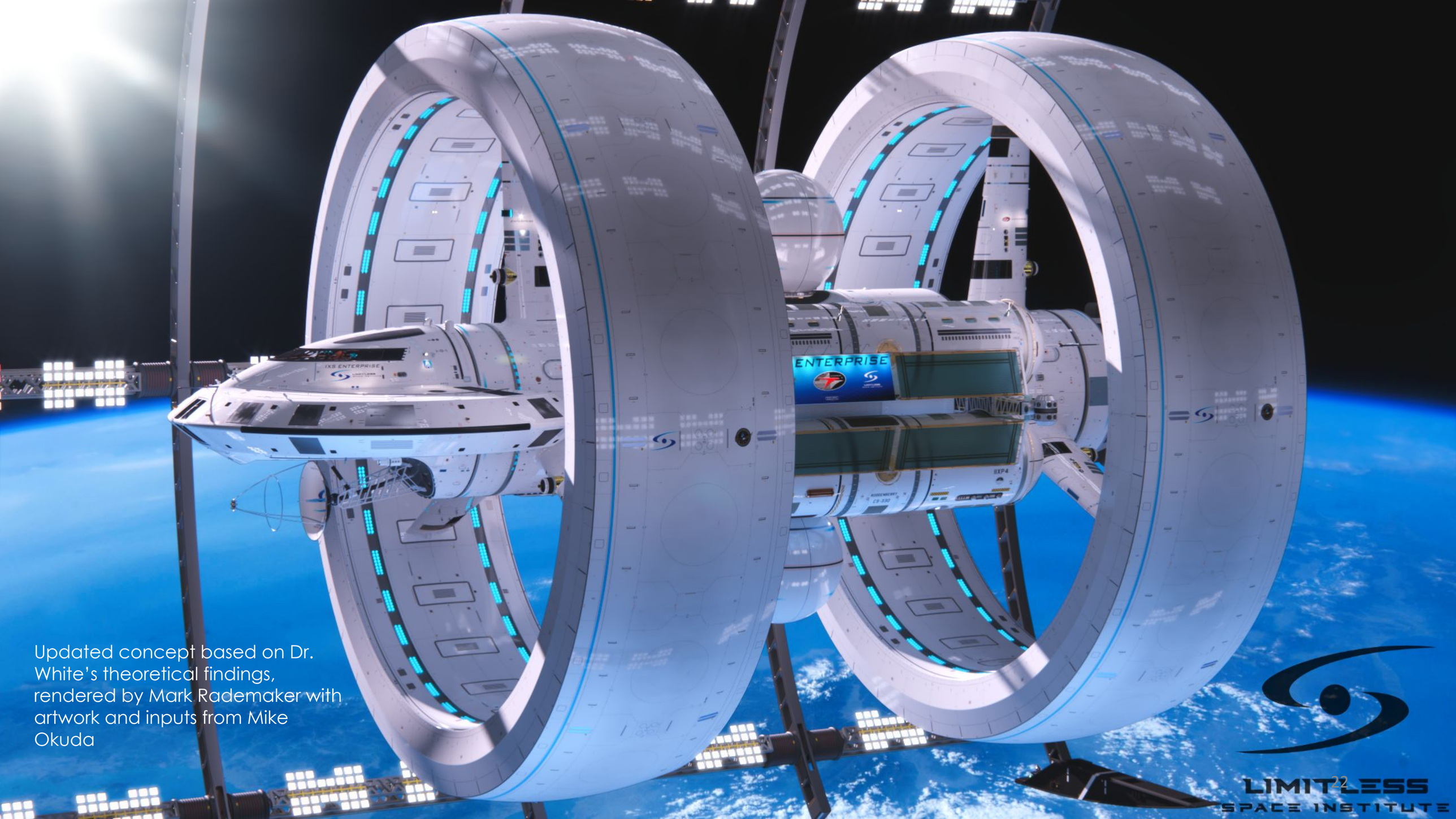


Image courtesy Mark Rademaker

Matthew Jeffries is the artist that created the familiar Star Trek enterprise look



Updated concept based on Dr. White's theoretical findings, rendered by Mark Rademaker with artwork and inputs from Mike Okuda

Standards

MS-PS4-1

Uses mathematical representations to describe a simple model for waves that includes how the amplitude of a wave is related to the energy in a wave.

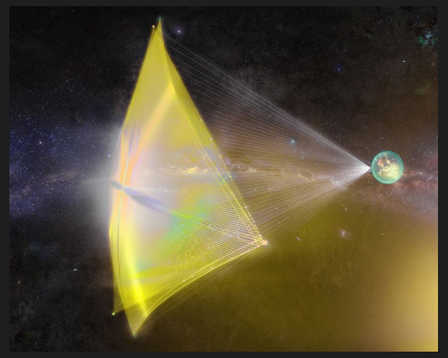
Crosscutting Concept

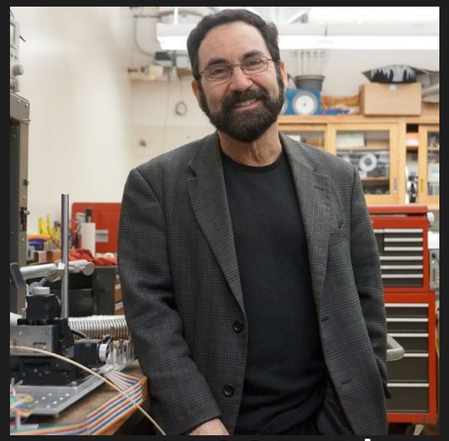
Charts and graphs can be used to identify patterns in data.

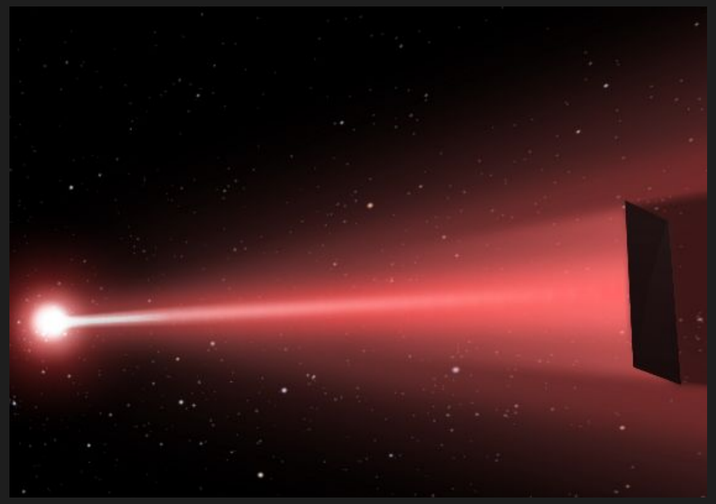
Science and Engineering Practices

Science knowledge is based upon logical and conceptual connections between evidence and explanations.

STEM Career Connection







Phil Lubin- Professor UCSB Physics Department

- specializes in astrophysics, gravitational physics, and high-energy physics
- Works in the field of directed energy propulsion, which involves using powerful lasers to propel spacecraft to near-light speeds
- Projects include the breakthrough Starshot initiative, which aims to send small, lightweight spacecraft to the nearest star system, Alpha Centauri. He has proposed using laser-driven sails to accelerate these spacecraft to a significant fraction of the speed of light.
- 518 publications credited on ResearchGate
- Click Here to learn more about Phil Lubin

STEM Career Connection

Dr Harold Sonny White- Director, Advanced Research & Development
Limitless Space Institute

Mechanical engineer, aerospace engineer, and applied physicist who is known for proposing new Alcubierre “warp” drive concepts and promoting advanced propulsion projects.

Click here to learn more about Limitless Space Institute and Dr. White LSI (limitlessspace.org)

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Student Name_____ Team Name_____ Period_____

1. Record your hypothesis to predict what will happen to the intensity of light as distance from the light source increases.

Hypothesis Statement _____

_____

1. What is the independent variable, the variable we will be **changing** in our experiment?

Independent Variable _____

_____

1. What is the dependent variable that we will be **measuring** in our experiment?

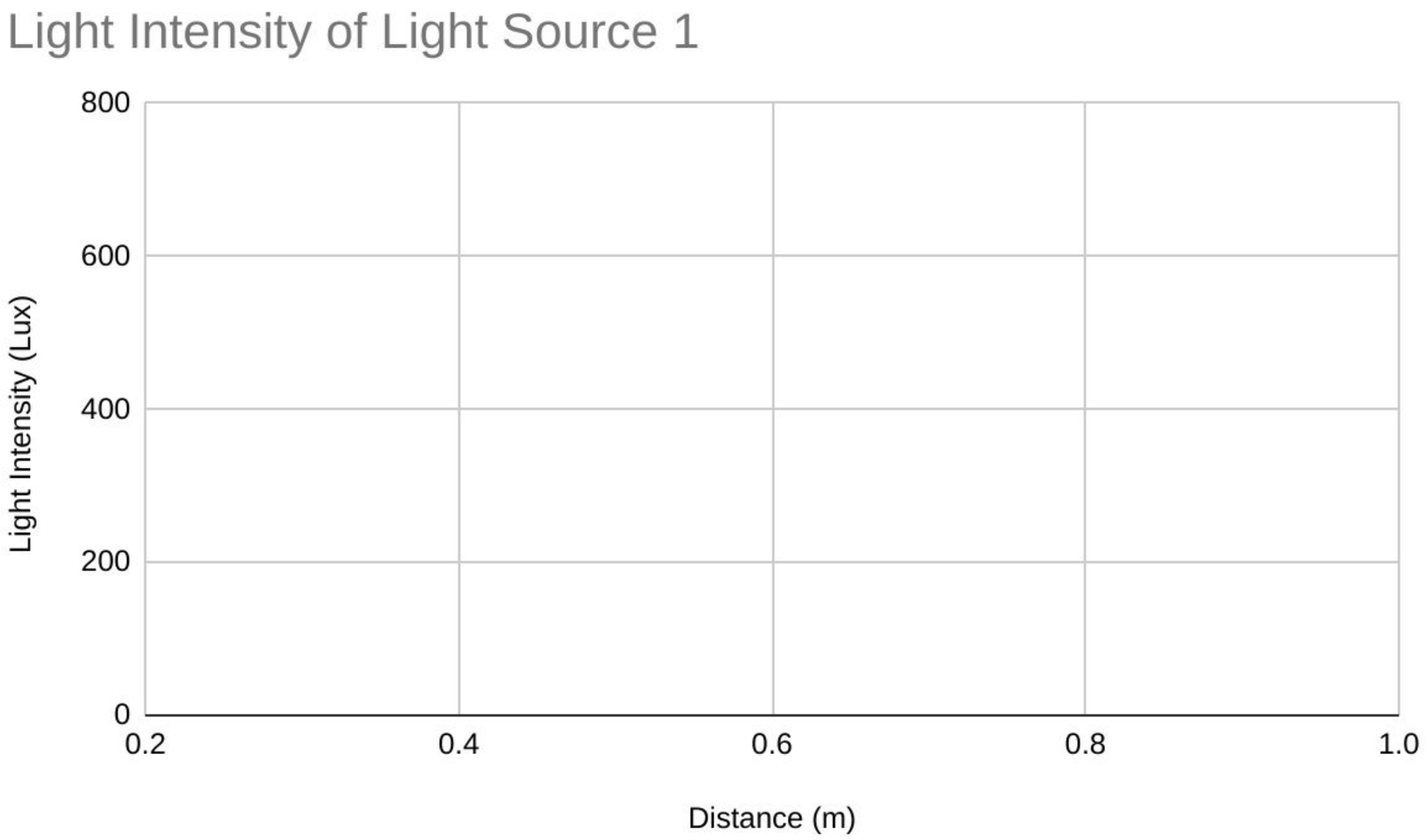
Dependent Variable _____

_____

4. Record the light intensity of the light source at each half meter increment in the table below:

Distance (m)	Light Intensity (lux)
0.2 m	
0.4 m	
0.6 m	
0.8 m	
1.0 m	

5. Create a graph using the space provided below (or use Google Sheets Template):

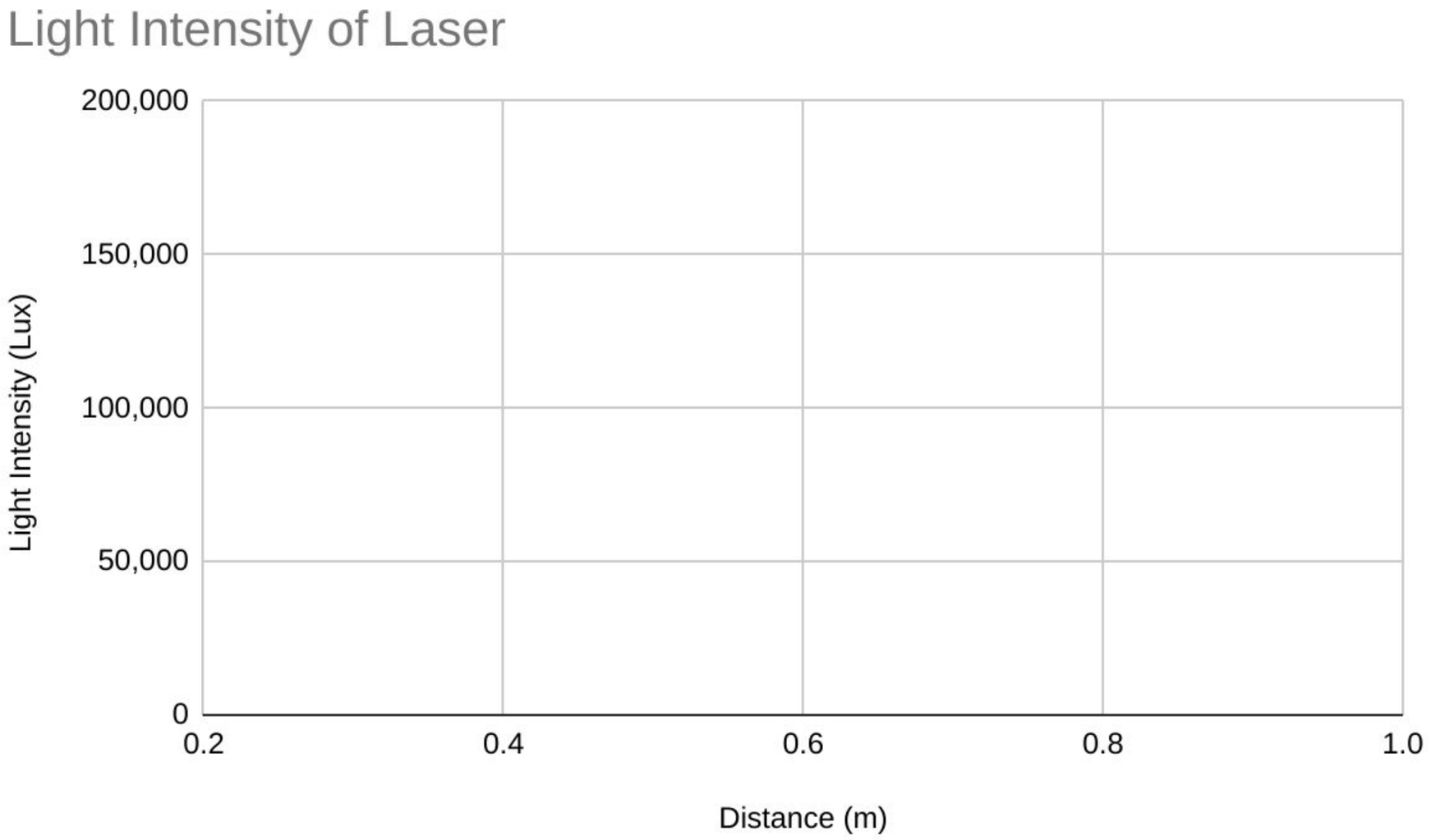


6. Record the light intensity of the laser at each half meter increment in the table below:

Distance (m)	Light Intensity (Lux)
0.2 m	
0.4 m	
0.6 m	
0.8 m	
1.0 m	

Color of Laser My Group Researched: _____

7. Create a graph using the space provided below (or use Google Sheets Template):



Analysis Questions: *please explain your answer in complete sentences.*

8. What happened to the light intensity as the distance increased? Was it different for the different types of light? _____

_____

9. How did your results compare to your hypothesis? _____

_____

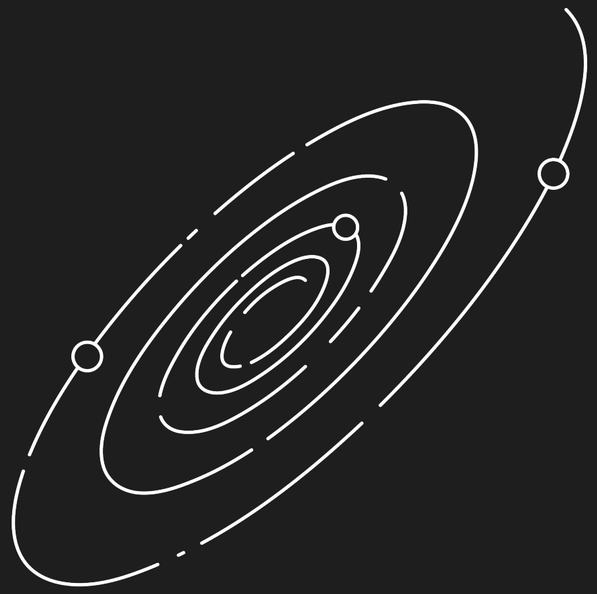
10. How would this relationship affect spacecraft propelled by solar sails? _____

_____

11. What would be the advantage of using lasers for propulsion instead of light?

_____

_____



Teacher Information

Included in this section:

- Answer key
- Sample graphs
- Additional resources

This lesson is also available as a PocketLab Notebook Lesson at this link.

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Answer Key

1. Record your hypothesis to predict what will happen to the intensity of light as distance from the light source increases.

Hypothesis Statement: The intensity of the light will decrease inversely as distance increases.

1. What is the independent variable, the variable we will be **changing** in our experiment?

Independent Variable: Distance (m)

1. What is the dependent variable that we will be **measuring** in our experiment?

Dependent Variable: Light Intensity (Lux)

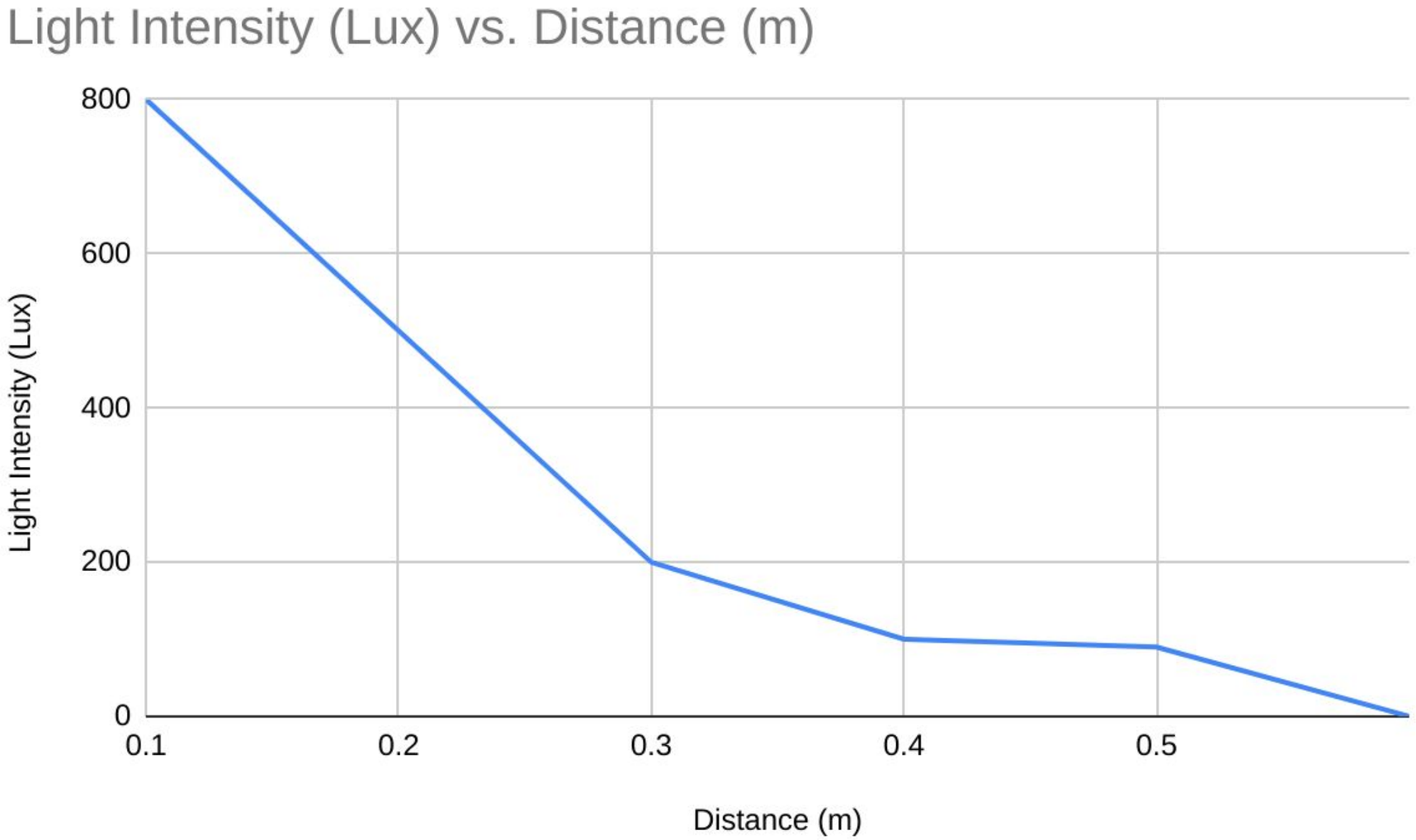
Answer Key (initial hotel testing)

4. Record the light intensity of the light source at each half meter increment in the table below:

Distance (m)	Light Intensity (Lux)
0 m	0
0.1 m	800
0.3 m	200
0.4 m	100
0.5 m	90
0.6 m	0

Answer Key (initial hotel testing)

5. Create a graph using the space provided below (or use Google Sheets Template):



Answer Key (initial hotel testing)

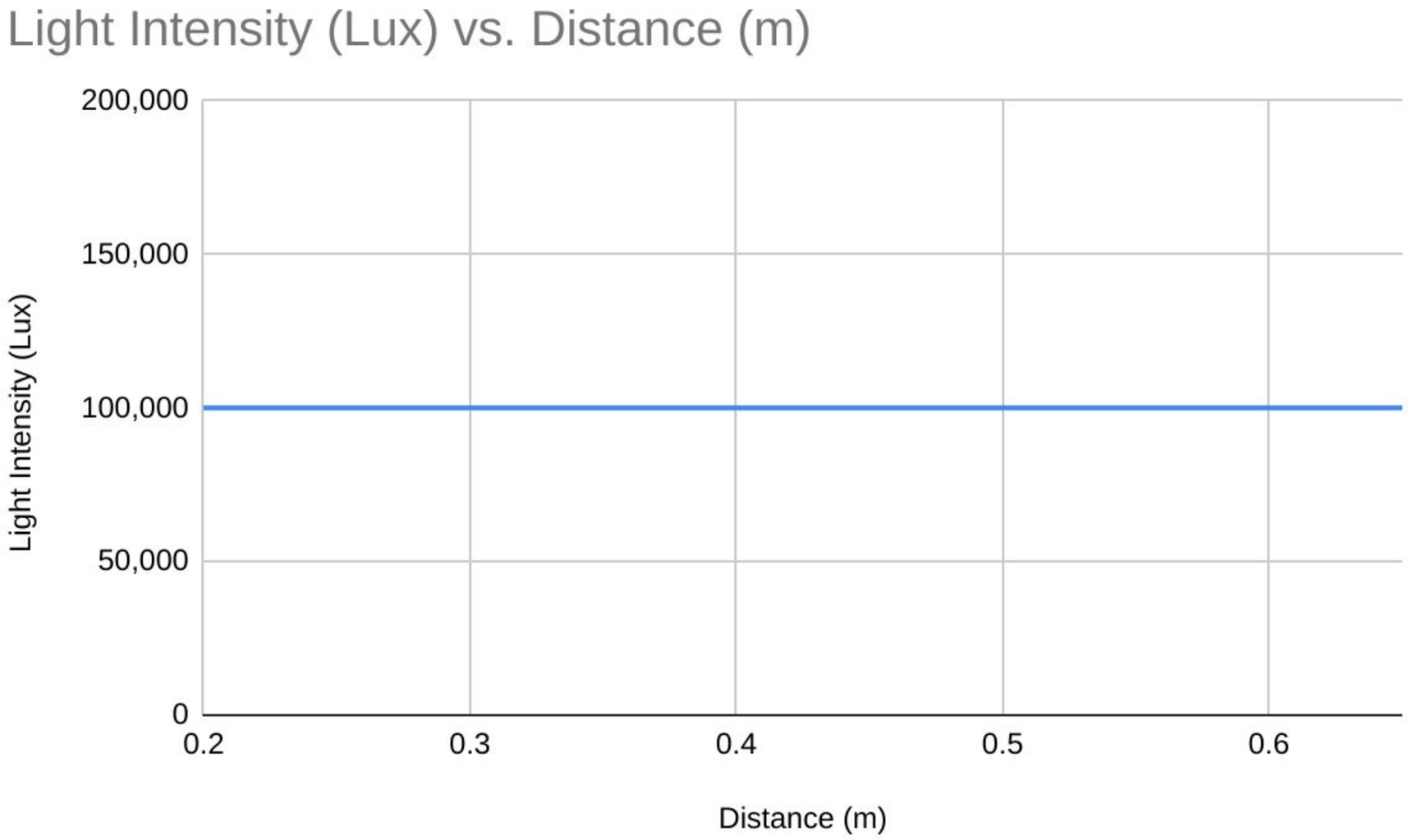
6. Record the light intensity of the laser at each half meter increment in the table below:

Distance (m)	Light Intensity (lux)
0.2	100,000
0.4	100,000
0.65	100,000

Color of Laser My Group Researched: _____

Answer Key (initial hotel testing)

7. Create a graph using the space provided below (or use Google Sheets Template):



Analysis Questions: Answer Key

8. What happened to the light intensity as the distance increased? Was it different for the different types of light? As the distance increases the light intensity decreases in an inverse relationship. All three colors of lasers, red-blue-green, evidenced the same light intensity of 100,000 lux.

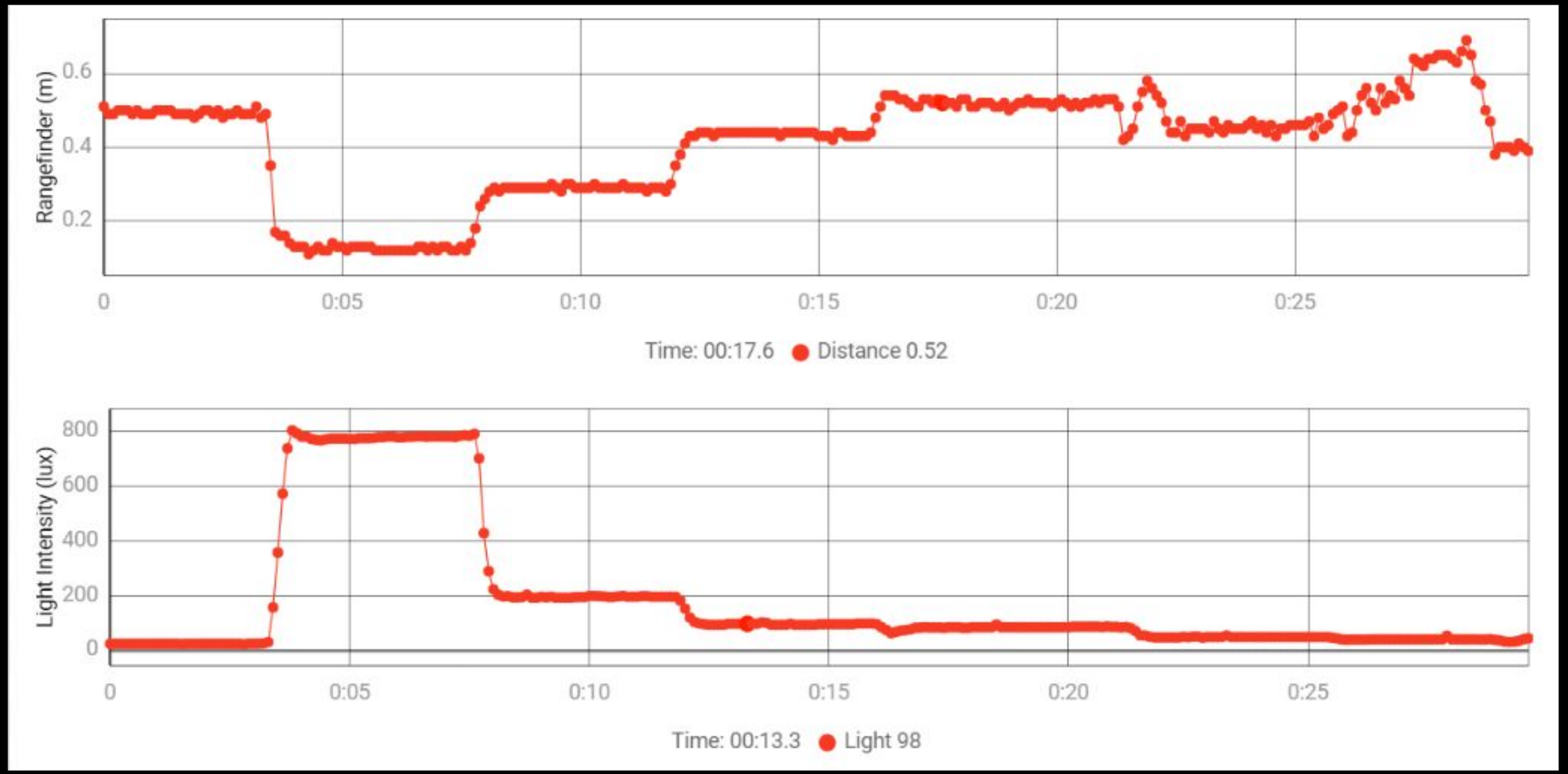
9. How did your results compare to your hypothesis? Results will vary based on individual/group hypotheses.

10. How would this relationship affect spacecraft propelled by solar sails? As spacecraft travel farther from the light source (in this case, the sun), the amount of energy available will decrease.

11. What would be the advantage of using lasers for propulsion instead of sunlight?

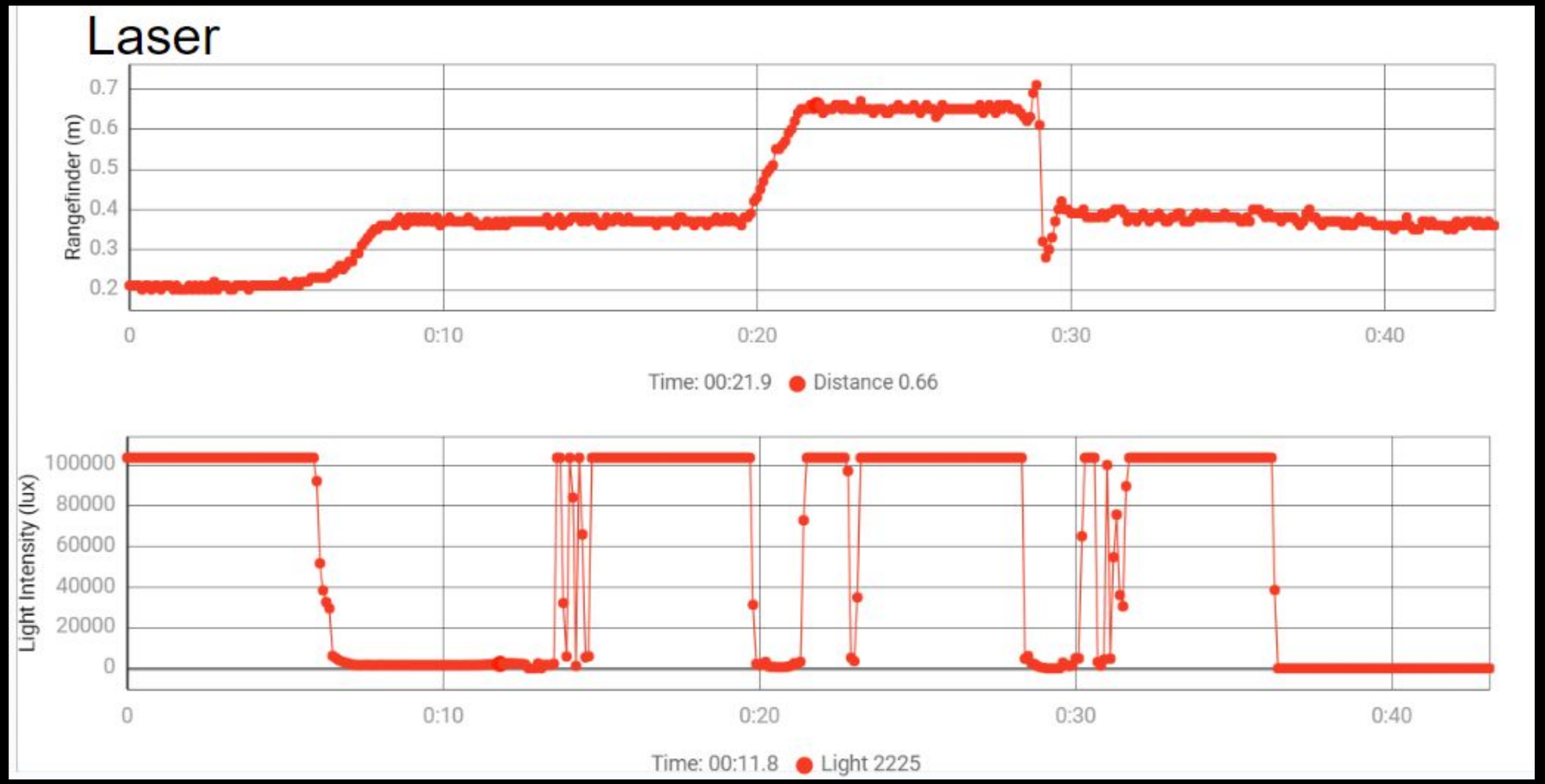
Laser propulsion could direct energy to further distances away from the sun, beyond where sunlight reaches into deep space.

Sample PocketLab Graph- Flashlight



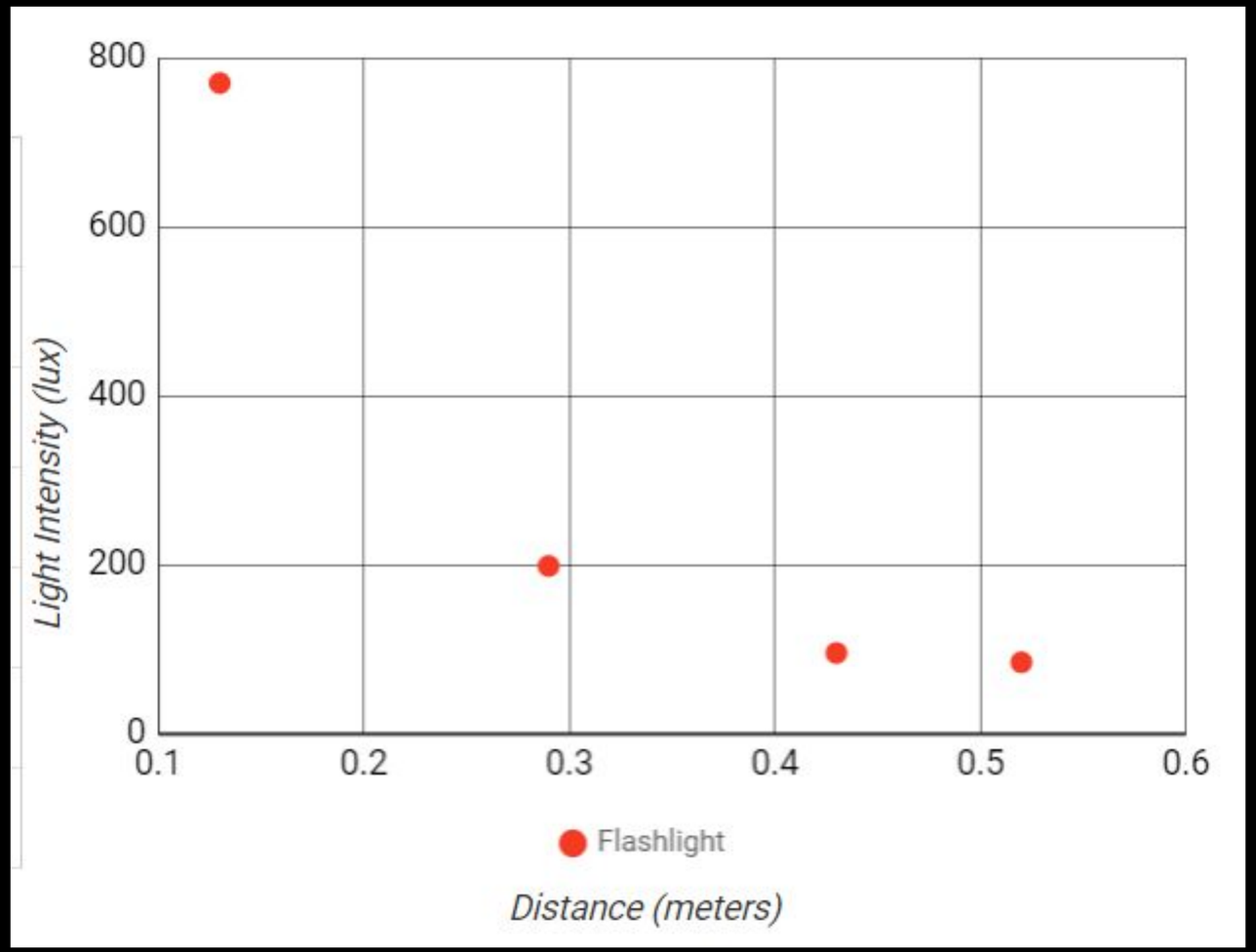
The top graph shows the distance away from the sensor, while the bottom graph shows the light intensity. Ignore the first 3-4 seconds as that was during the set up phase. When analyzing the data, we can see that the light intensity decreases as the distance increases.

Sample PocketLab Graph- Laser



The top graph shows the distance away from the sensor, while the bottom graph shows the light intensity. When analyzing the data, we can see that the light intensity of the laser does NOT decrease as the distance increases. Since it doesn't follow the inverse square law, it could propel spacecraft without the diffusion of the light that is experienced with sunlight.

Sample Scatter Plot Data



With this graph we once again see the inverse relationship where light decreases as distance increases.

Expanded Propulsion Definitions

Chemical Propulsion: Chemical propulsion systems use chemical reactions to produce thrust or the force that pushes a spacecraft forward. They work by burning a mixture of fuel and oxidizer (a substance that helps burn the fuel) to create hot gases. These gases are expelled out of a nozzle at high speeds, which propels the spacecraft in the opposite direction.

Light Propulsion: Light propulsion, also known as photon propulsion, is a concept that involves using light or photons to generate thrust. Light carries momentum, and when it reflects off a surface or is absorbed and re-emitted, it can exert a tiny force on an object. Scientists are exploring ways to capture and utilize this force to propel small spacecraft, such as using large reflective sails to catch the sunlight and "sail" through space.

Laser Propulsion: Laser propulsion is an idea that uses laser beams to generate thrust. It works by focusing a powerful laser beam onto a spacecraft's surface. The laser beam heats up a specific area, causing the surface material to vaporize and shoot off like a small explosion. This explosion creates a burst of gas that pushes the spacecraft forward. Laser propulsion is still a concept under development and has not been widely used in space travel yet.

Ion Propulsion: Ion propulsion, also called electric propulsion, is a type of propulsion system that uses electrically charged particles, called ions, to create thrust. It works by using electricity to ionize a gas, usually xenon, by removing electrons from its atoms. These ionized particles are then accelerated using electric fields and expelled out of a nozzle at high speeds. Although ion engines produce low thrust, they can operate for long periods, making them ideal for long-duration space missions.

THANK YOU

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