



GRAVITATIONAL TELESCOPE

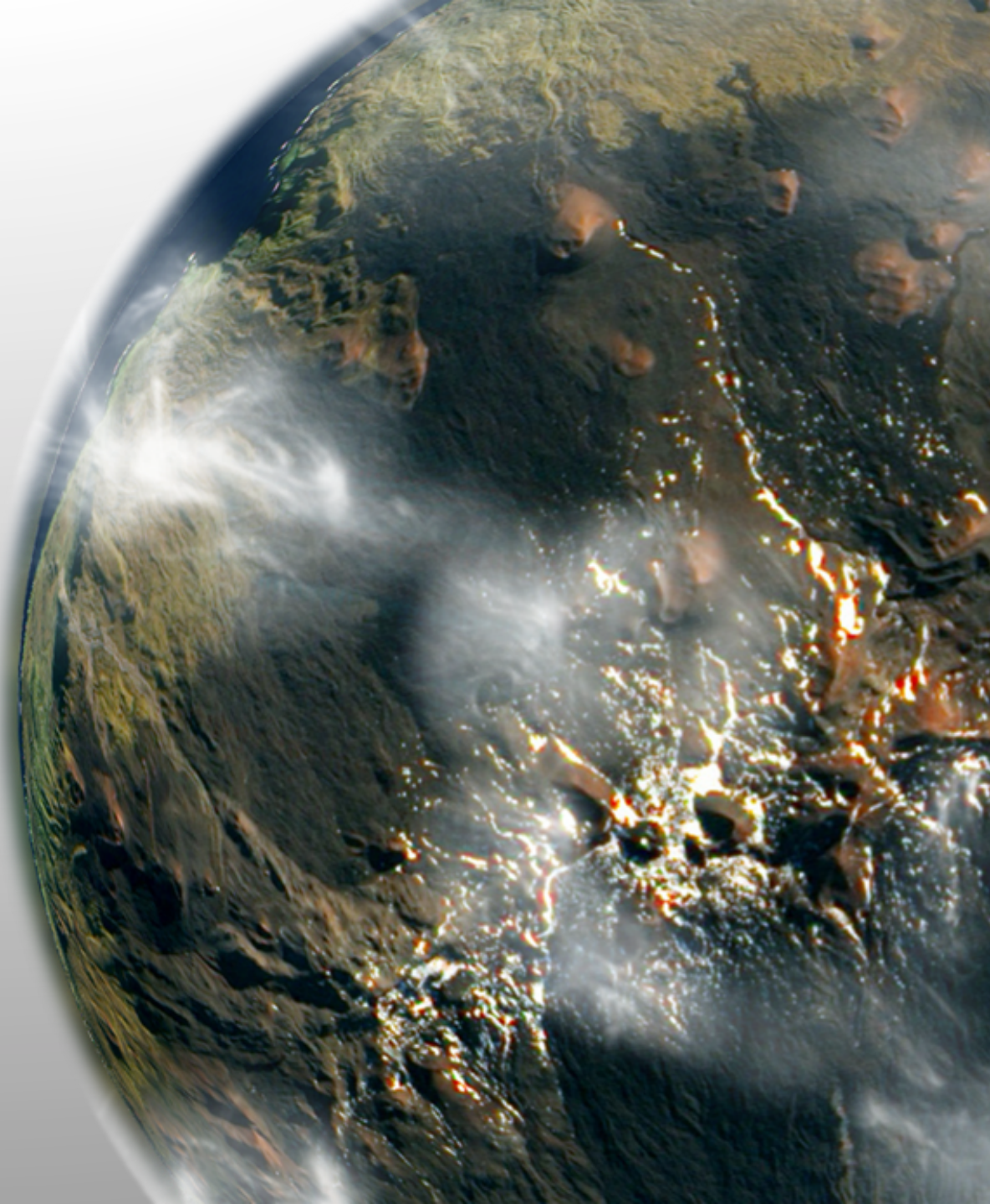
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With the special support of Mr. Geoffrey Landis ("NASA John Glen Research Center")

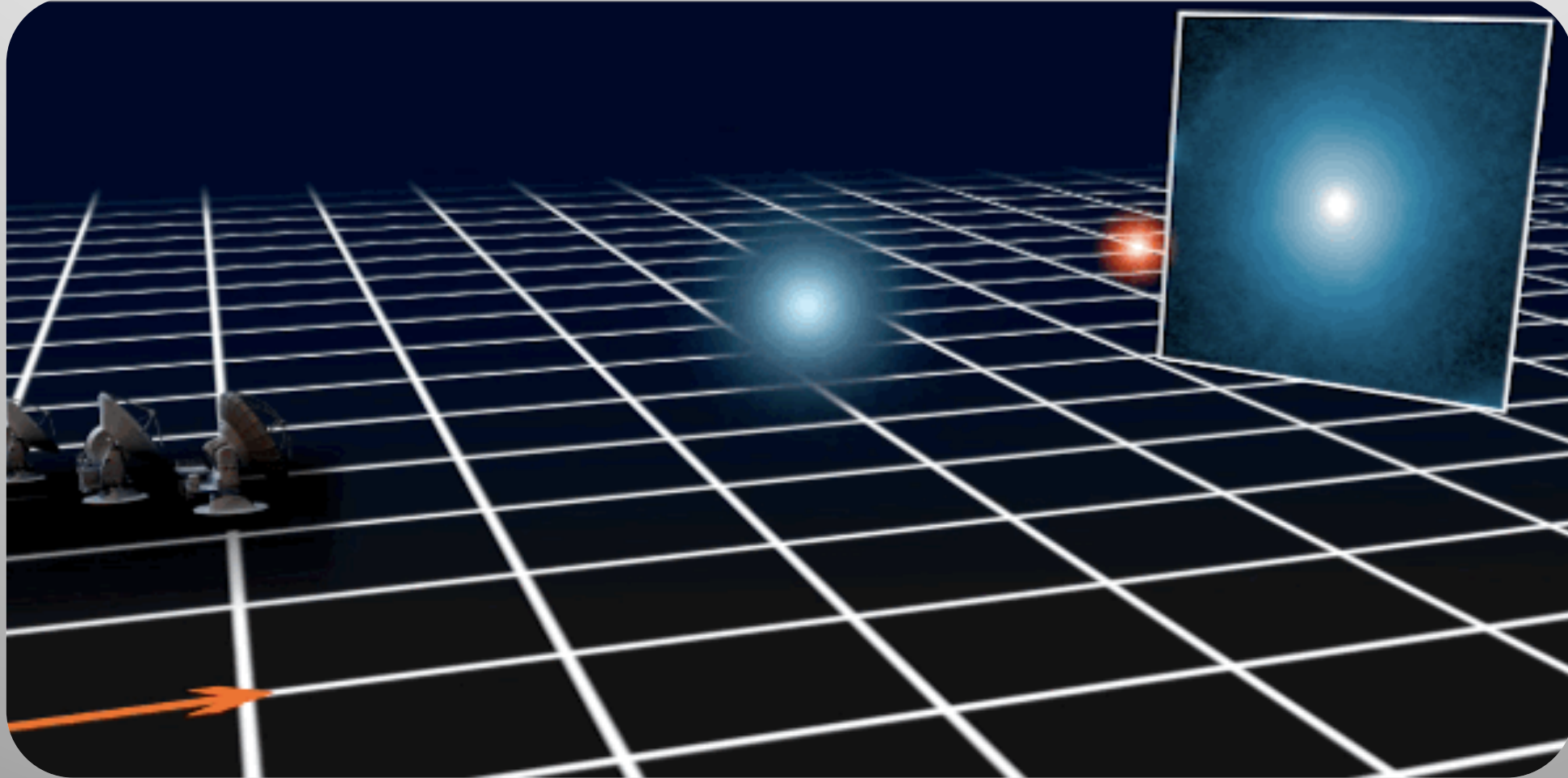
Content

- History
- What is a gravitational lens
- Parameters and capabilities of the gravity telescope
- Way of transporting the spacecraft
- Characteristics of the elements of the spacecraft
- Objects



What is a gravitational lens?

Gravitational lens effect



The Discovery of the Phenomenon

Henry
Cavendish
(1731 – 1801)



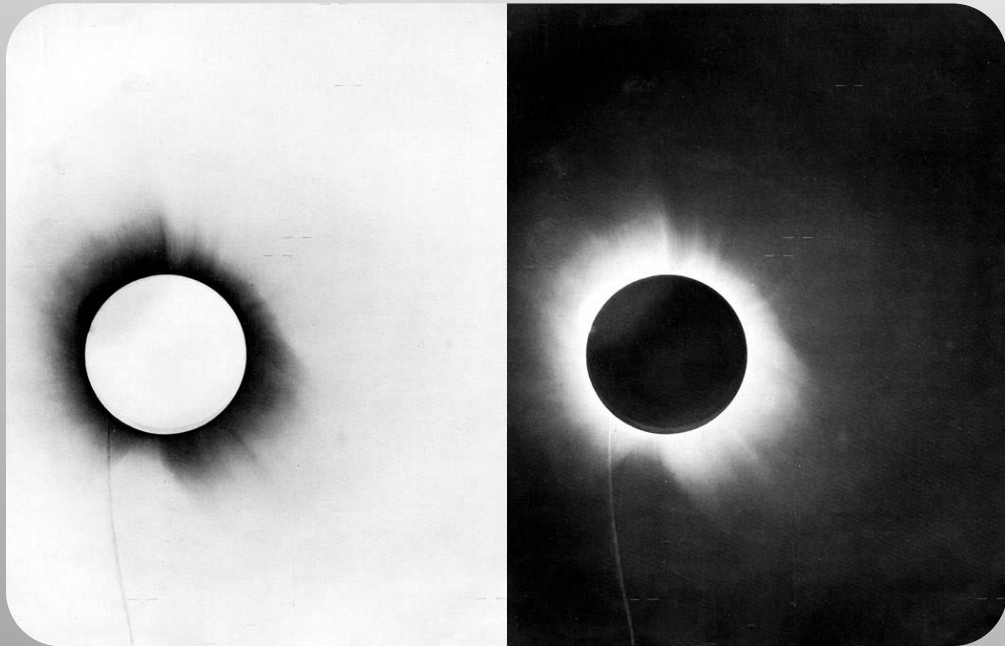
Johann Georg von
Soldner
(1776- 1833)



Albert Einstein
(1879 - 1955)



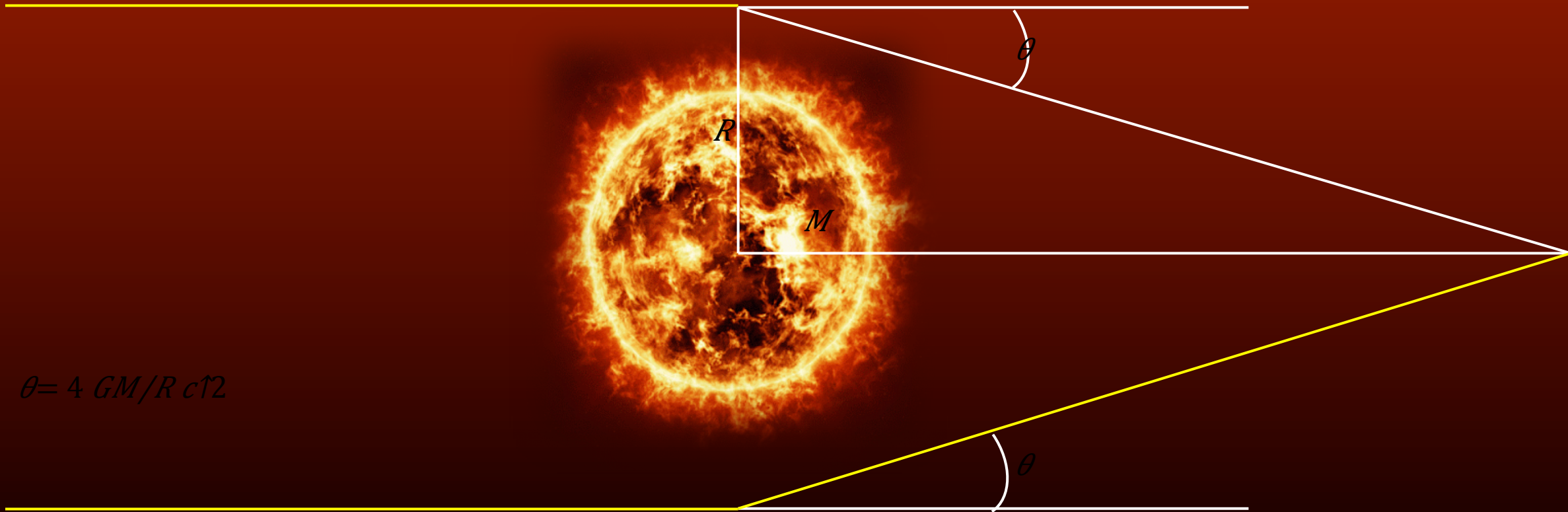
THE OBSERVATION OF THE SOLAR ECLIPSE 29.05.1919



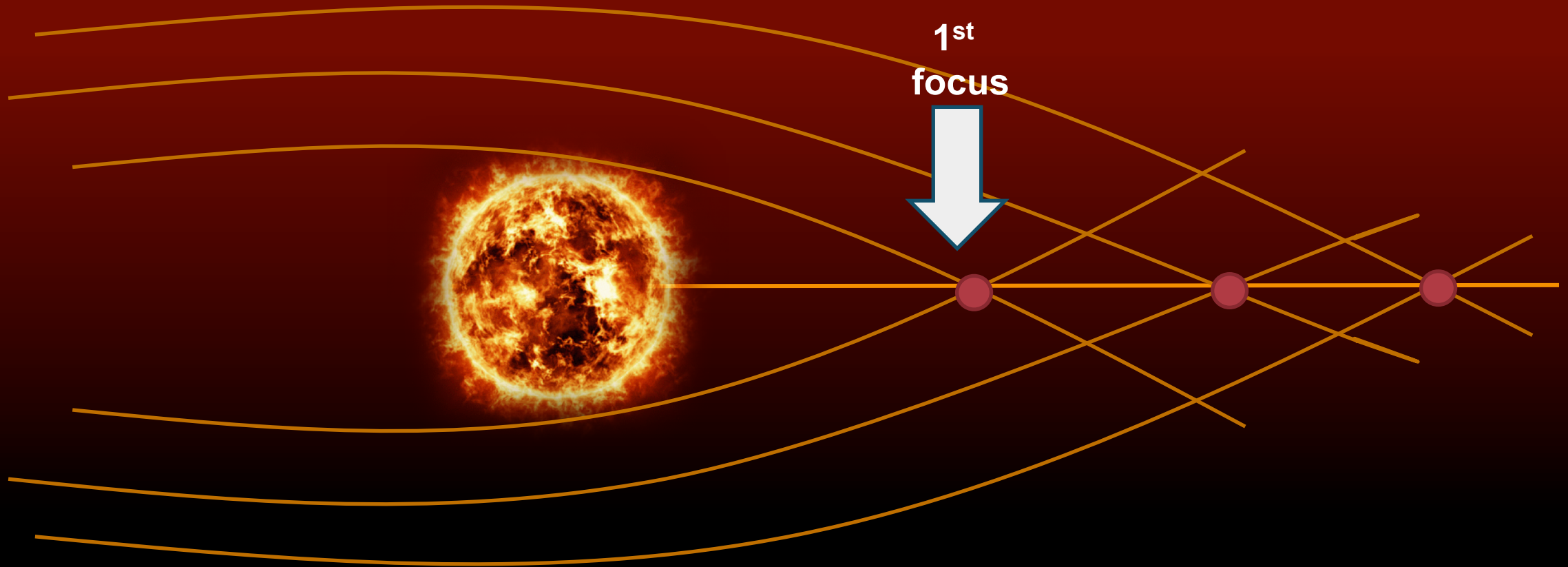
GRAVITATIONAL LENS EFFECT



- Bending of the light

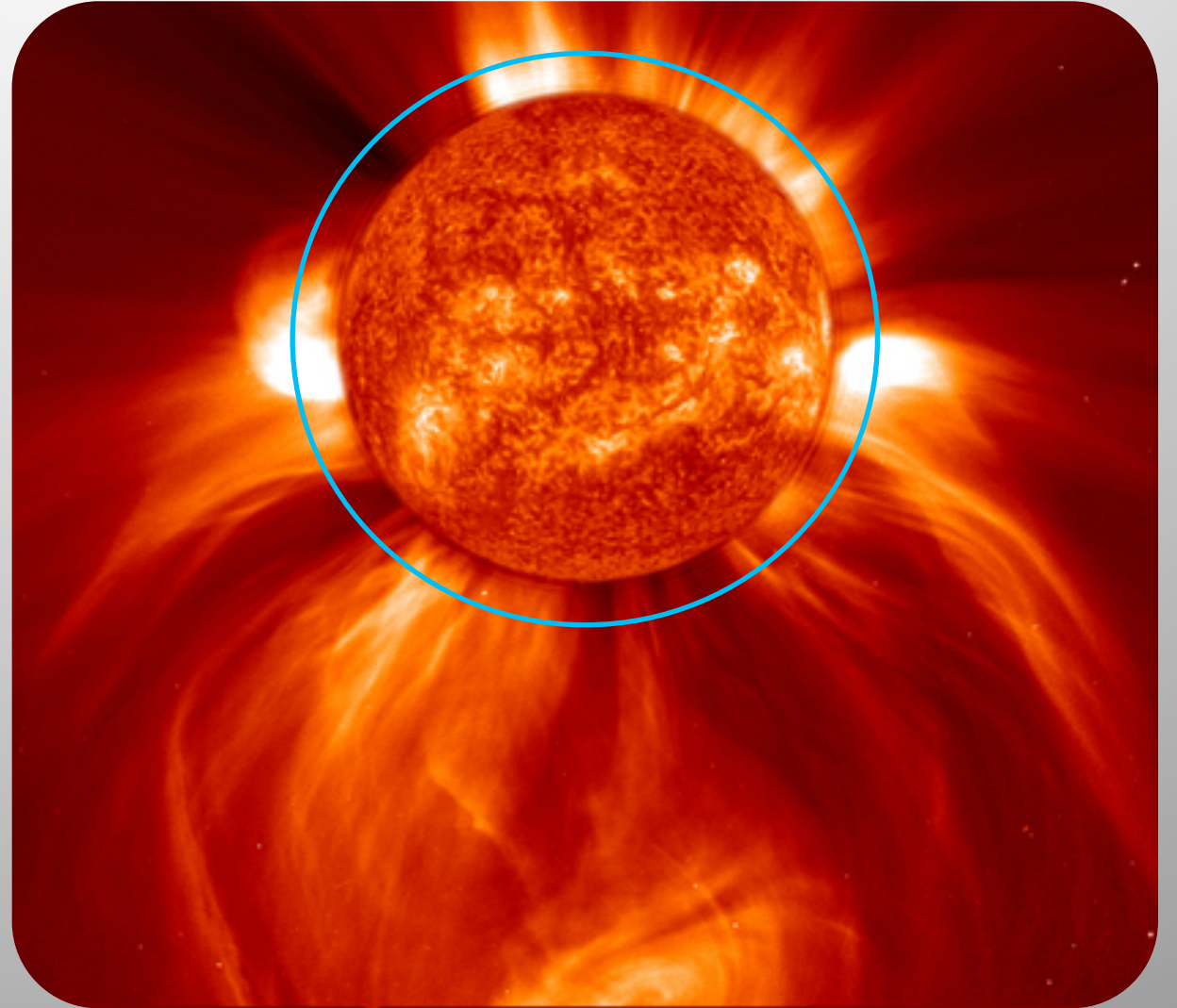


- Line of focuses

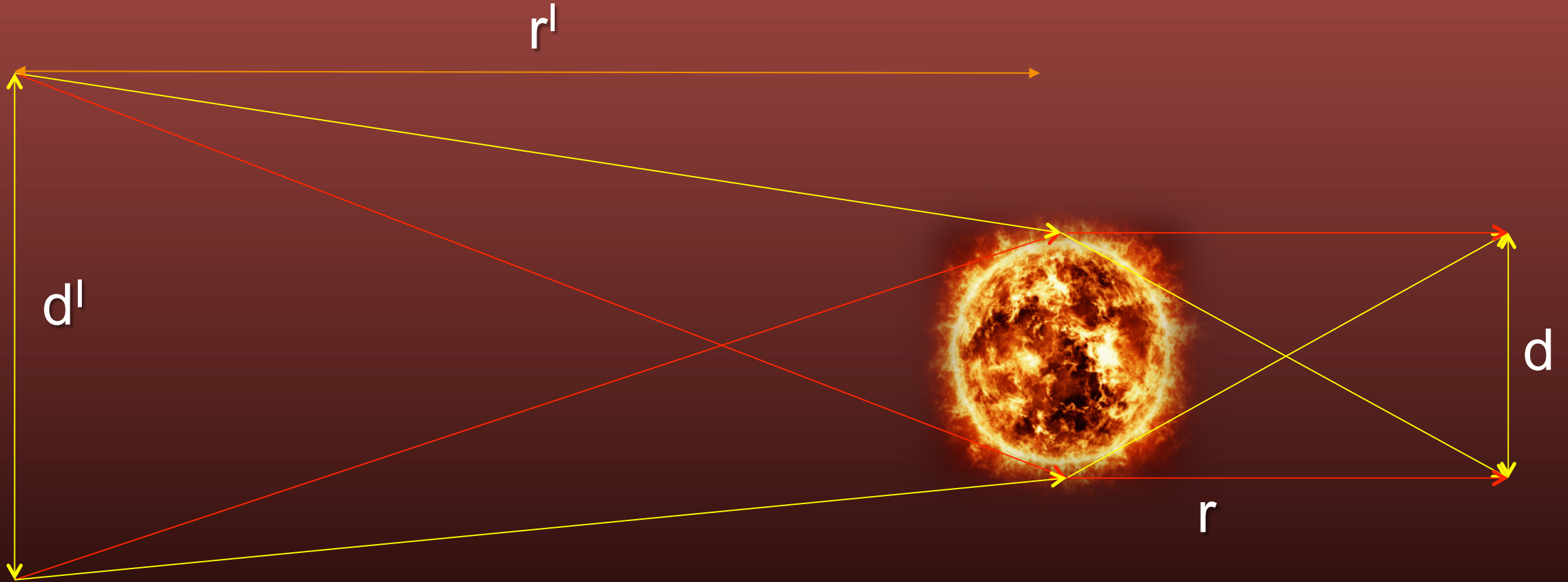


Parameters and capabilities of the gravity telescope

○First Focus - 784 AU



Scheme of a gravitational lens

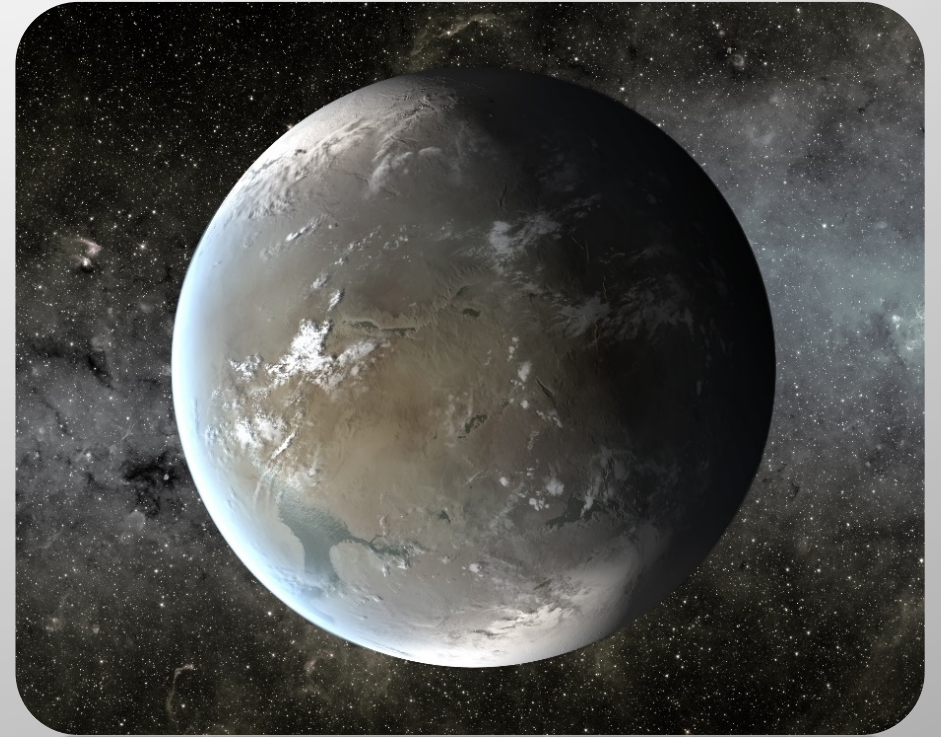


Using the formula $d^l / r^l = d / r$ we can determine the diameter of the planet's image obtained with the solar gravitational lens.

The scale of the image



Andromeda Galaxy: $r^l = 780\,000\text{ pc}$



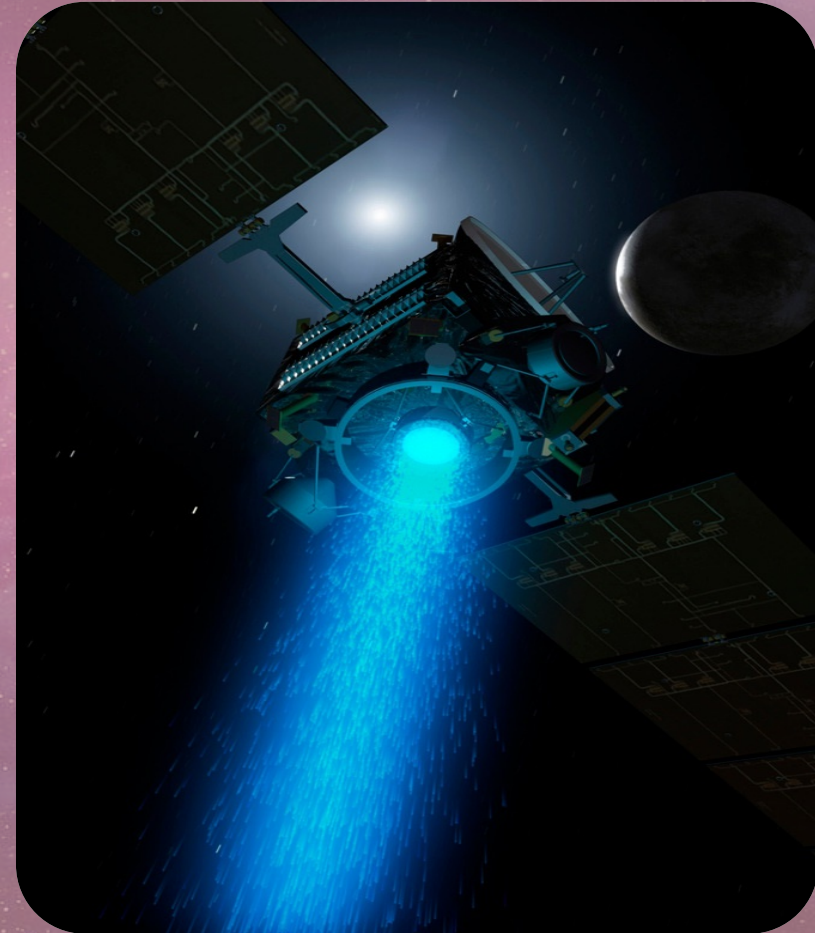
Earth like exoplanet: $d=6\text{cm}$
(image on the matrix)

Transportation

- The most popular method of traveling in space is through jet engines:

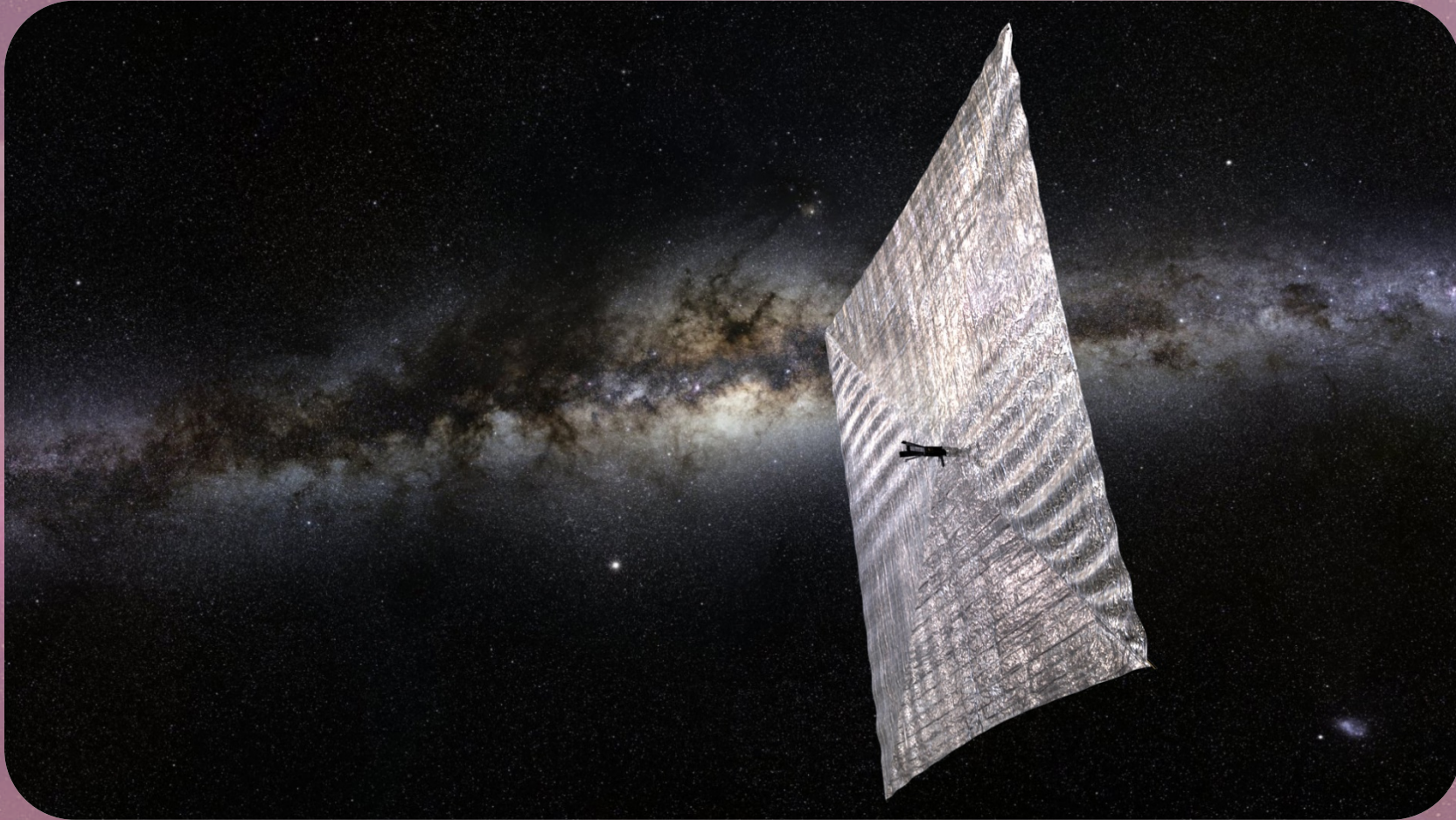


- Another more efficient method would be an ion motor:



Transportation

- Solar sail



Used Formulae for Light Pressure

$$\triangleright E = \frac{L_{SUN} \cdot S}{4\pi r^2}$$

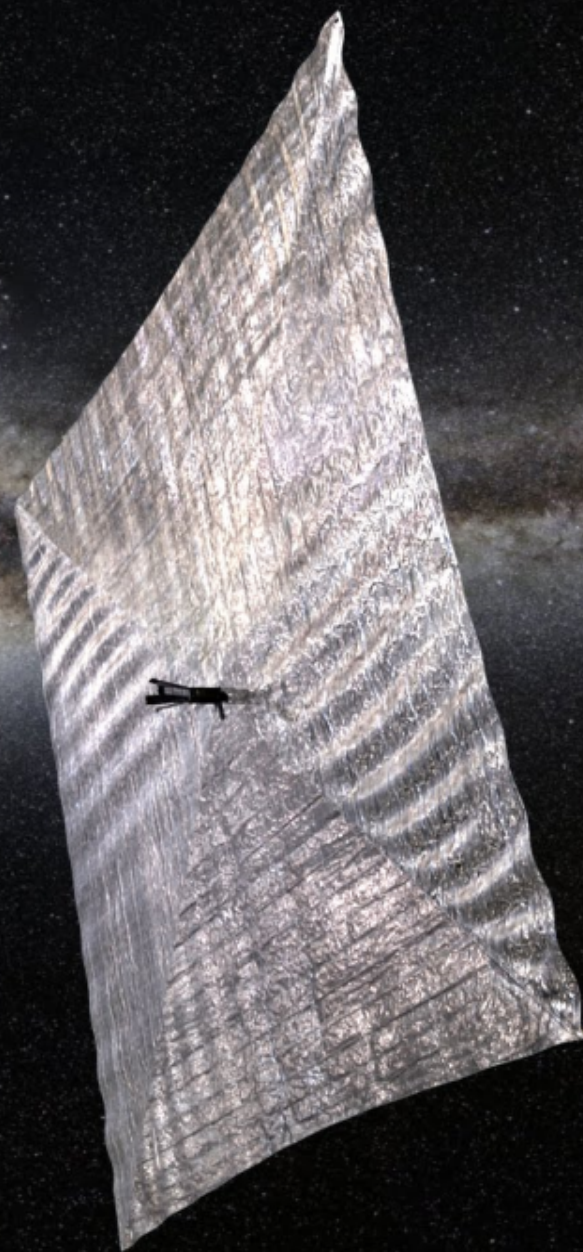
$$\triangleright \varepsilon = p \cdot c$$

$$\triangleright m \cdot a = F_{rad} ; F_{rad} = \frac{\Delta P}{\Delta t}$$

$$\triangleright F_{GR(\text{gravitational force})} = \frac{GM_{SUN}m}{r^2}$$



Mass of the Star	<input type="text" value="1"/>	M_{\odot}	Calculate	Estimated Time	<input type="text" value="44"/>	years,	<input type="text" value="5"/>	months,	<input type="text" value="16"/>	days,
Star Radius	<input type="text" value="1"/>	R_{\odot}		<input type="text" value="15"/>	hours,	<input type="text" value="58"/>	minutes,	<input type="text" value="51,49999"/>	seconds.	
Star Temperature	<input type="text" value="5498,85"/>	$^{\circ}\text{C}$								
Mass of the ship	<input type="text" value="4,368"/>	tons								
Surface of the Sail	<input type="text" value="3,14159"/>	sq. km.		Terminal Velocity	<input type="text" value="83,5963787245767"/>	km/s				
Albedo of the Sail	<input type="text" value="0,92"/>									
Initial distance	<input type="text" value="0,0145367506"/>	AU								
Destination	<input type="text" value="784"/>	AU								
Initial Velocity	<input type="text" value="0"/>	km/s								
Time Interval	<input type="text" value="0,5"/>	sec								

Load Defaults for
the SunLoad Travel
DefaultsLoad Spacecraft
DefaultsSet the Default
Time Interval

Program Code

The screenshot displays the Microsoft Visual Studio IDE with the 'Form1.cs' file open in the editor. The code is written in C# and defines a partial class `Form1` within the `LightSails` namespace. The code includes several using statements for system namespaces and implements two click events for buttons.

```
1 using System;
2 using System.Collections.Generic;
3 using System.ComponentModel;
4 using System.Data;
5 using System.Drawing;
6 using System.Linq;
7 using System.Text;
8 using System.Threading.Tasks;
9 using System.Windows.Forms;
10 namespace LightSails
11 {
12     public partial class Form1 : Form
13     {
14         public Form1()
15         {
16             InitializeComponent();
17         }
18         private void button2_Click(object sender, EventArgs e)
19         {
20             short sunRadius = 1;
21             short sunMass = 1;
22             double sunTemperature = 5498.85;
23             textBox10.Text = sunMass.ToString();
24             textBox17.Text = sunRadius.ToString();
25             textBox9.Text = sunTemperature.ToString();
26         }
27         private void button3_Click(object sender, EventArgs e)
28         {
29             double mass = 3.5;
30             double surface = 3.14159;
```

The Solution Explorer on the right shows the project structure for 'LightSails', including files like `AssemblyInfo.cs`, `Resources.resx`, `Settings.settings`, `App.config`, `Form1.cs`, `Form1.Designer.cs`, `Form1.resx`, and `Program.cs`.

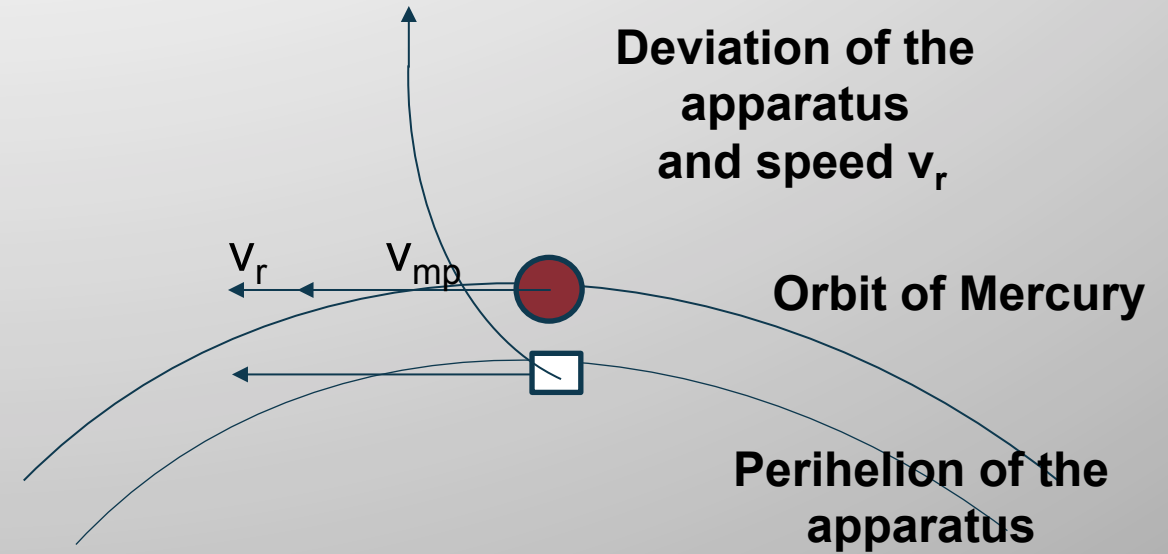
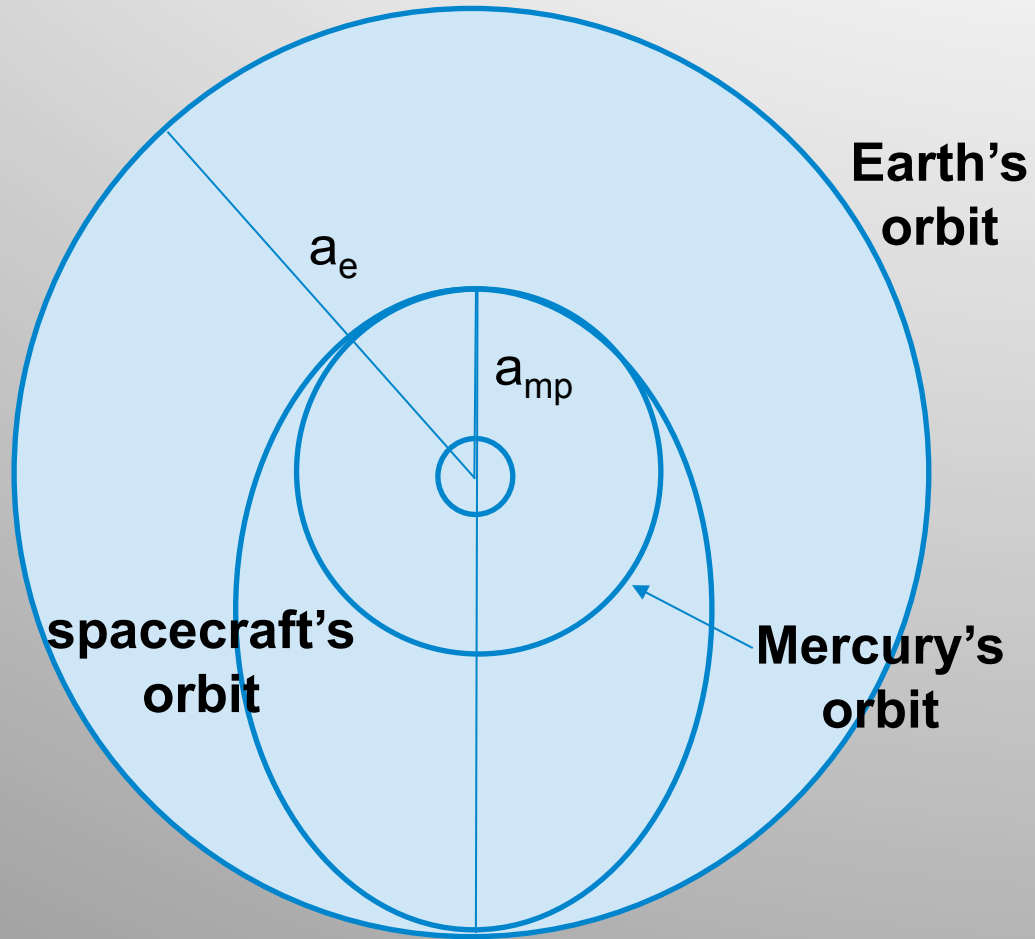
The status bar at the bottom indicates the current line is 1, column is 14, and the file is in the 'LightSails' project. The Windows taskbar at the very bottom shows the system clock as 19:46 on 7.6.2017.

Mercury Slingshot



Our goal is to use the effect of the gravity slingshot and to achieve an even higher initial velocity.

Mercury Slingshot Scheme



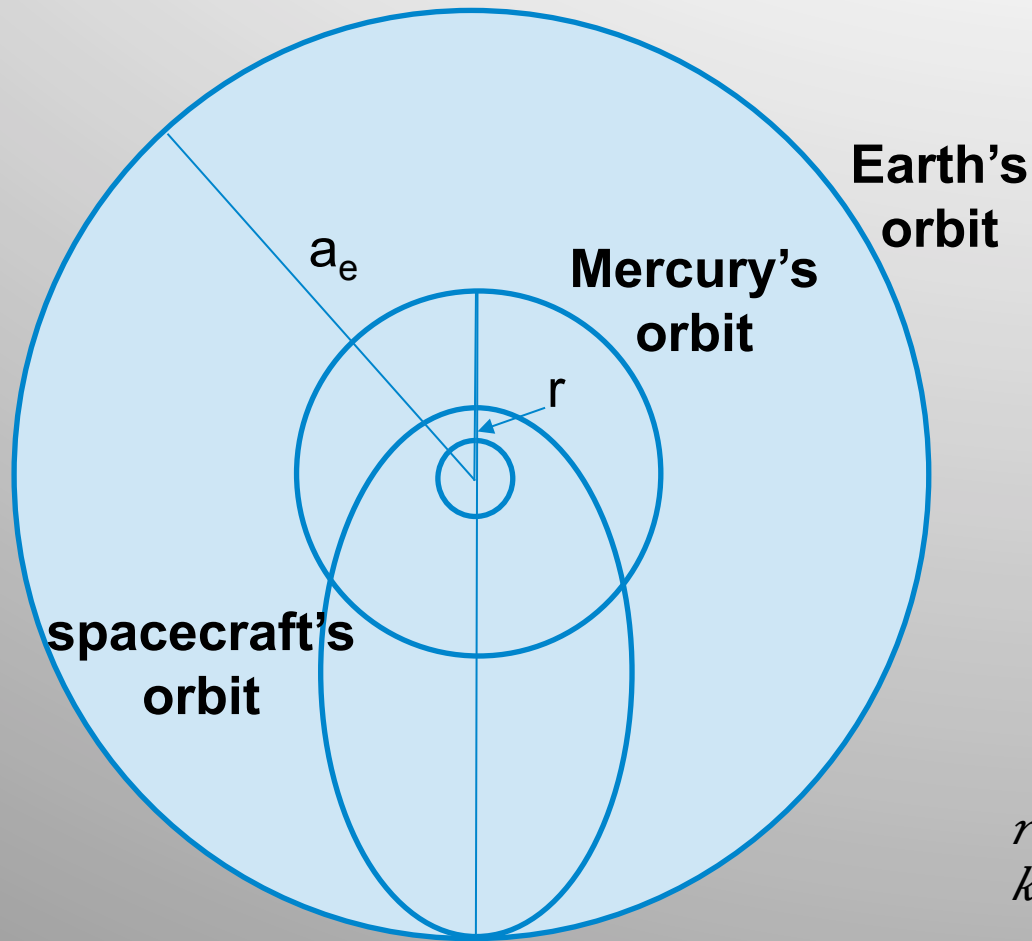
Used Formulae for The Mercury Slingshot

- Mass - 4300 kg
- Surface of the sail - 3,14159 sq.km
- Albedo of the sail - 0.92
- Minimum distance from the Sun - 0.02207 AU

$$\begin{aligned} \triangleright V_{\text{imp}} &= \sqrt{G \frac{M_{\odot}}{a_{\text{im}}}} \\ \triangleright v_{\text{tx}} &= \sqrt{G \frac{M_{\odot}}{a_{\text{tm}}}} \cdot \sqrt{\frac{1+e_{\text{im}}}{1-e_{\text{tm}}}} \\ a &= a_{\text{te}} + a_{\text{tm}} \cdot \frac{(1-e)}{2} \end{aligned}$$

Time to travel
186 years 2 months 9 days

Closer approach to the Sun



Magnesium sail

Minimal distance – below melting point of

$$r_{\downarrow 0} = R_{\downarrow 0} T_{\downarrow 0}^{1/2} \sqrt{1 - A/2\varepsilon} / T_{\downarrow 2}^{1/2} = 10410213,863 \text{ km} = 0,0695 \text{ AU}$$

Time to travel

95 years 8 months 29 days

Magnex sail

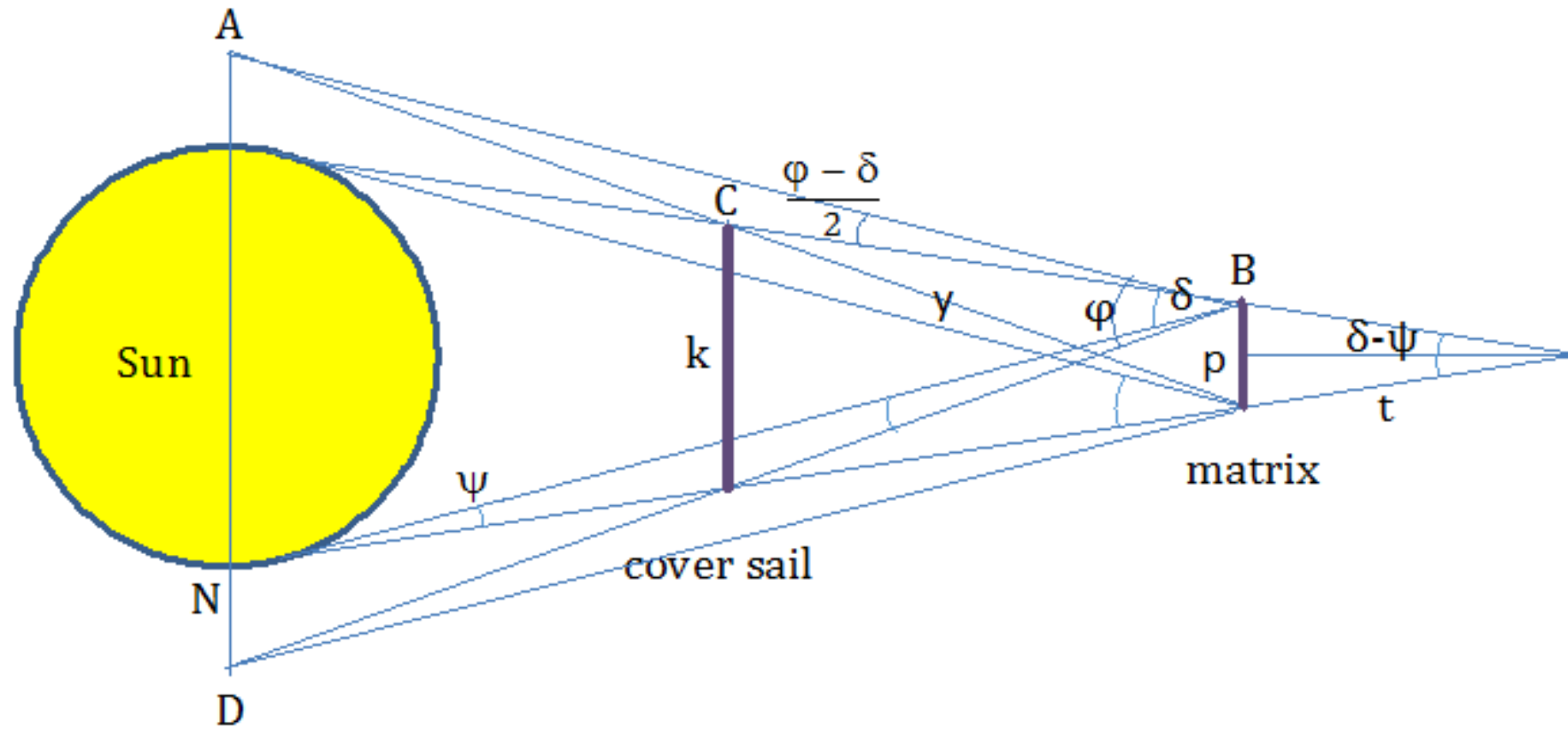
Minimal distance – below melting point of silica

$$r_{\downarrow 1} = R_{\downarrow 0} T_{\downarrow 0}^{1/2} \sqrt{1 - A/2\varepsilon_{\downarrow 1}} / T_{\downarrow 1}^{1/2} = 1640570,3921 \text{ km} = 0,0109665246 \text{ AU}$$

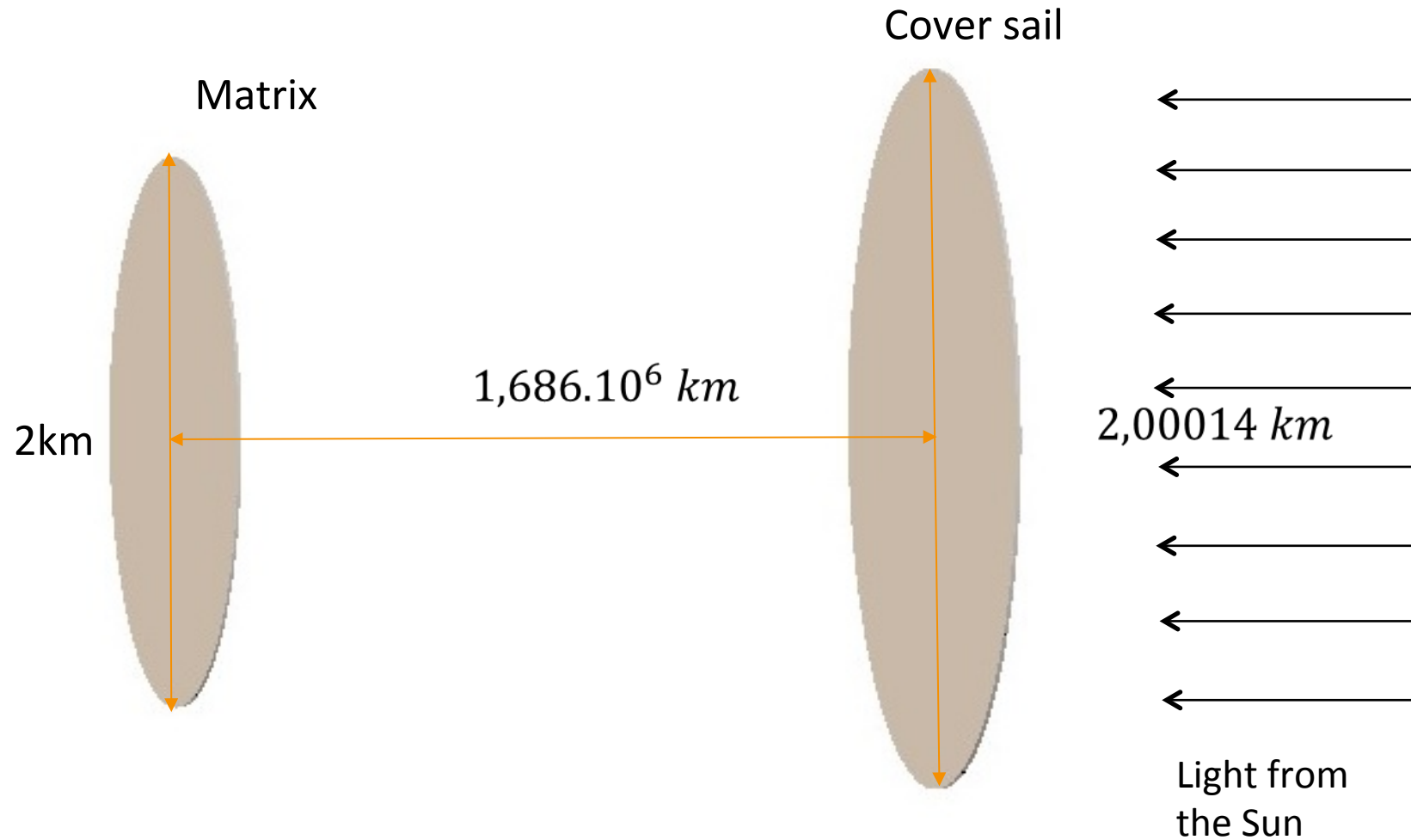
Time to travel

37 years 11 months 29 days

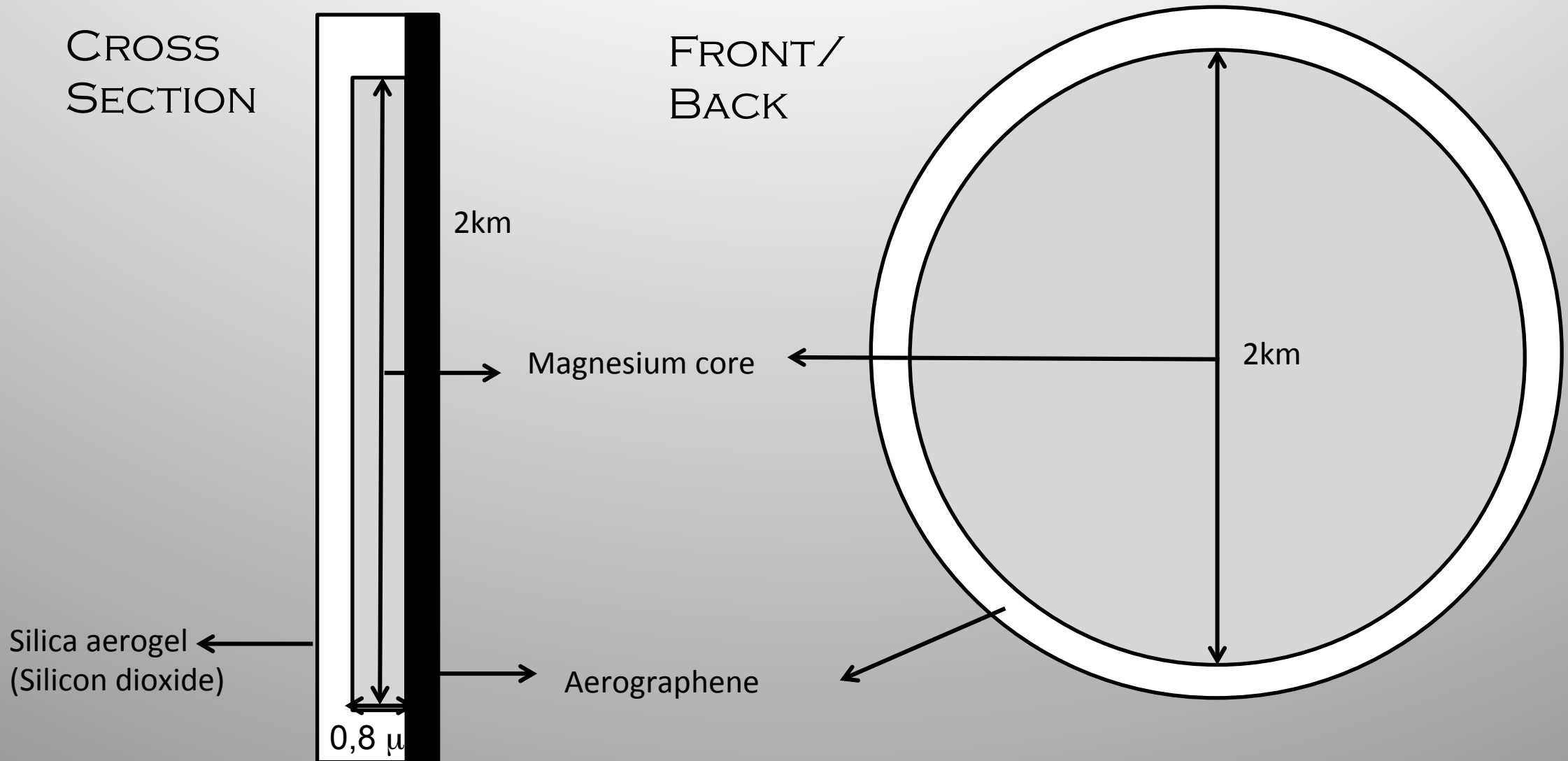
General scheme of the telescope



Positions of the matrix and cover sail

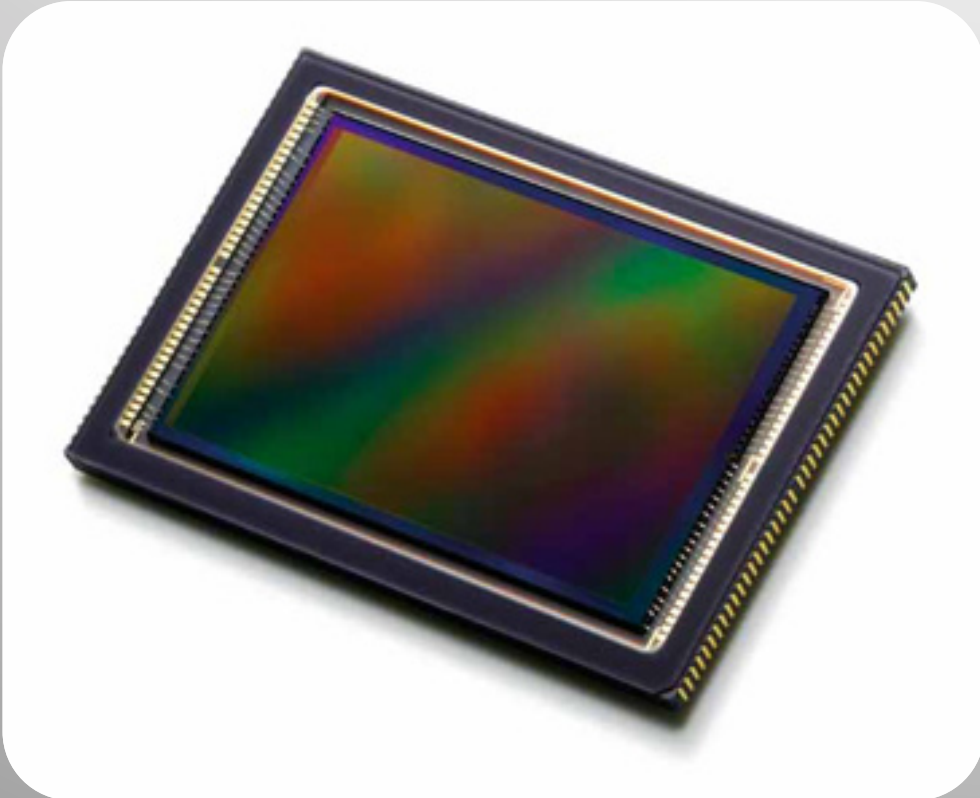


Characteristics of the Sail



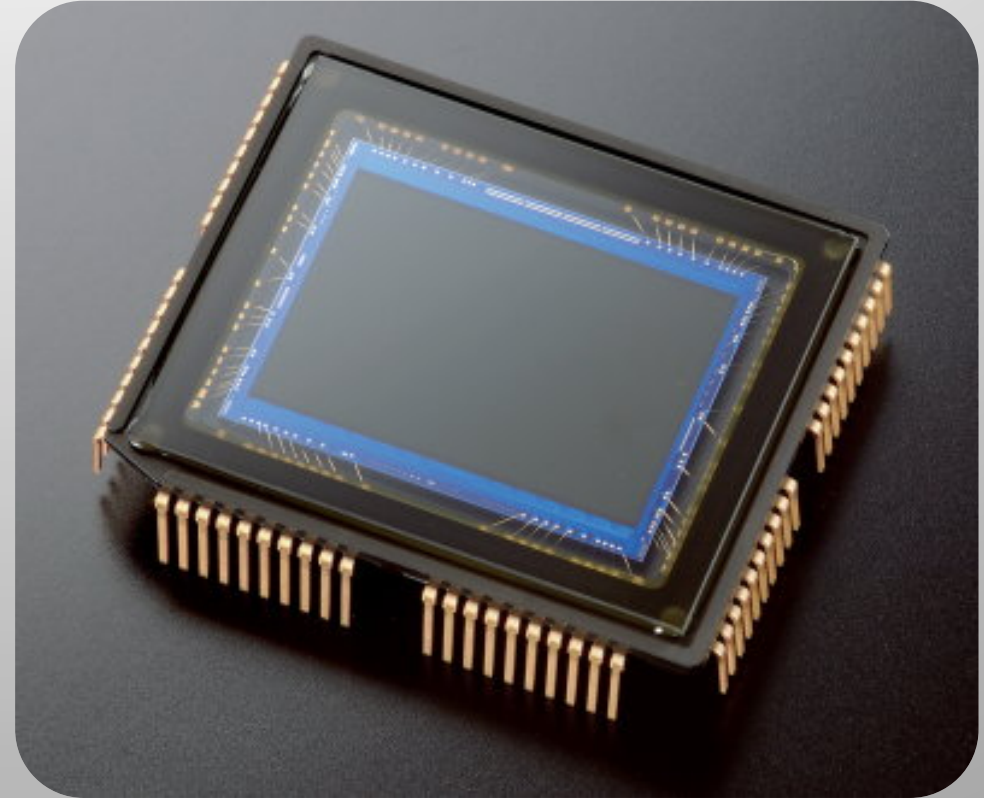
Characteristics of the Matrix

CMOS Technology



Every single pixel is being read individually.

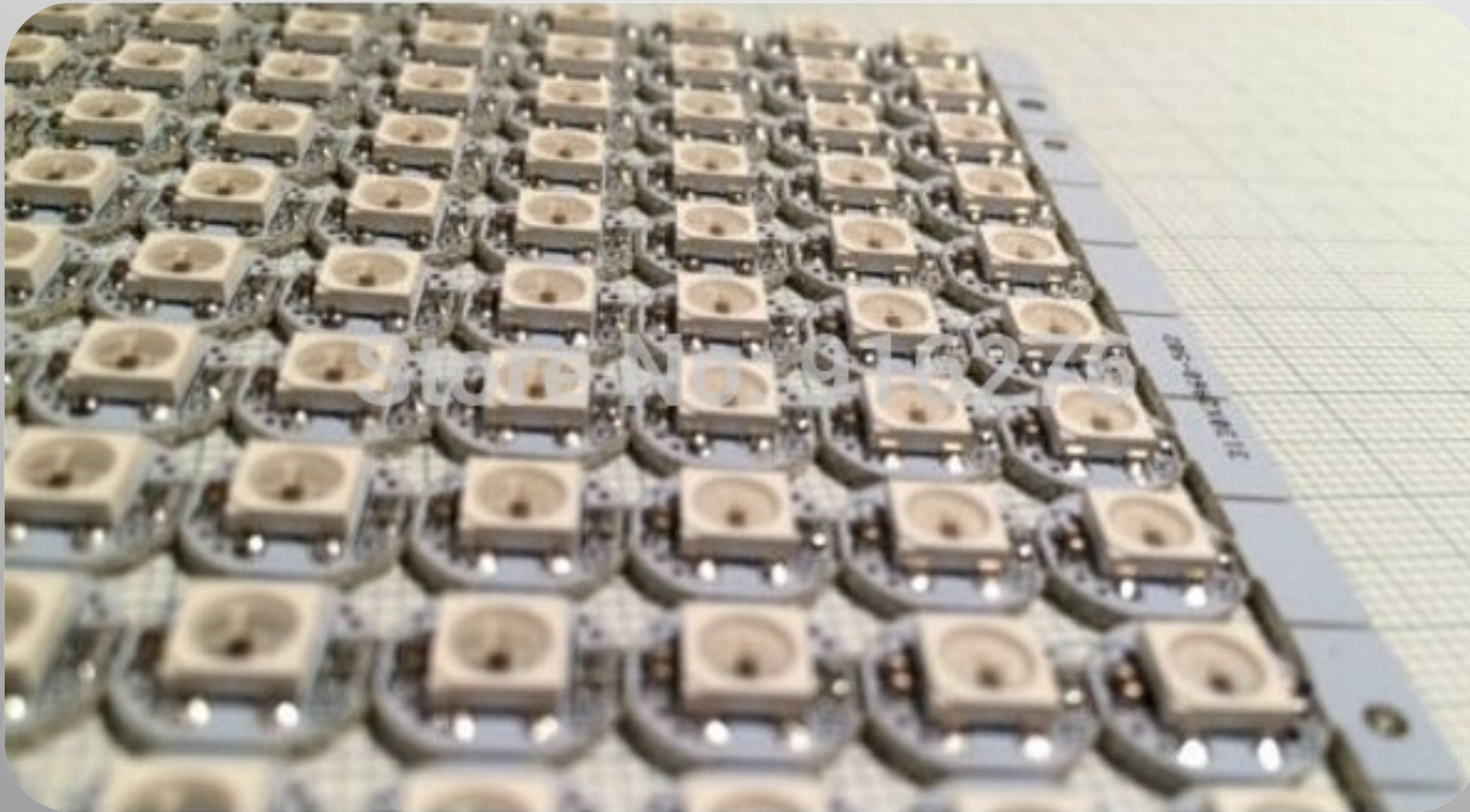
CCD Matrix



Every row of pixels is being read simultaneously.

Larger but Thinner Pixels

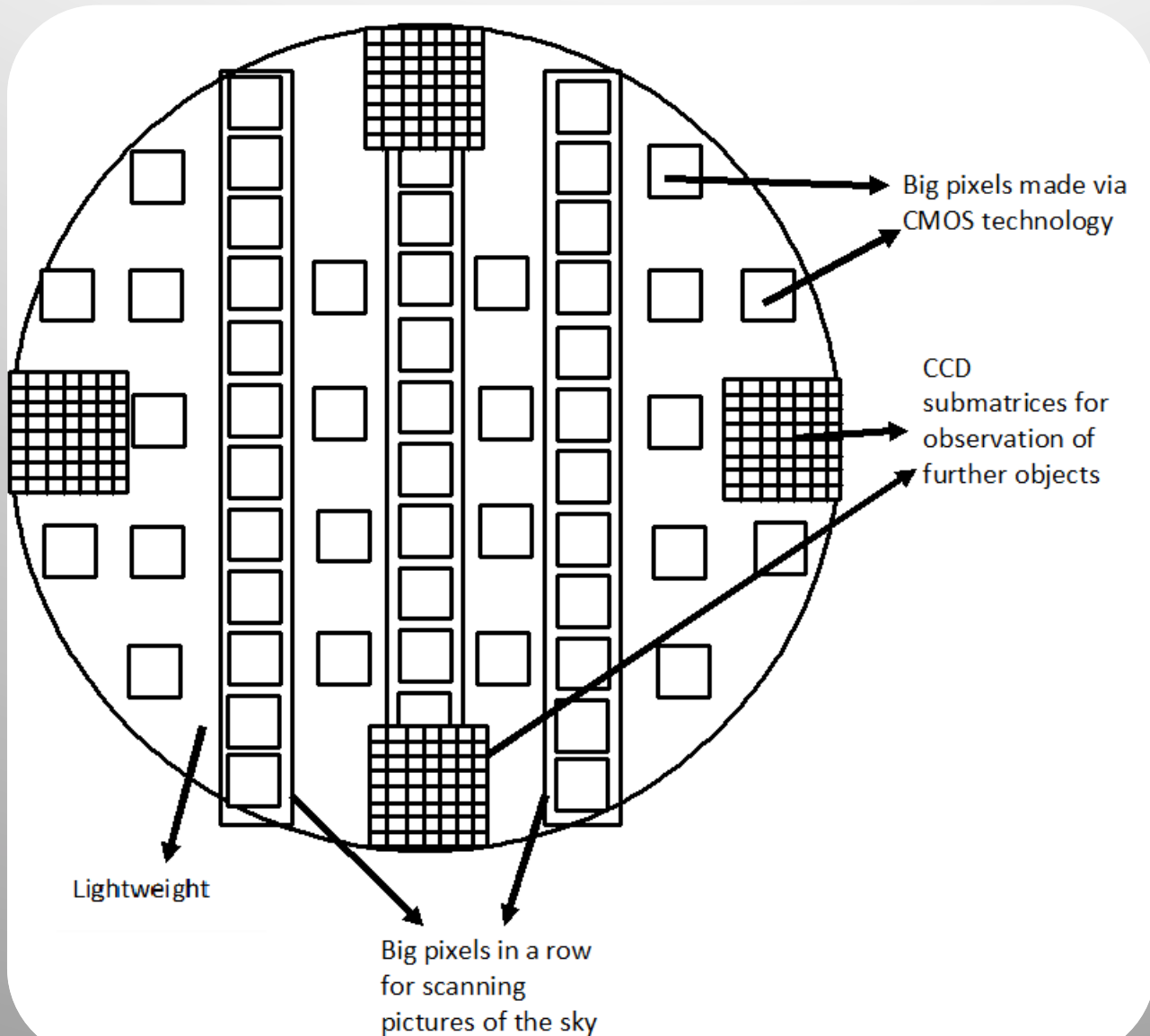
The pixels of the matrix would be with similar sizes.



Probable appeal of the future pixels.

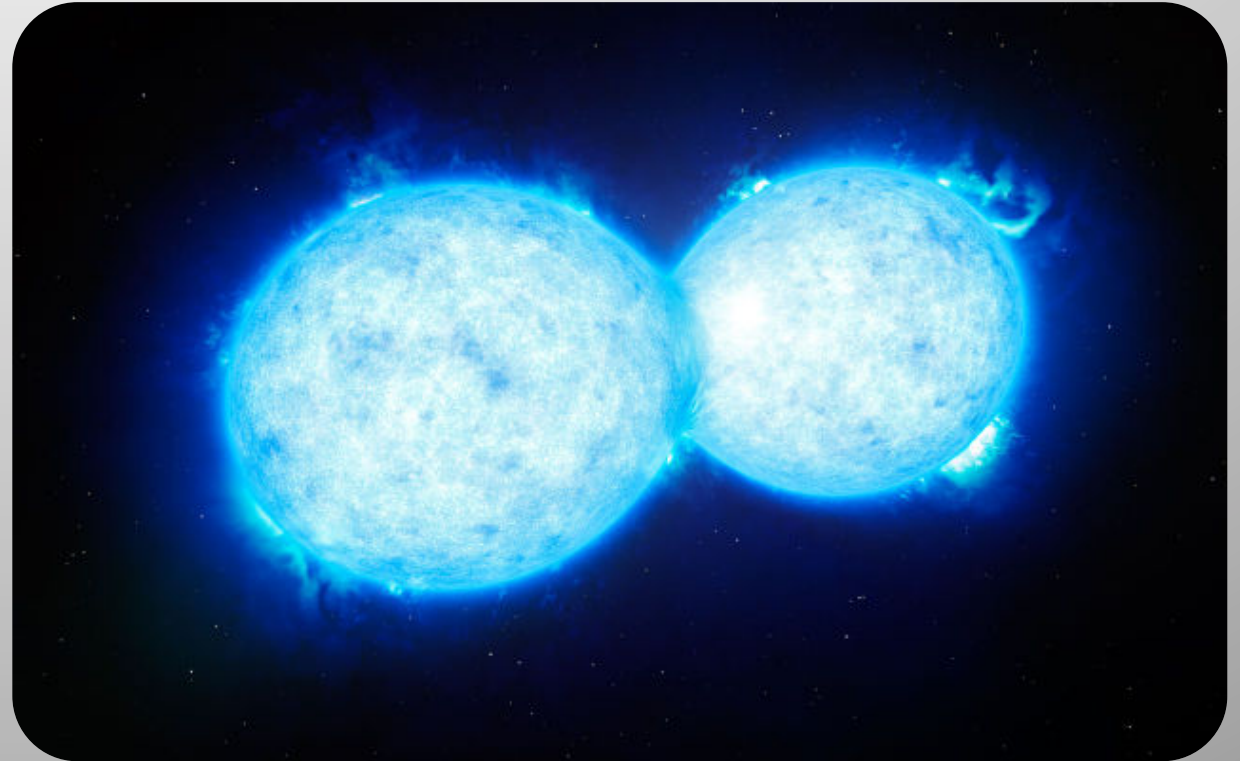
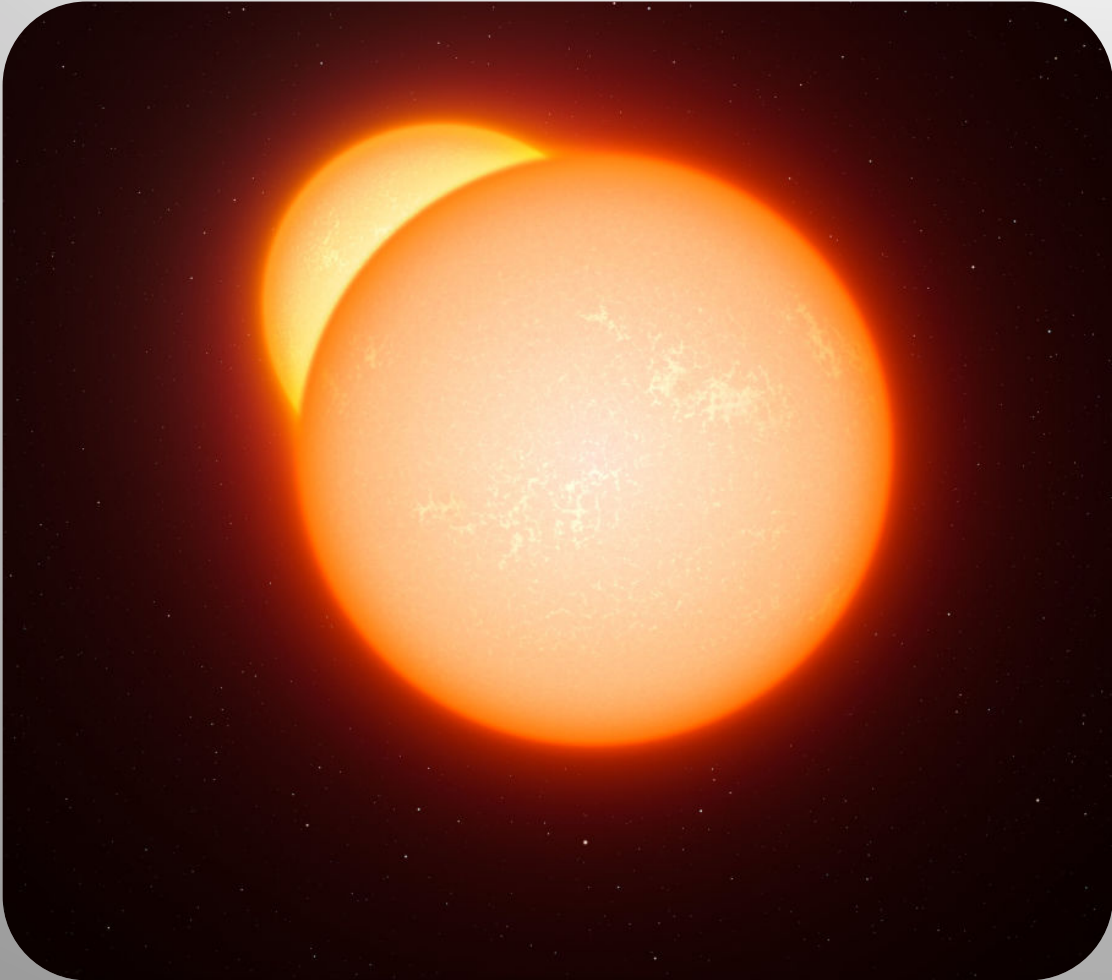


Scheme of the Matrix

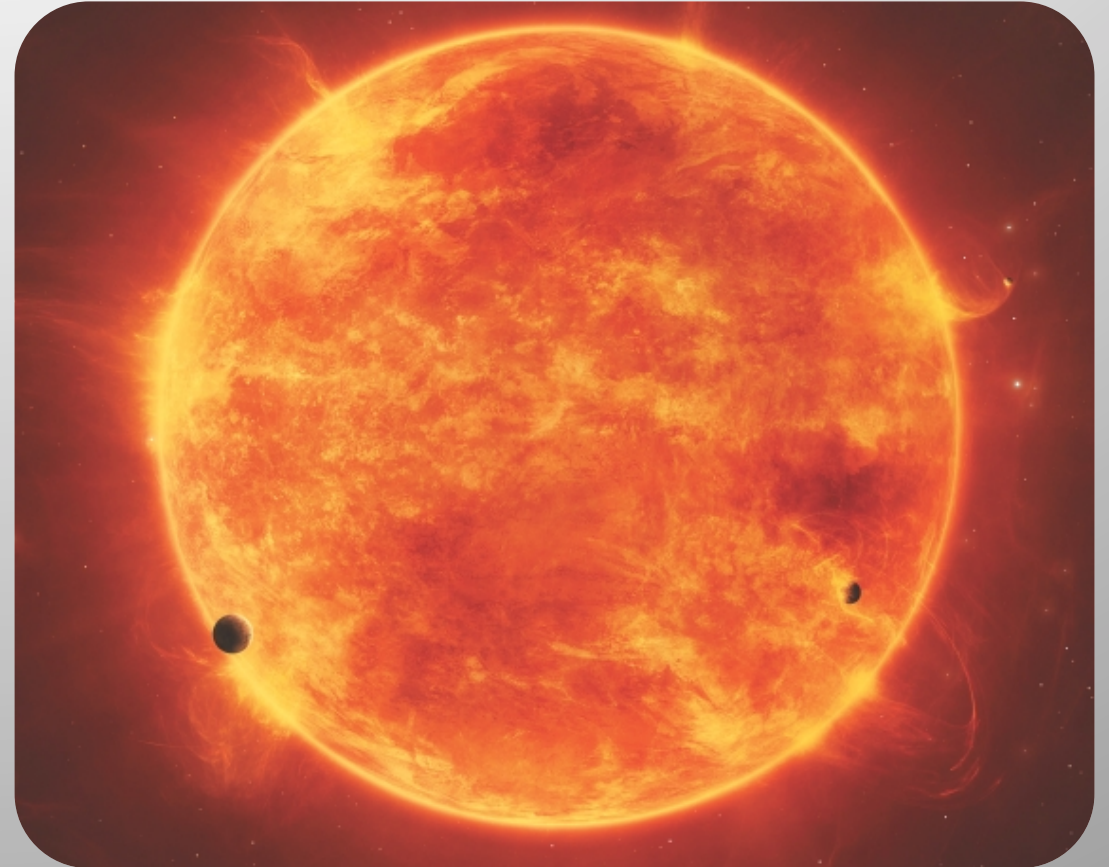
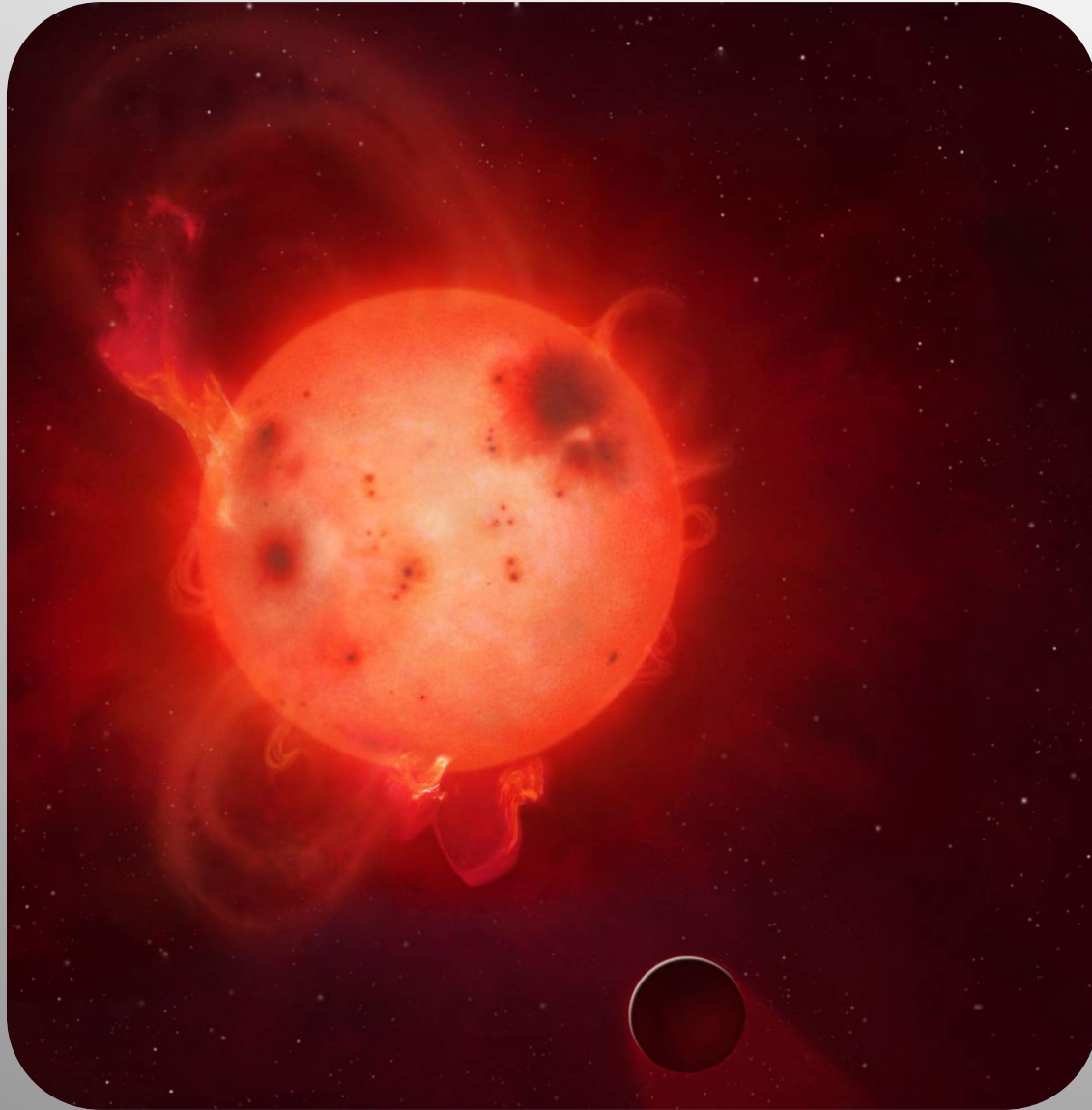


Goals and Objects

BINARY STAR SYSTEMS



RED DWARFS



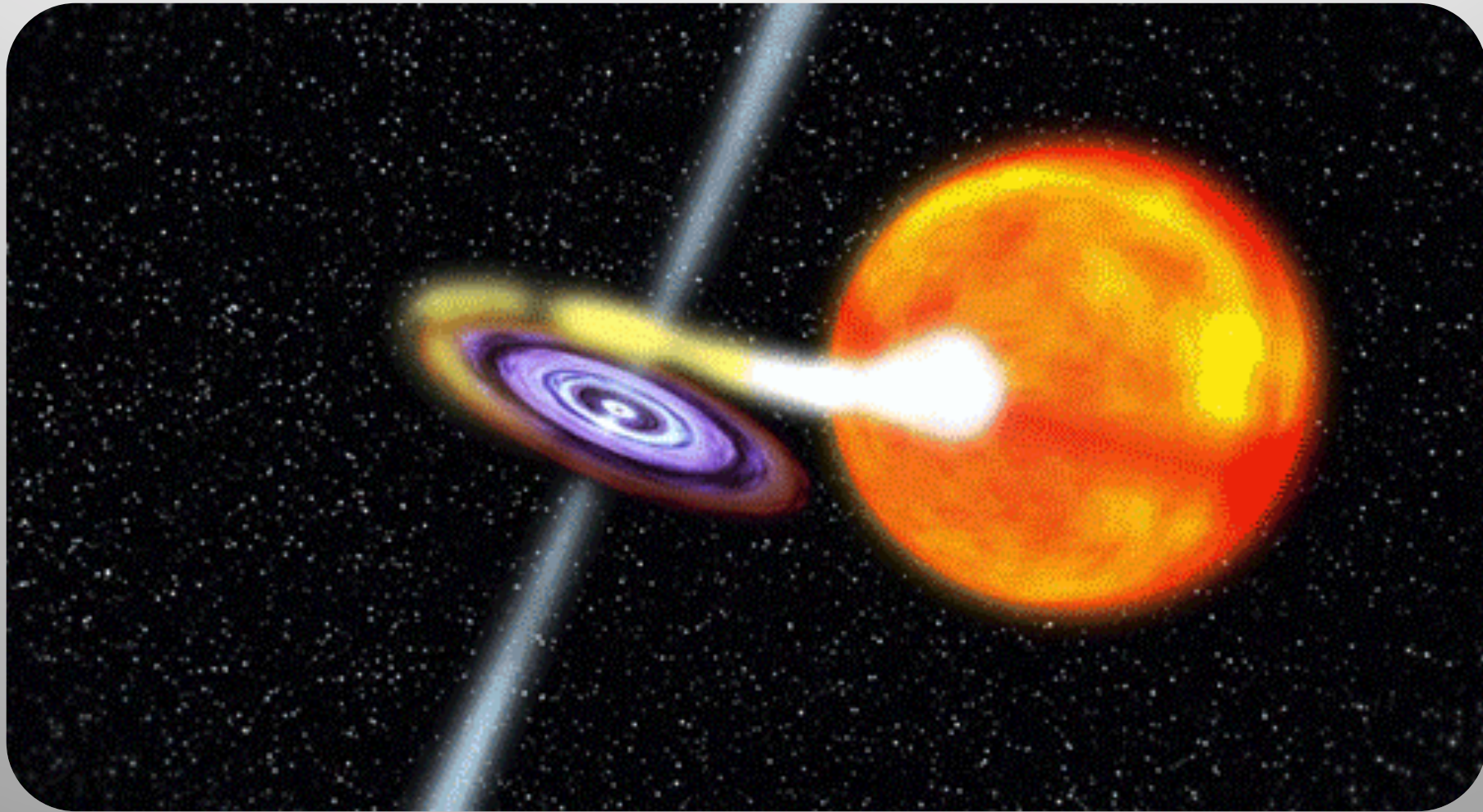
EXOPLANET MAPPING



ACTIVE GALAXY NUCLEI



ACCRETION DISKS AROUND COMPACT OBJECTS



Conclusion

Using the Sun as gravitational lens would provide amazing opportunities to observe extremely interesting astronomical objects and see unprecedented details of the majestic phenomena that happen in the far space.

The implementation of such a project will require solving of extremely difficult technical problems. But we believe that with the technology advancement in the future, they will be overcome.

Refernces

<https://abihollettdrp.files.wordpress.com/2014/12/screen-shot-2015-04-29-at-16-08-58.png> (1)

http://pre06.deviantart.net/06ba/th/pre/i/2015/226/b/0/habitable_exoplanet_by_emperorkk-d95mlty.png (2)

http://www.roe.ac.uk/~heymans/website_images/Gravitational-lensing-galaxyApril12_2010-1024x768.jpg (3)

<http://cdn.pcwallart.com/images/universe-background-wallpaper-3.jpg> (5)

<https://avatanplus.com/files/resources/original/573c87ce7609c154c4727e93.png> (4)

https://i.ytimg.com/vi/bl_FH_2Cqr8/maxresdefault.jpg (7)

<https://www.google.bg/search?q=albert>

[+einstein&source=lnms&tbm=isch&sa=X&sqi=2&ved=0ahUKEwiRxIvw2_3SAhWE2xoKHXCeB1wQ_AUIBigB&biw=1366&bih=651#tbm=isch&q=albert+einstein+high](https://www.google.bg/search?q=albert+einstein&source=lnms&tbm=isch&sa=X&sqi=2&ved=0ahUKEwiRxIvw2_3SAhWE2xoKHXCeB1wQ_AUIBigB&biw=1366&bih=651#tbm=isch&q=albert+einstein+high+quality*&imgsrc=vPFWYpz6t7nA0M:&spf=397)

[+quality*&imgsrc=vPFWYpz6t7nA0M:&spf=397](https://www.google.bg/search?q=albert+einstein+high+quality*&imgsrc=vPFWYpz6t7nA0M:&spf=397) (8)

https://theysaidso.com/img/bgs/einstein_1.jpg (9)

http://www.einstein-online.info/spotlights/grav_lensing_history (11)

<https://en.wikipedia.org/wiki/Aerographene> (12)

<https://en.wikipedia.org/wiki/Aerogel> (13)

[https://en.wikipedia.org/wiki/Magnox_\(alloy\)](https://en.wikipedia.org/wiki/Magnox_(alloy)) (14)

http://www.engineeringtoolbox.com/emissivity-coefficients-d_1417.html



Thank you for your attention!

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