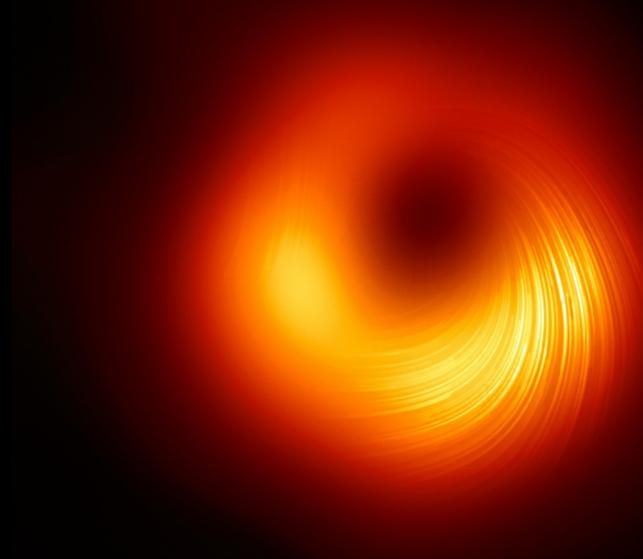


Desvendando o Invisível:

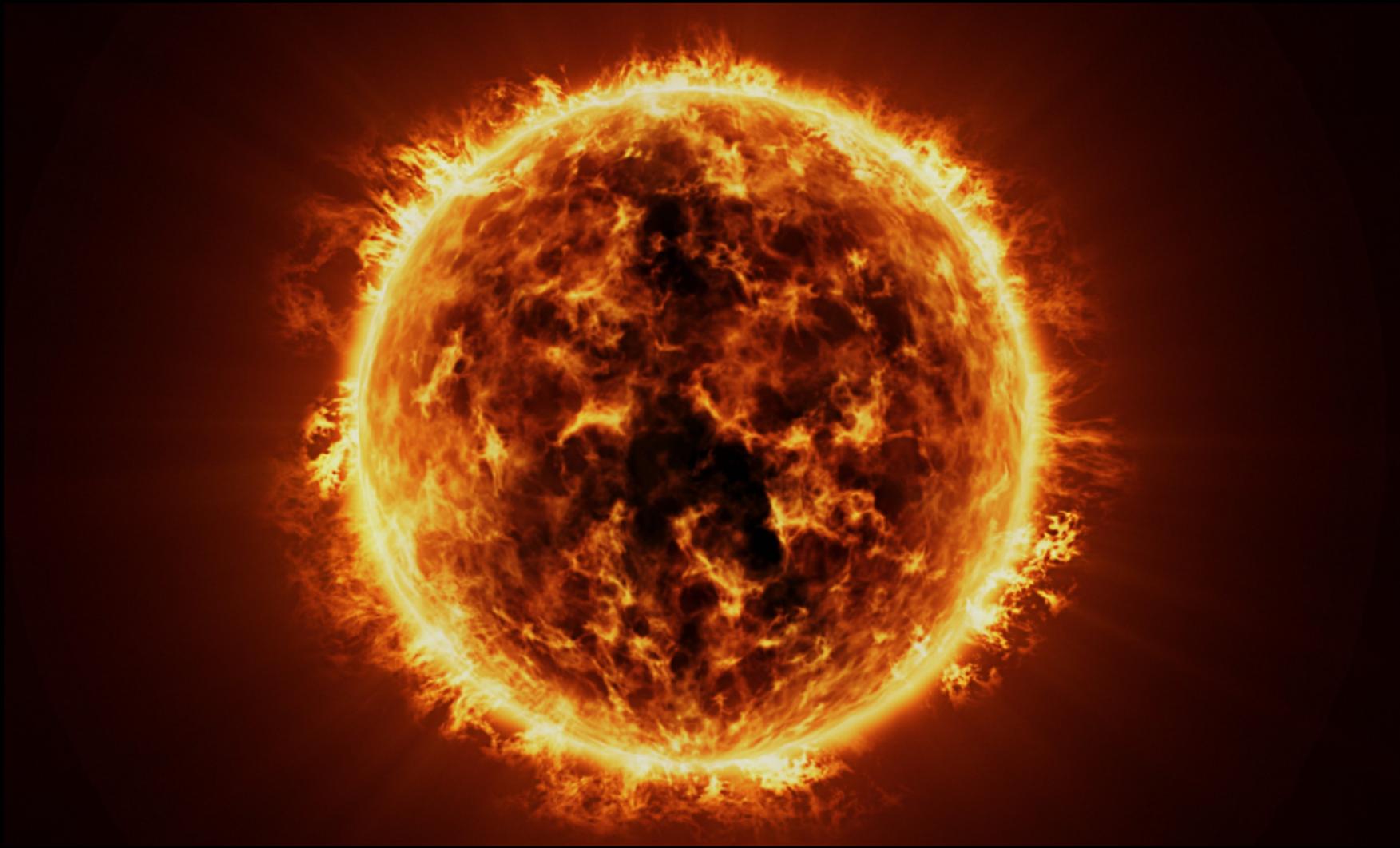
A fotografia de Buracos Negros e suas sombras

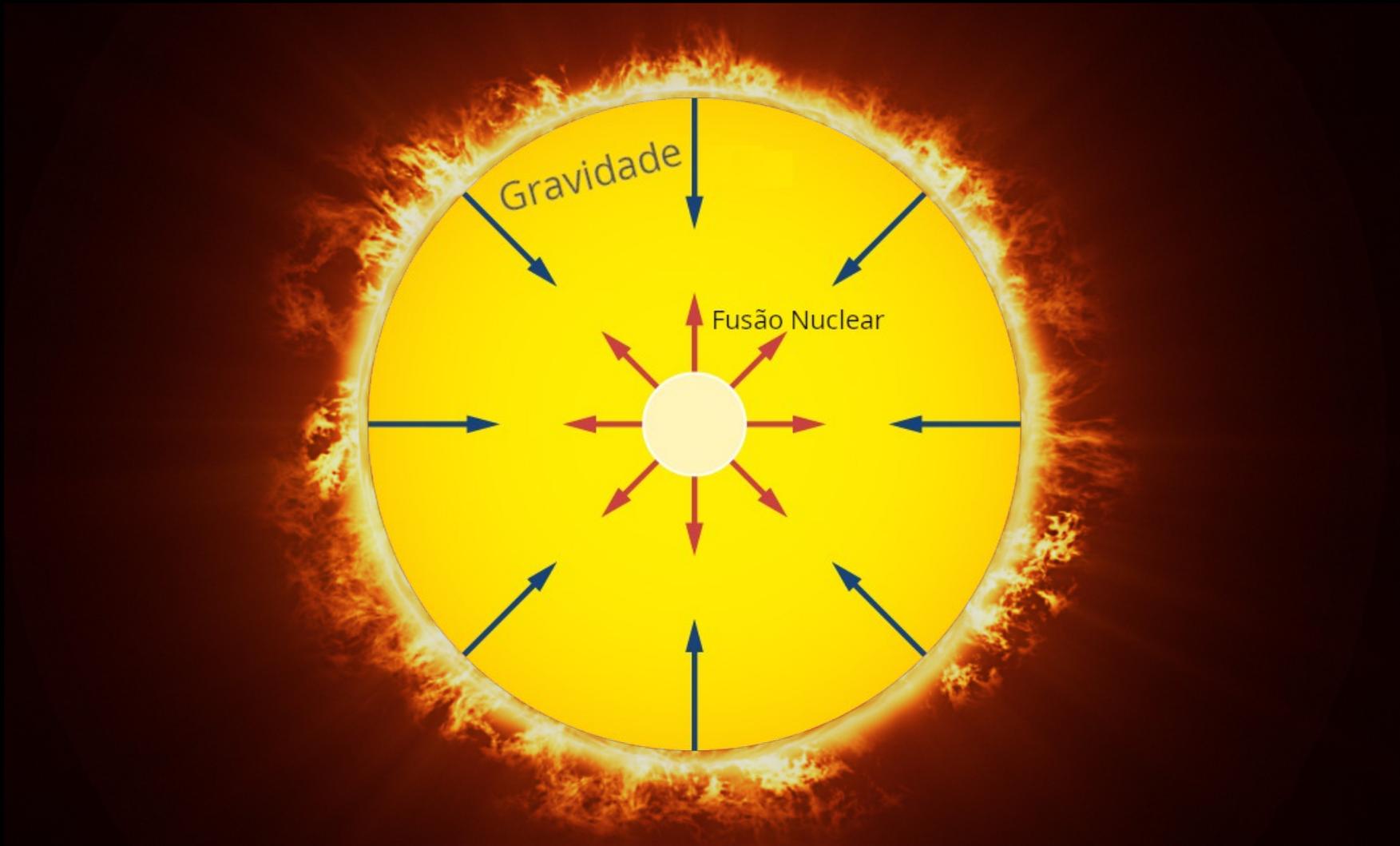


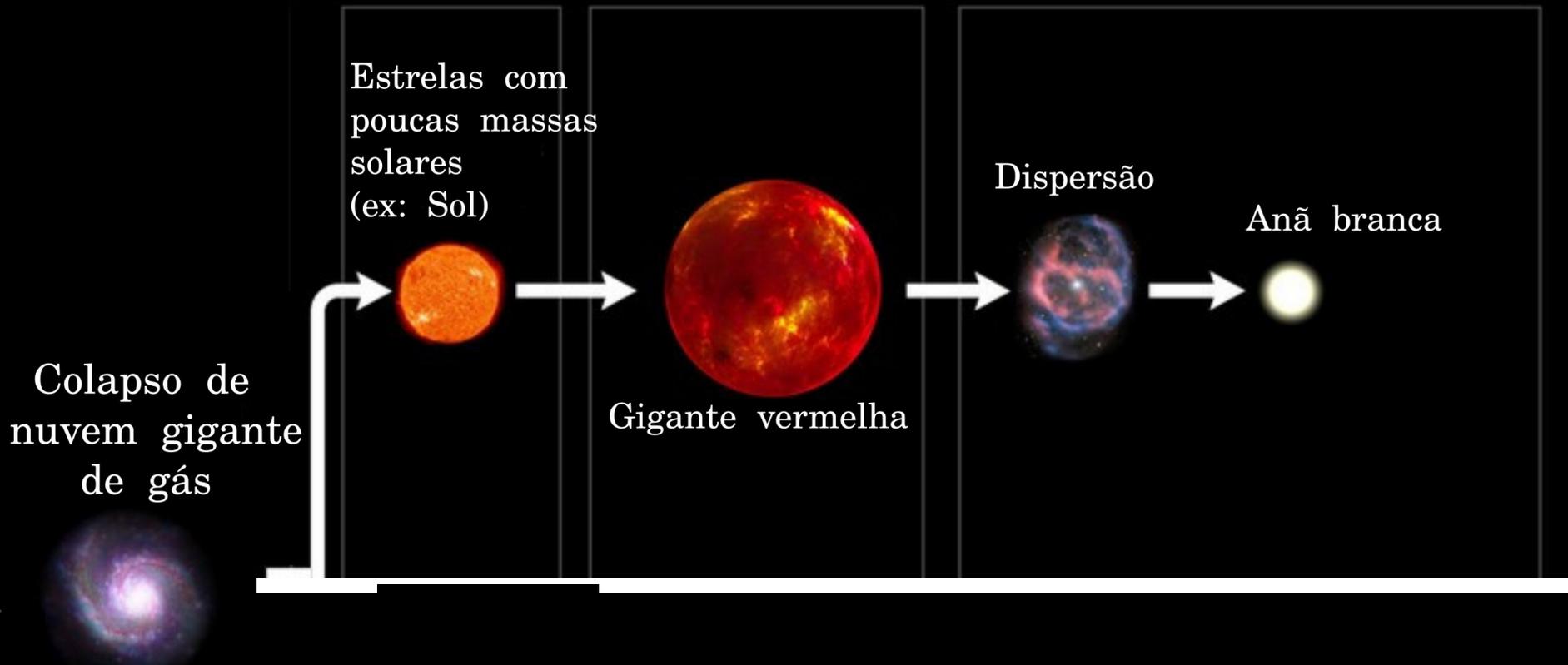
Pedro Cunha

Universidade de Aveiro







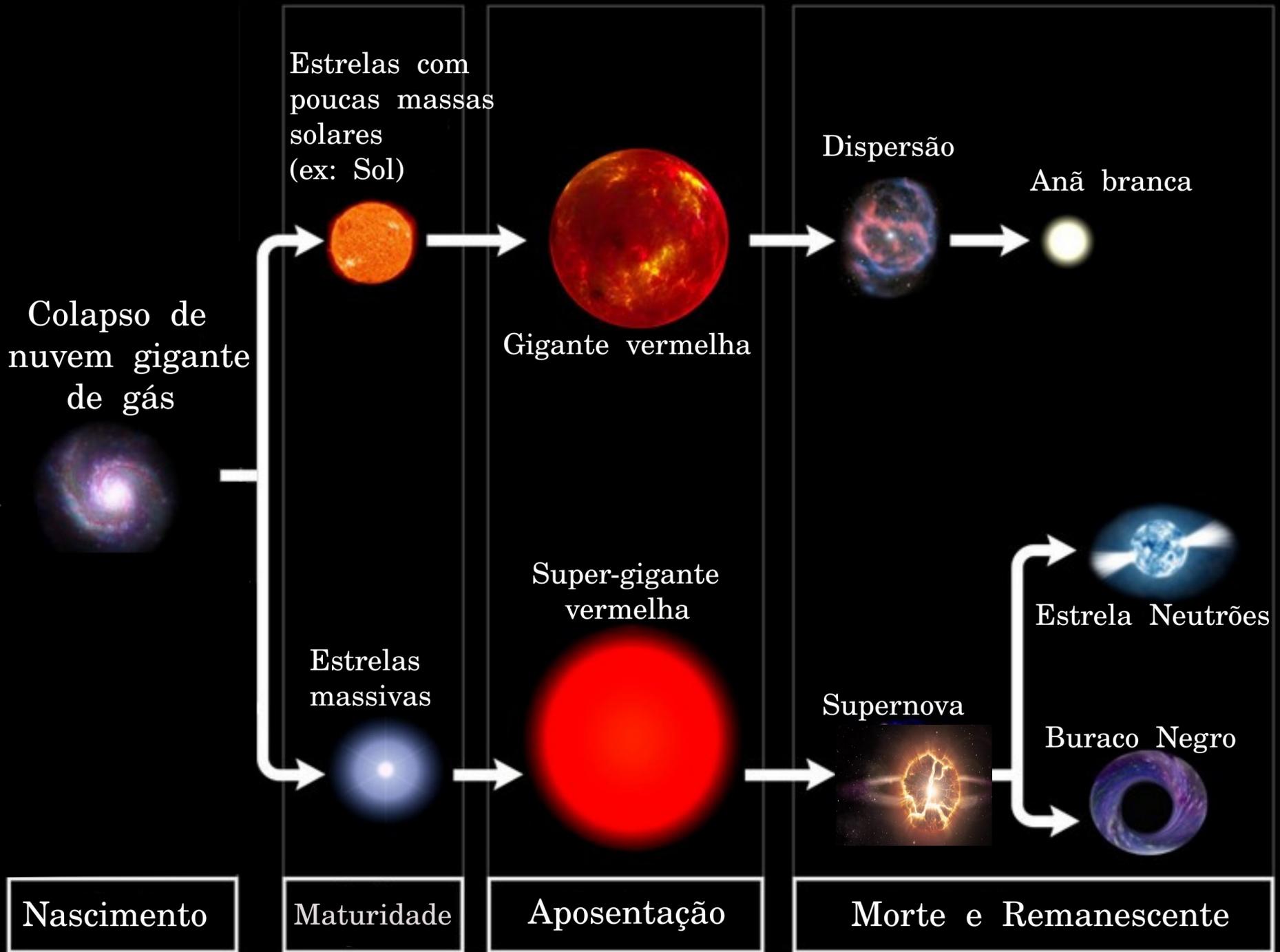


Nascimento

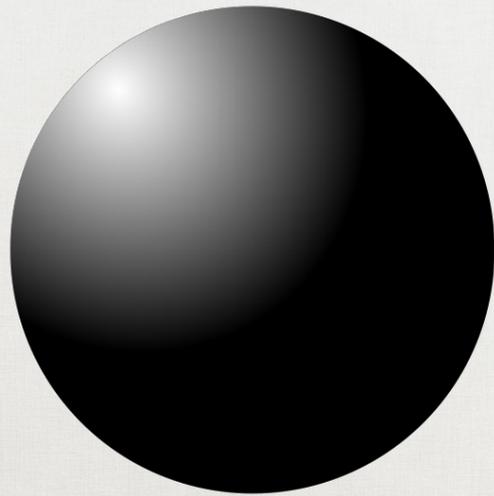
Maturidade

Aposentação

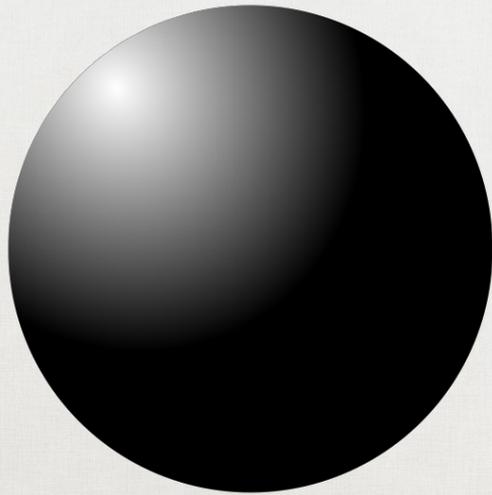
Morte e Remanescente



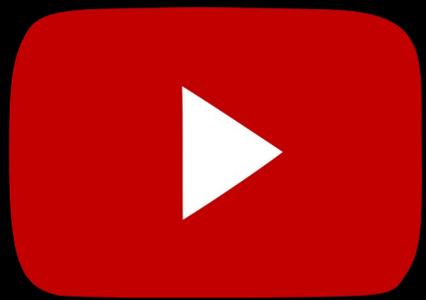
O que é um Buraco Negro?



O que é um Buraco Negro?



→ É uma região no espaço-tempo de onde nada consegue escapar, nem mesmo a **luz**.

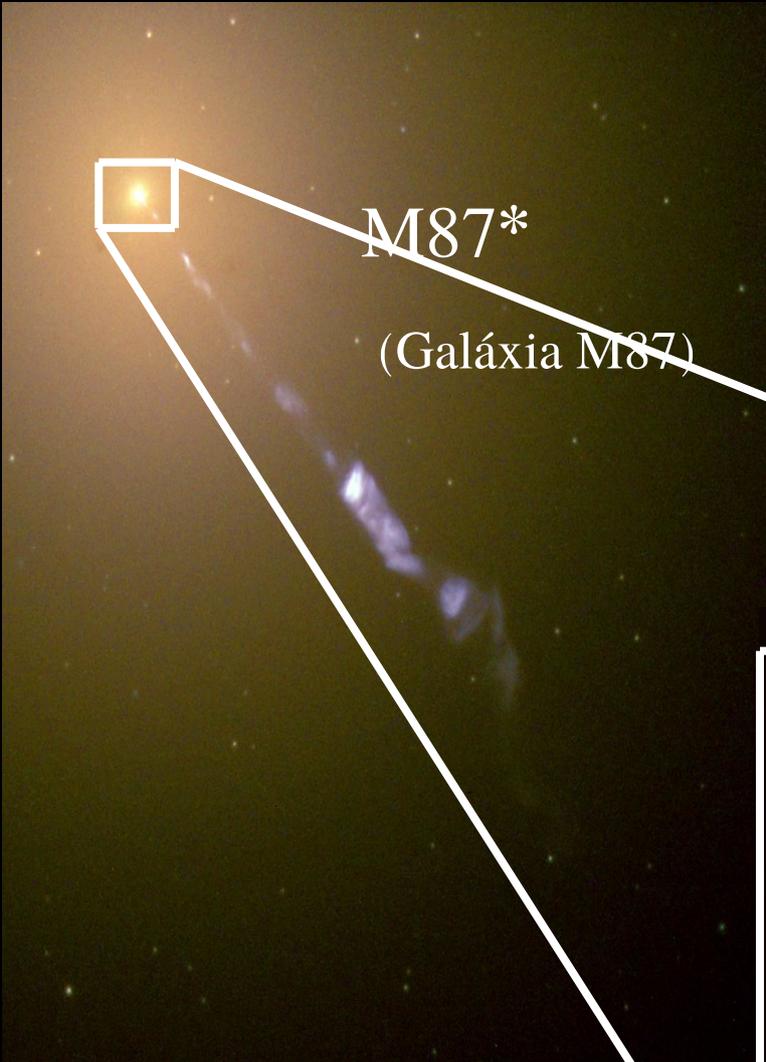


Vídeo adaptado Kurzgesagt



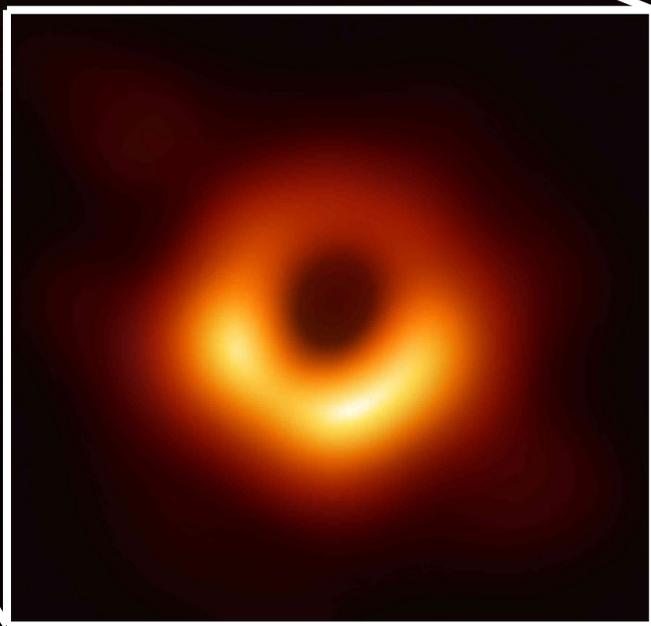
M87*

(Galáxia M87)



M87*

(Galáxia M87)



Fotografia M87* (2019)
Telescópio do Horizonte de Eventos

"All the News
That's Fit to Print"

The New York Times

National Edition

Snow and sleet north. Periodic rain in Iowa into southern Wisconsin. Mostly cloudy south. Afternoon severe thunderstorms. Highs in 30s to lower 80s. Weather map, Page B14.

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THURSDAY, APRIL 11, 2019

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Migrants Pour Into a System That's 'on Fire'

U.S. Border Could Be at a Breaking Point

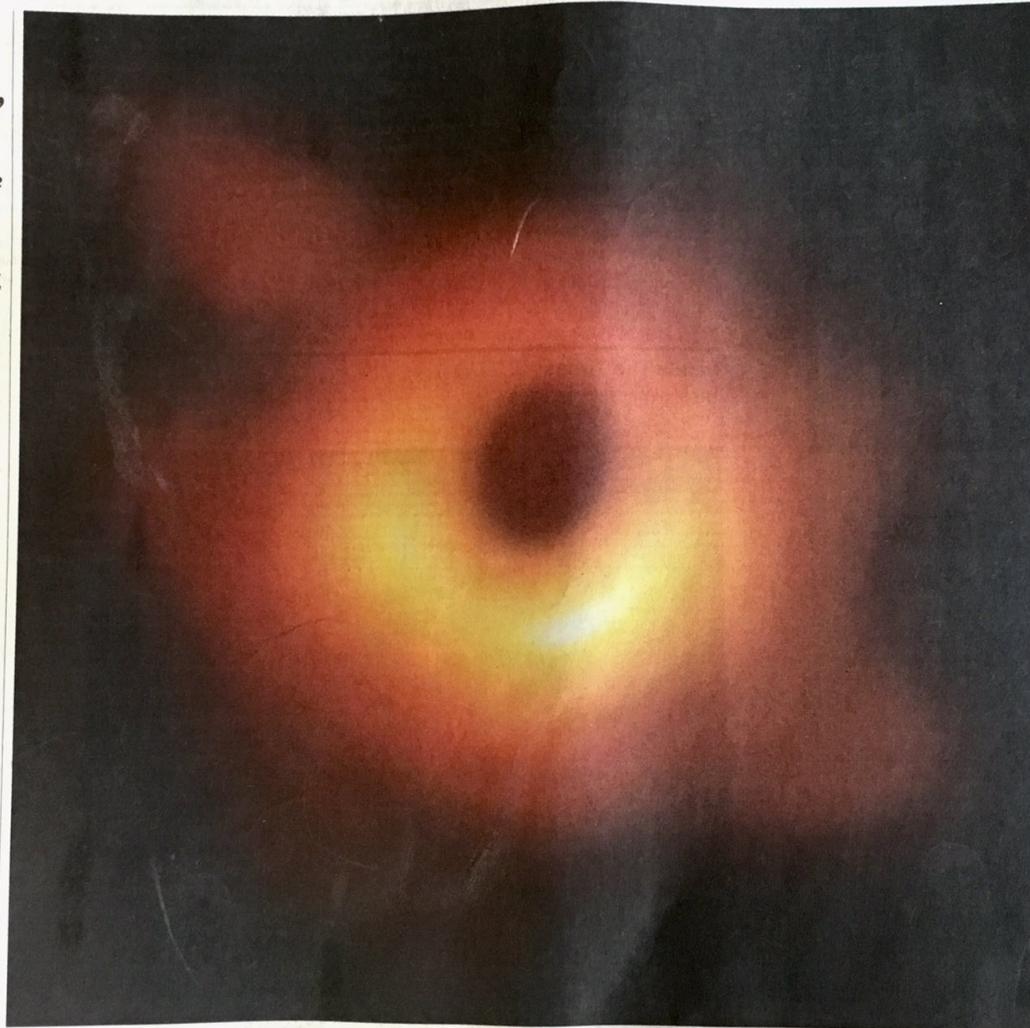
This article is by **Michael D. Shear, Miriam Jordan and Manny Fernandez.**

SAN YSIDRO, Calif. — It was never like this before.

The migrants come now in the middle of the night or in the bright light of day. Men and women arrive by the hundreds, caked with dirt, with teens and toddlers in tow. They jump the small fences in remote parts of Texas, and they gather on the hot pavement at the main border crossing in California. Tired and fearful, they look for the one thing that they pray will allow them to stay in the United States, at least for a while: a Border Patrol agent.

Gone are the days when young, strong men waited on the Tijuana River levees for their chance to wade across the water, evade capture and find work for the summer. These days, thousands of people a day simply walk up to the border and surrender. Most of them are from Central America, seeking to escape gang violence, sexual abuse, death threats and persistent poverty. The smugglers have told them that they will be quickly released, as long as they bring a child, and that they will be allowed to remain in the United States for years while they pursue their asylum cases.

The very nature of immigration to America changed after 2014, when families first began showing up in large numbers. The resulting crisis has overwhelmed a system unable to detain, care for and quickly decide the fate of tens of thousands of people who claim to be fleeing for their lives. For years, both political parties have tried — and failed — to overhaul the nation's immigration laws, mindful that someday the govern-



Scientists captured a view of a black hole at the heart of a galaxy known as Messier 87, some 55 million light-years away from Earth.

Peering Into Light's Graveyard: The First Image of a Black Hole

pher Nolan's outer-space epic "In-

NEWS ANALYSIS

Israelis Lean On Stability With Leader

Netanyahu Is Symbol of Cherished Security

By **DAVID M. HALBFINGER**

JERUSALEM — Benjamin Netanyahu's apparent re-election as prime minister of Israel attests to a starkly conservative vision of the Jewish state and its people about where they are and where they are headed.

They prize stability, as well as the military and economic security that Mr. Netanyahu has delivered.

Though in many ways they have never been safer, they remain afraid — especially of Iran and its influence over their neighbors, against which Mr. Netanyahu has relentlessly crusaded. They are persuaded by his portrayal of those who challenge him, whether Arab citizens or the left, as enemies of the state. They take his resemblance to authoritarian leaders around the world as evidence that he was ahead of the curve.

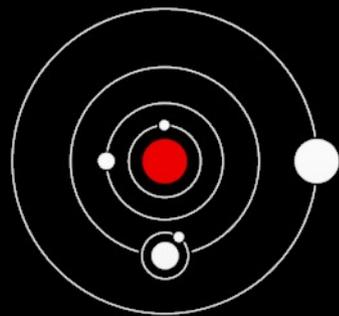
They credit Mr. Netanyahu, whose strategic vision values power and fortitude above all, with piloting Israel to unprecedented diplomatic heights and believe still more is possible. And they are loath to let anyone less experienced take the controls.

"Let's be honest with ourselves," said Michael B. Oren, a former Israeli ambassador to Washington. "Our economy is excellent, our foreign relations were never better, and we're secure. We've got a guy in politics for 40 years: We know him, the world knows him — even our enemies know him."

Not everyone is so enamored of him.



Buraco Negro M87*



Sistema Solar

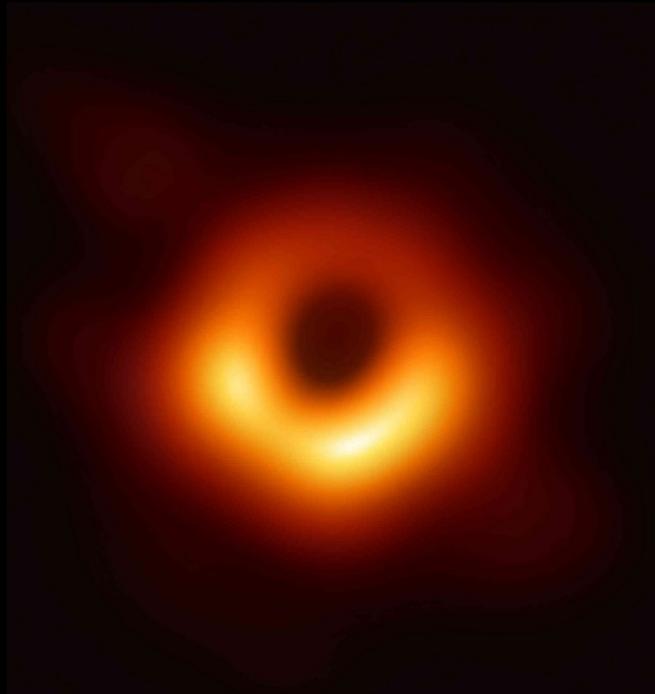
Como funciona o Telescópio do Horizonte de Eventos?

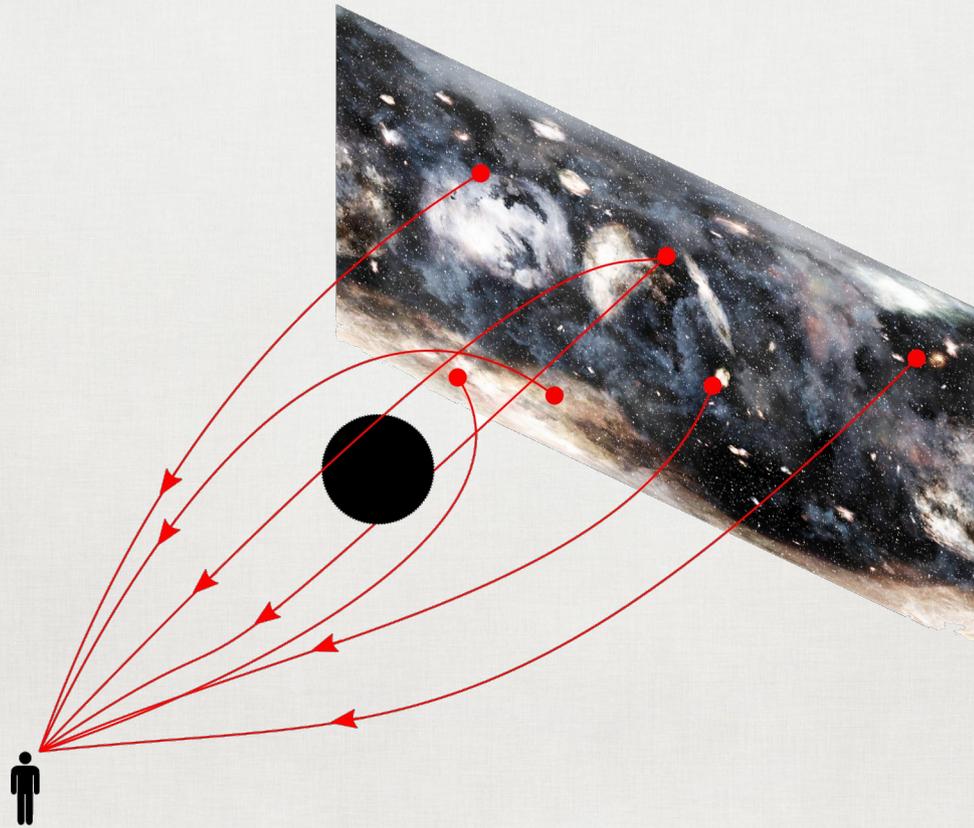


≈



Como compreender a imagem de
um Buraco Negro?





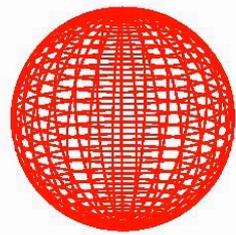
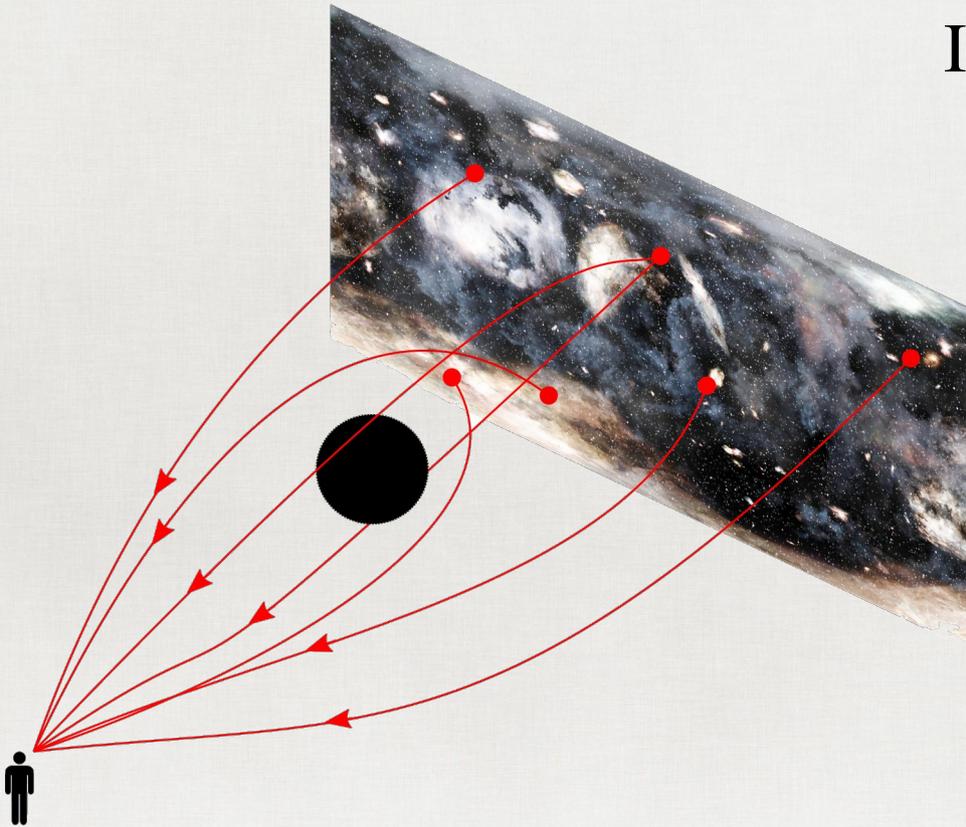


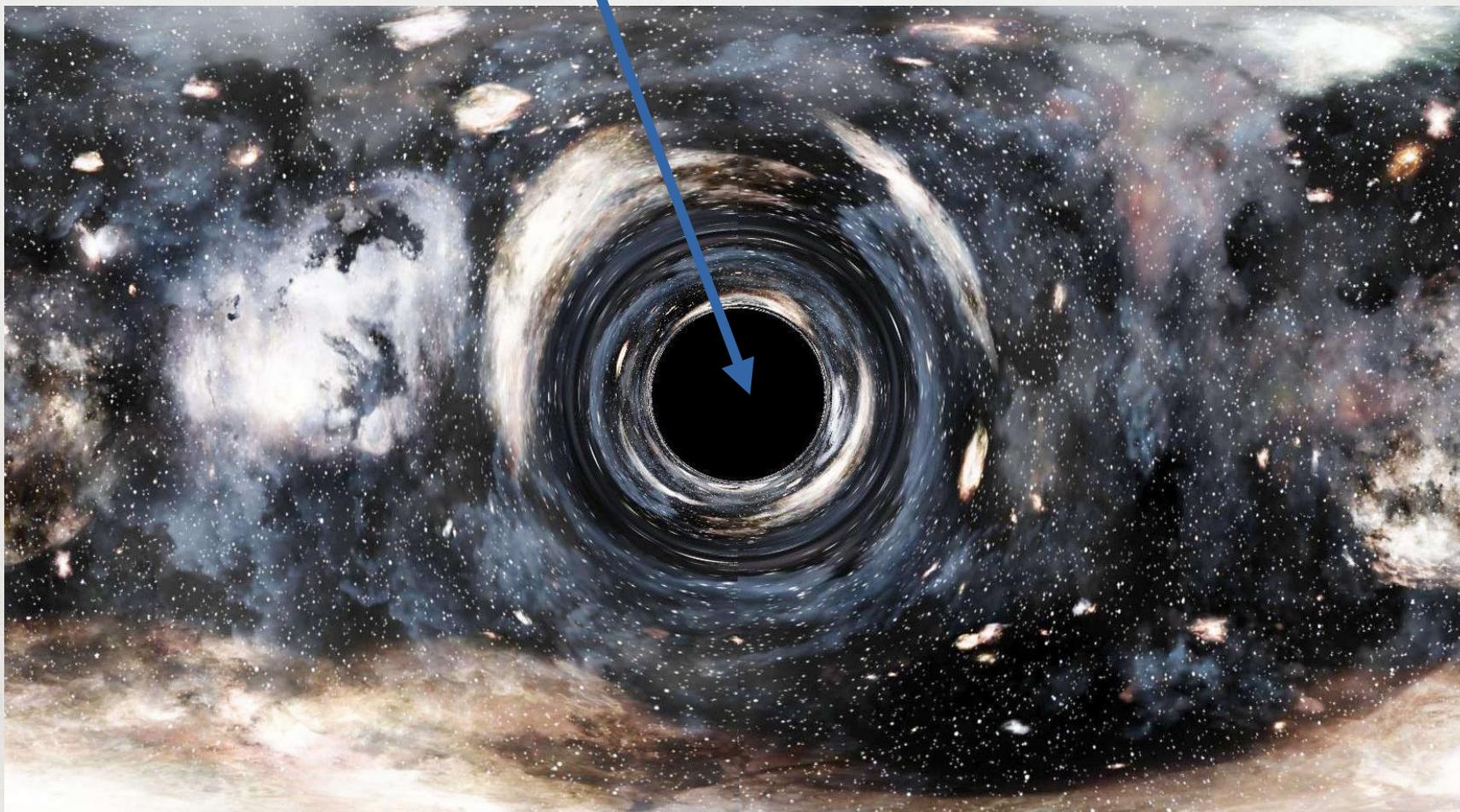


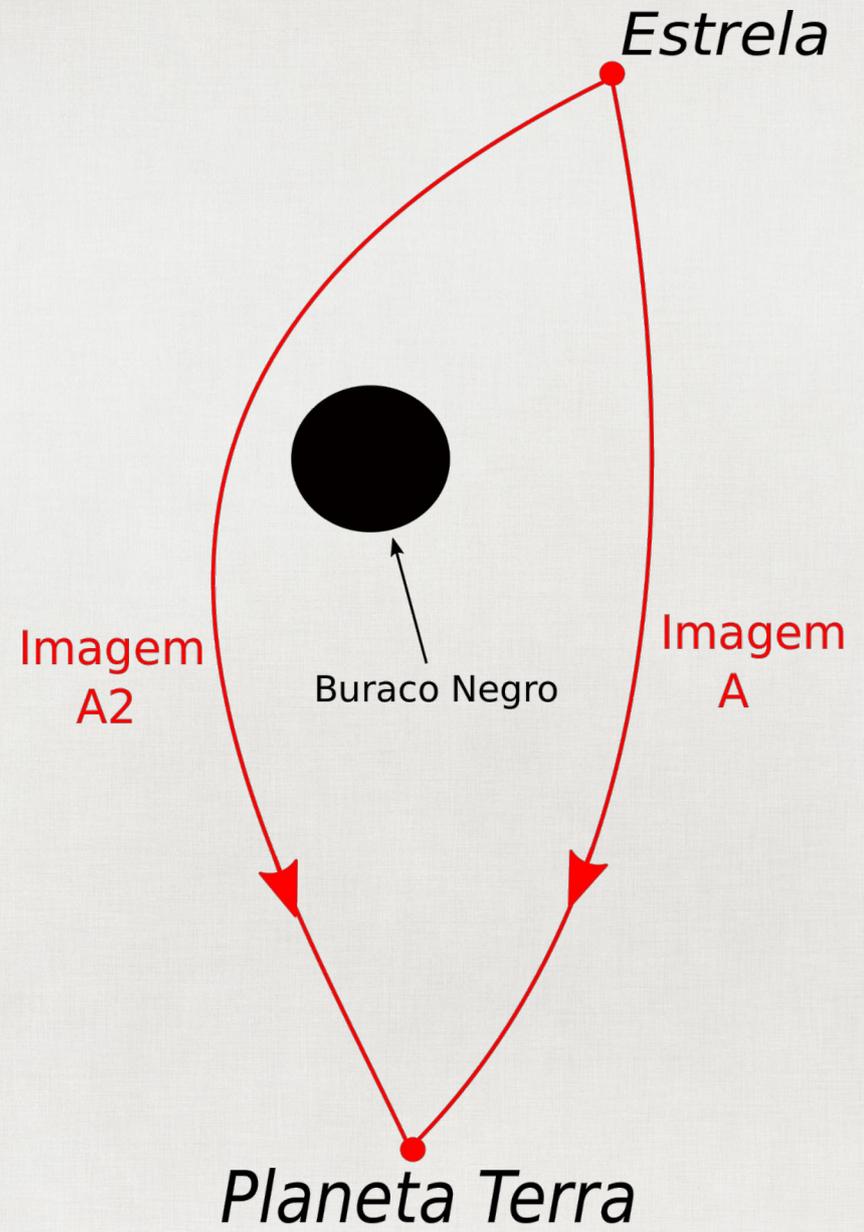
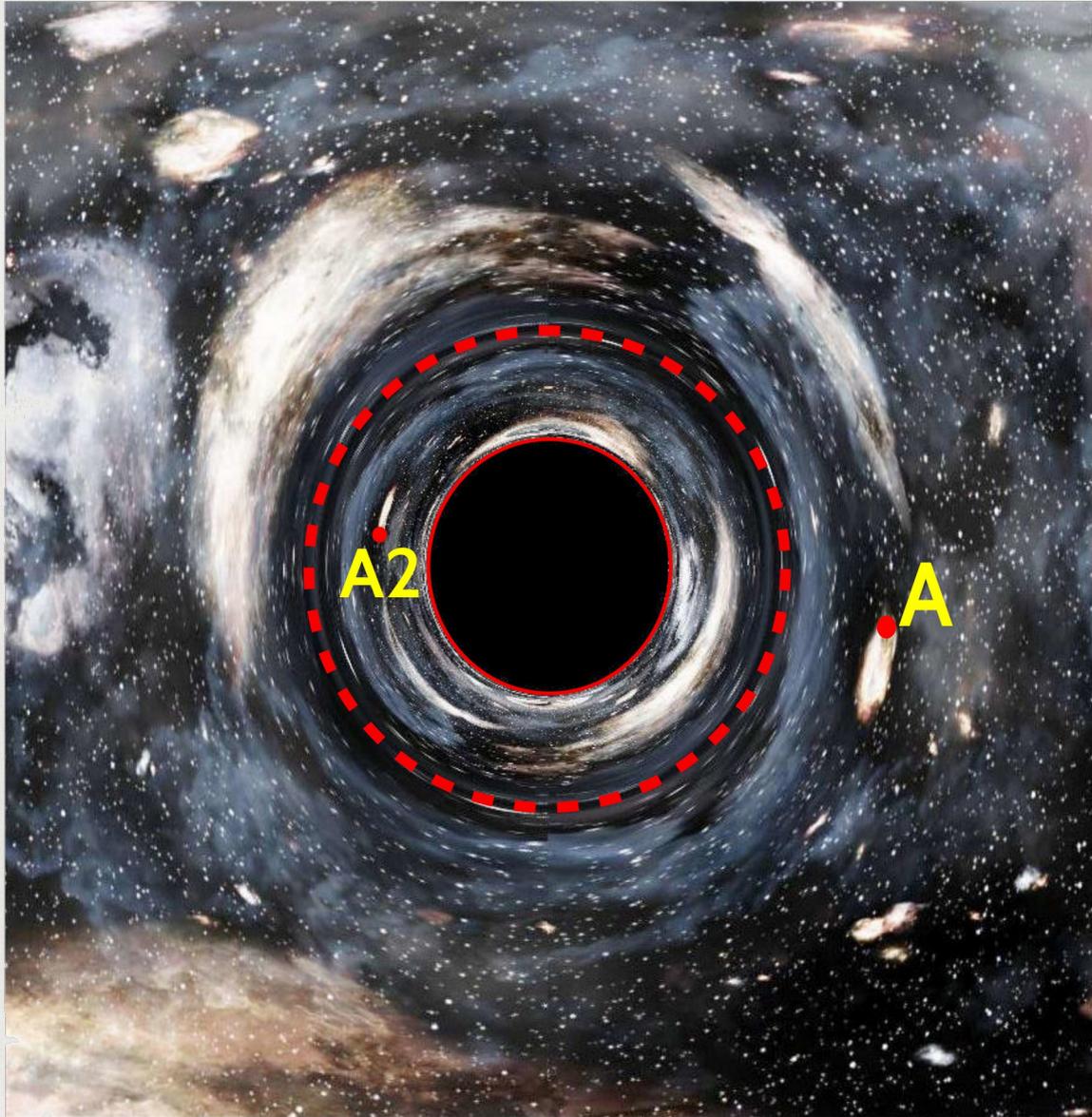
Imagem observada pela pessoa





“Sombra” do Buraco Negro

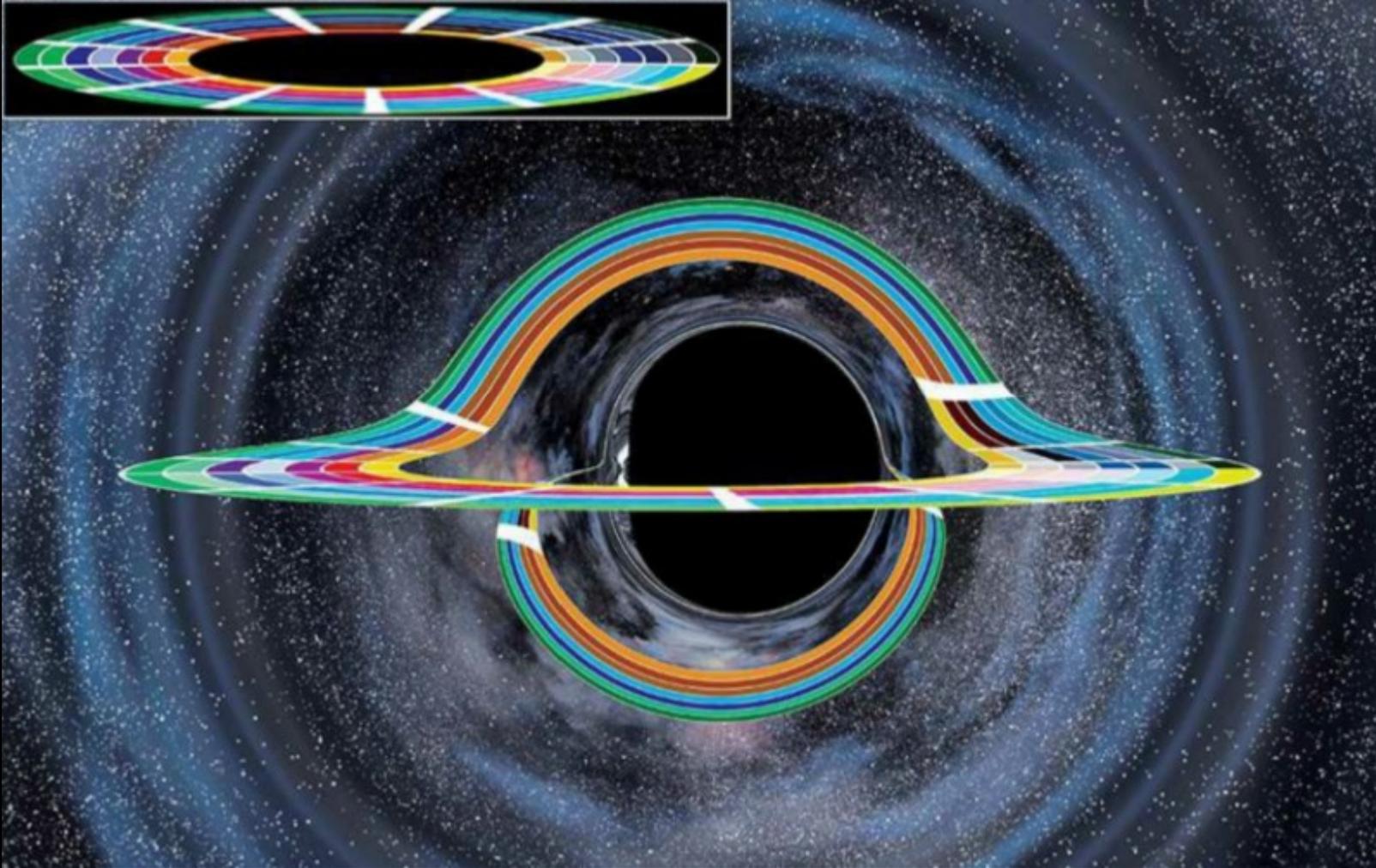




Qual é a imagem de um Buraco Negro iluminada por um disco fino?



Filme *Interstellar*



Como seria a imagem de um Buraco Negro mais realista?

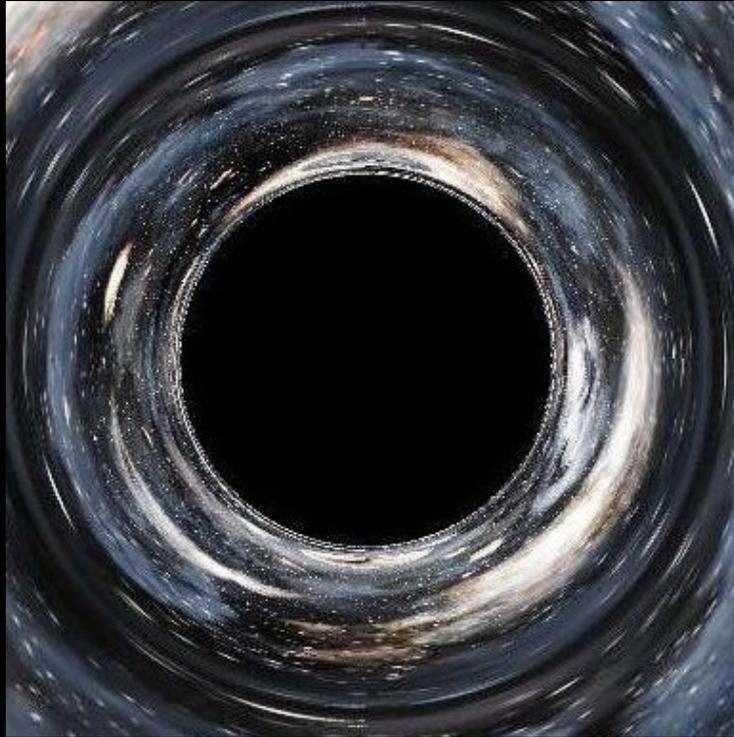


Imagem acadêmica
(luz vem das estrelas)



Imagem sintética
(luz vem de disco dinâmico)



Imagem sintética
(luz vem de disco dinâmico)

Desfocagem

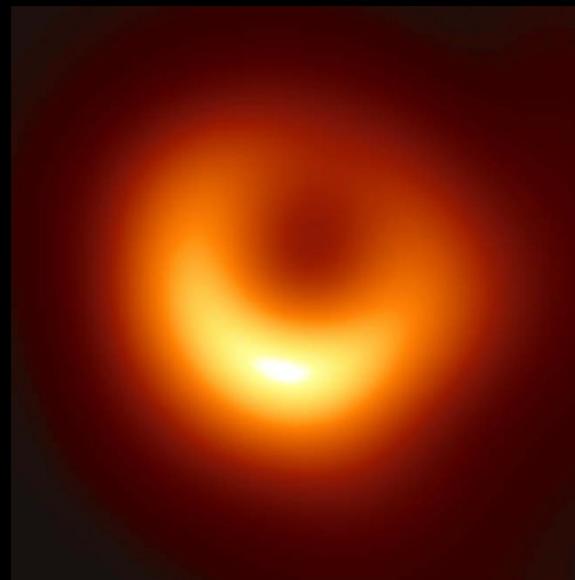


Imagem sintética desfocada



Imagem sintética
(luz vem de disco dinâmico)

Desfocagem

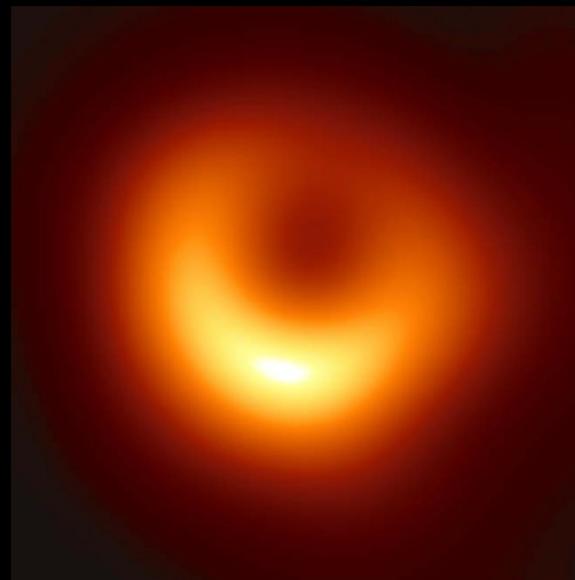
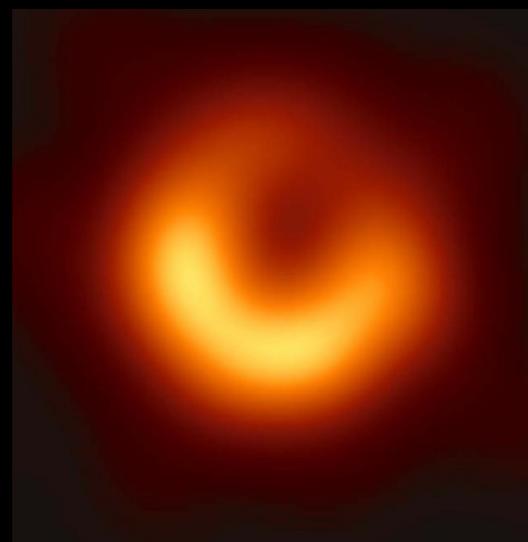
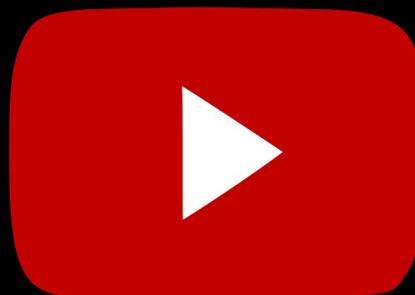


Imagem sintética desfocada

Imagem observada de M87* →



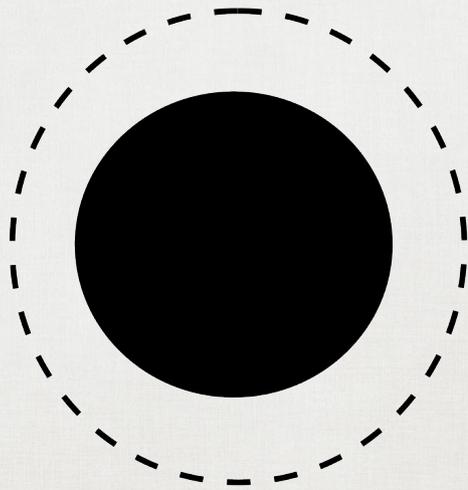
Qual é a relação com a imagem do filme do Interstellar?

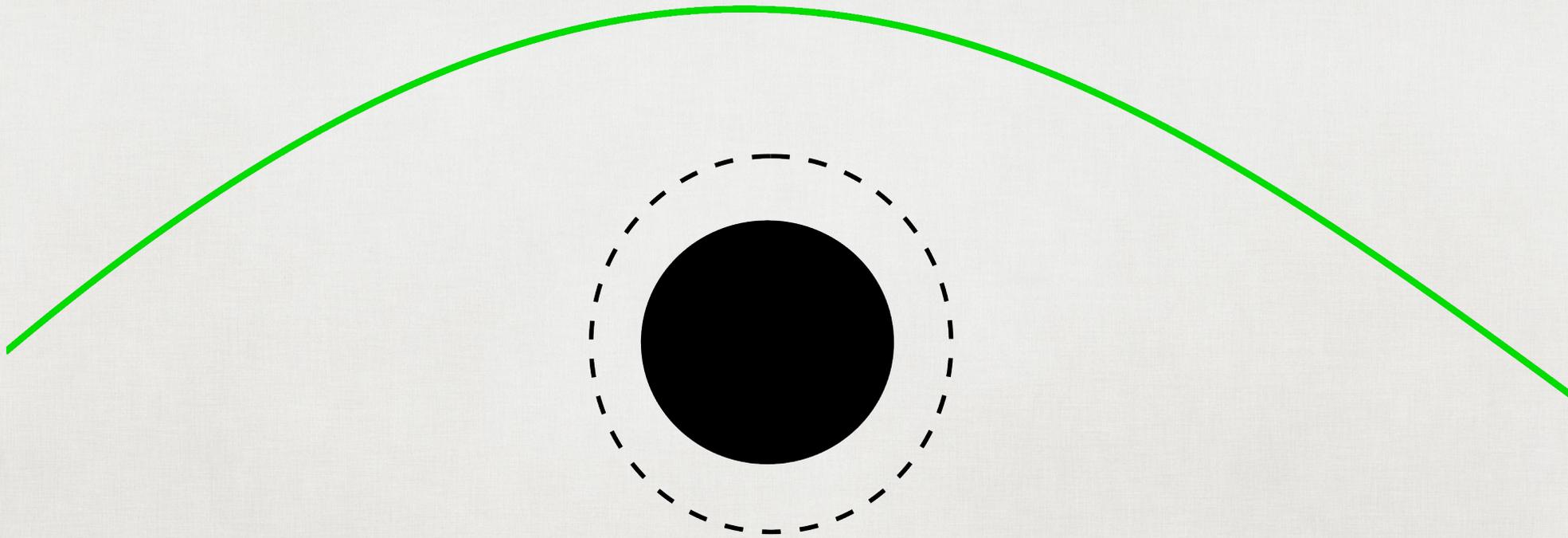


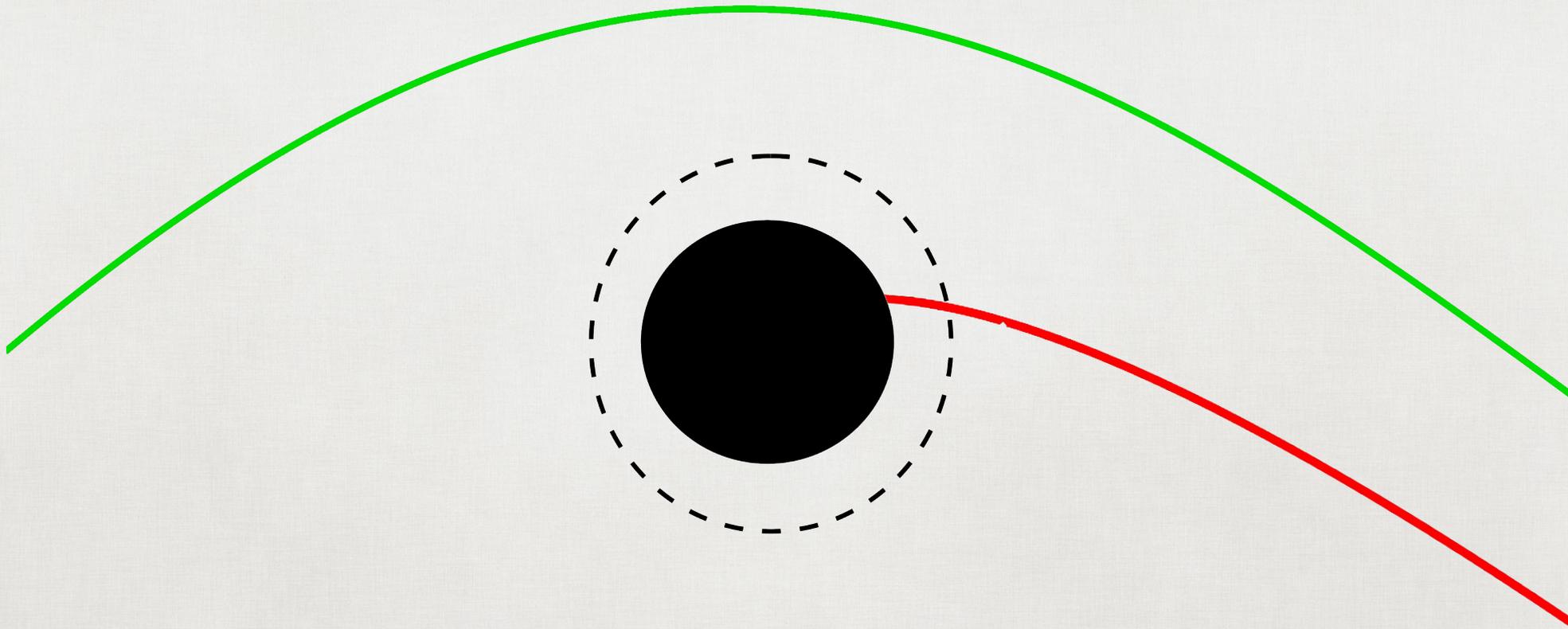
Vídeo cortesia: *Double Negative*

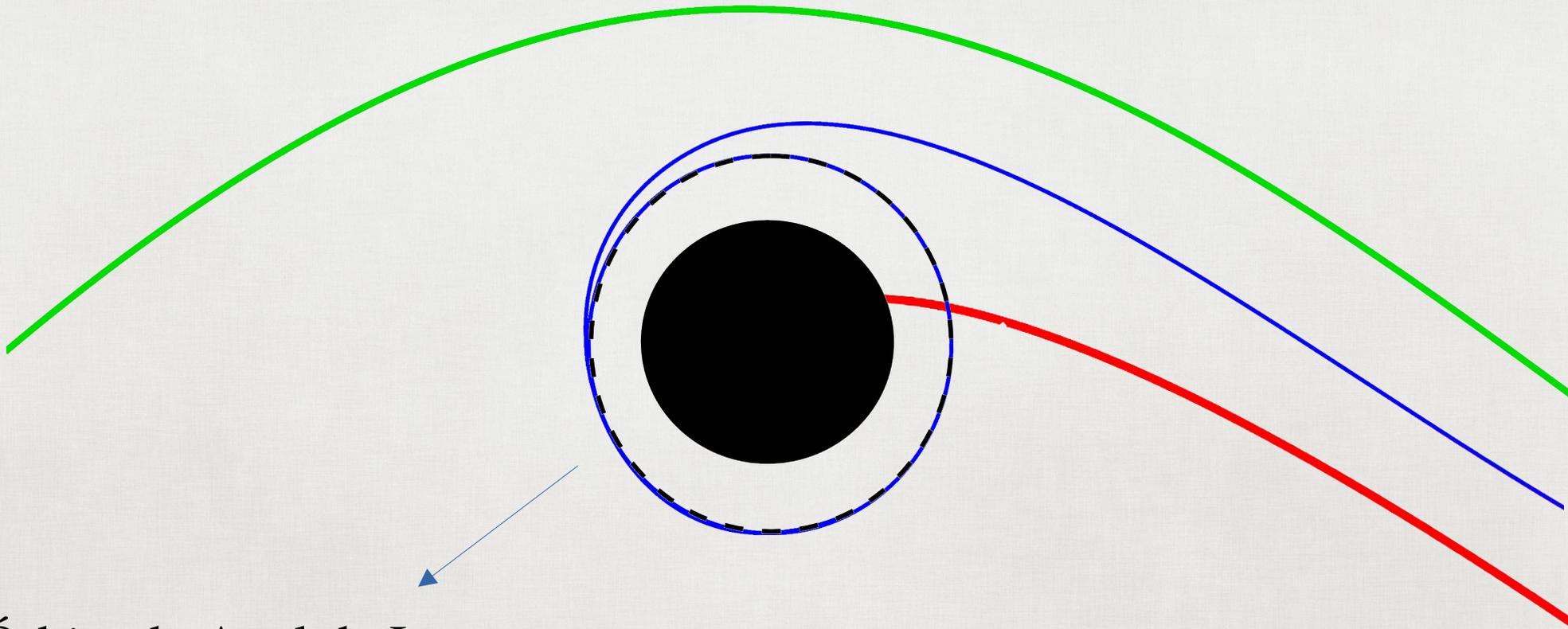
O que determina o contorno da
sombra do Buraco Negro?





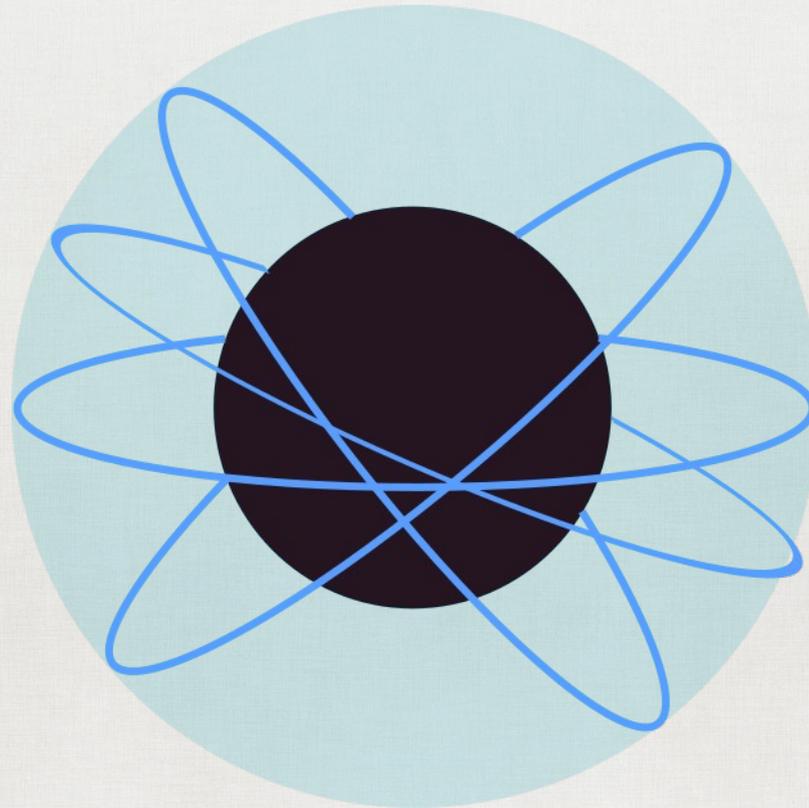


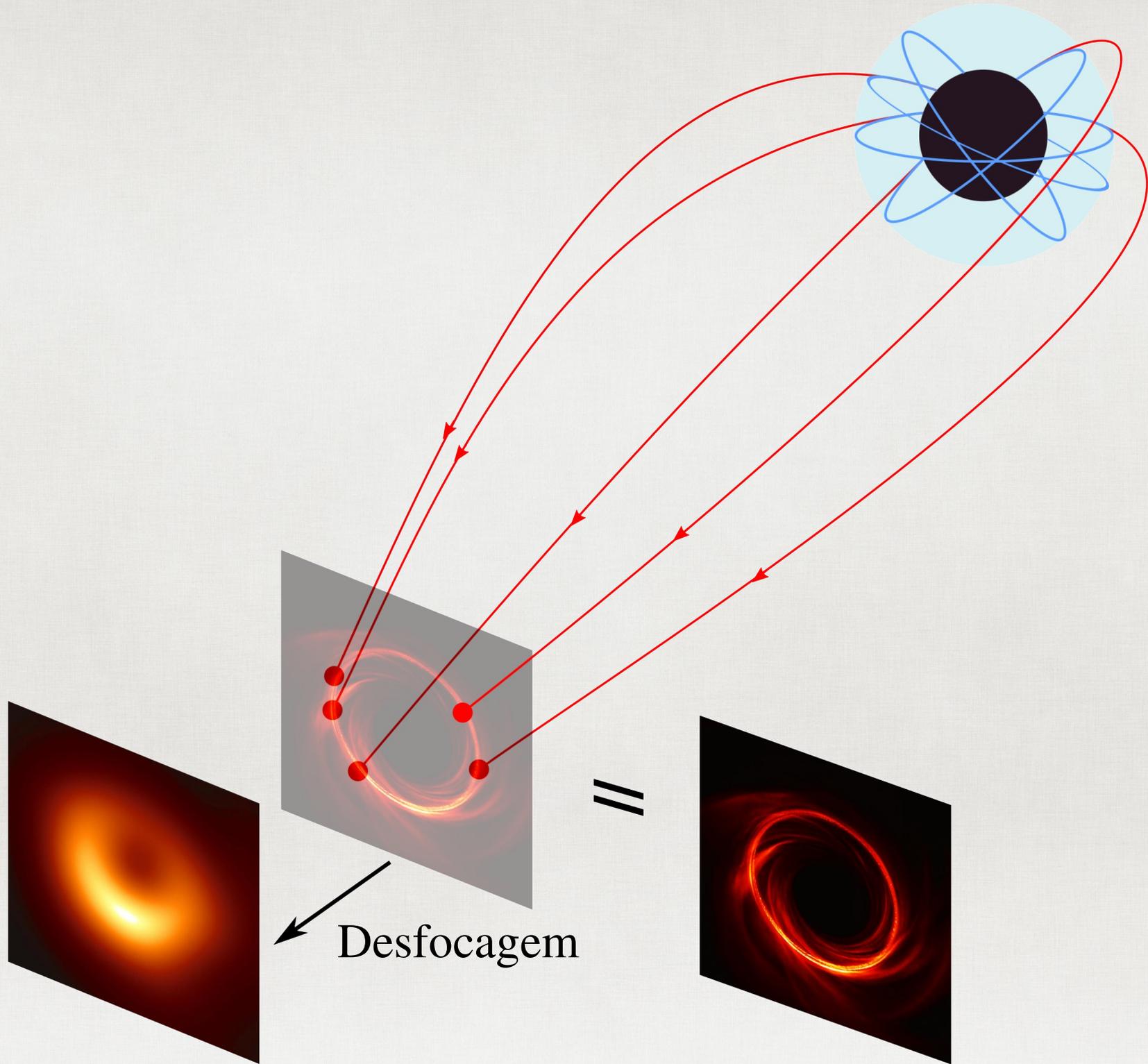




Órbita de Anel de Luz

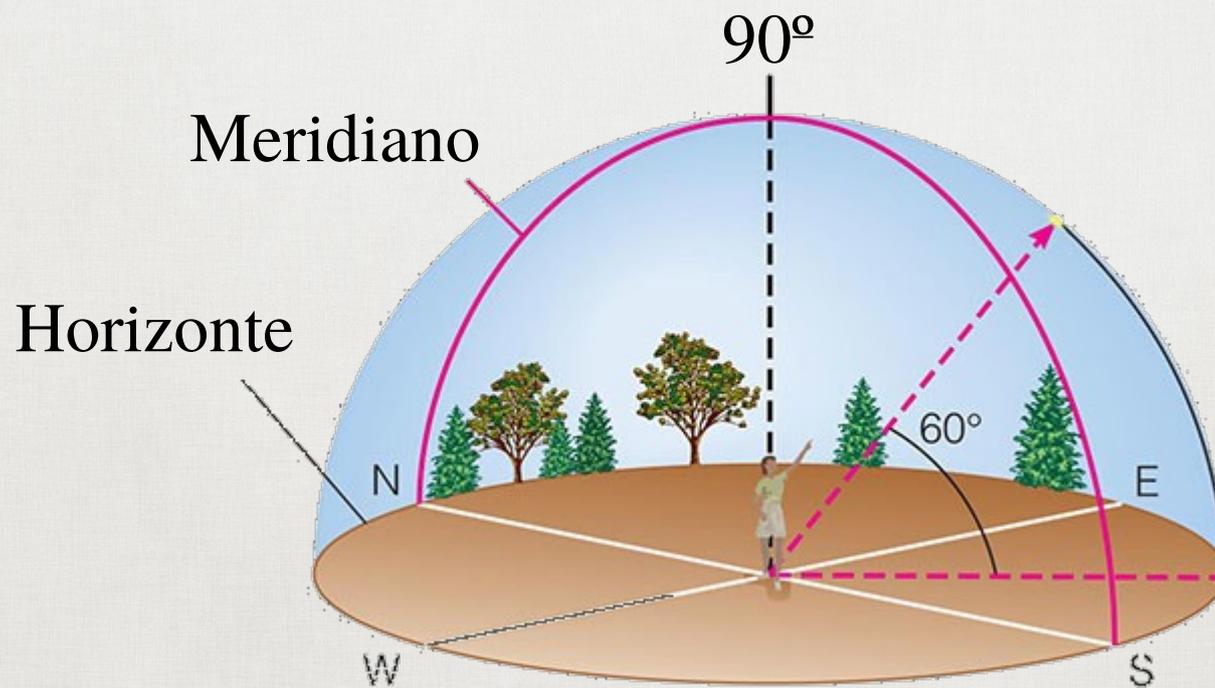
→ São estas órbitas circulares de raios de luz que determinam a sombra do Buraco Negro

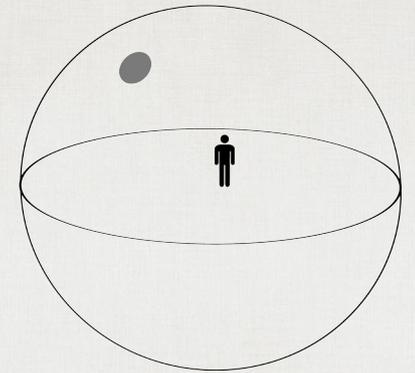




Se nos aproximarmos de um
Buraco Negro o que iríamos ver?

O nosso céu local

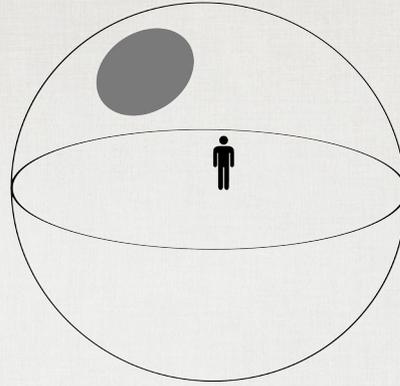




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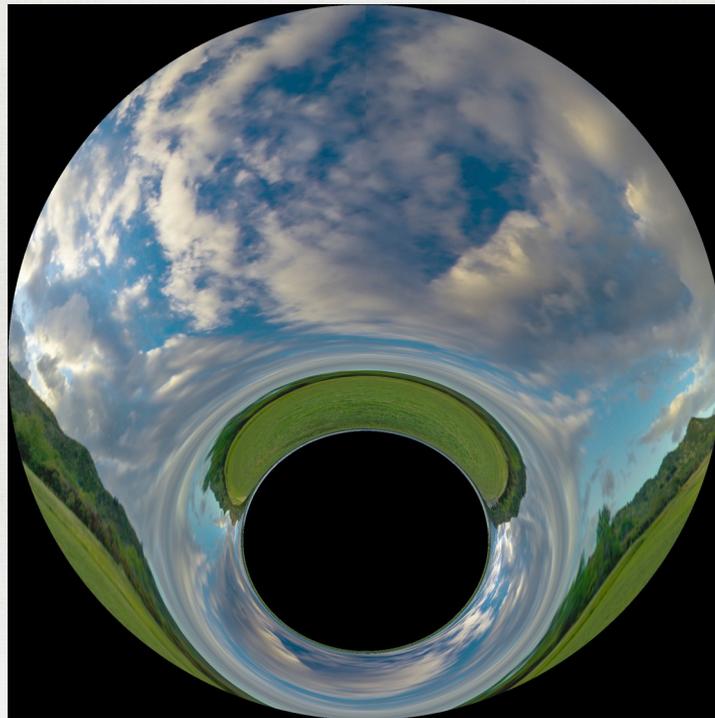
Distância ao Buraco Negro

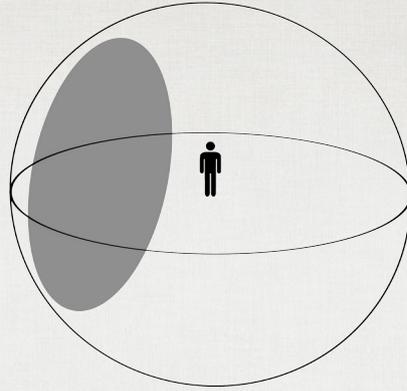




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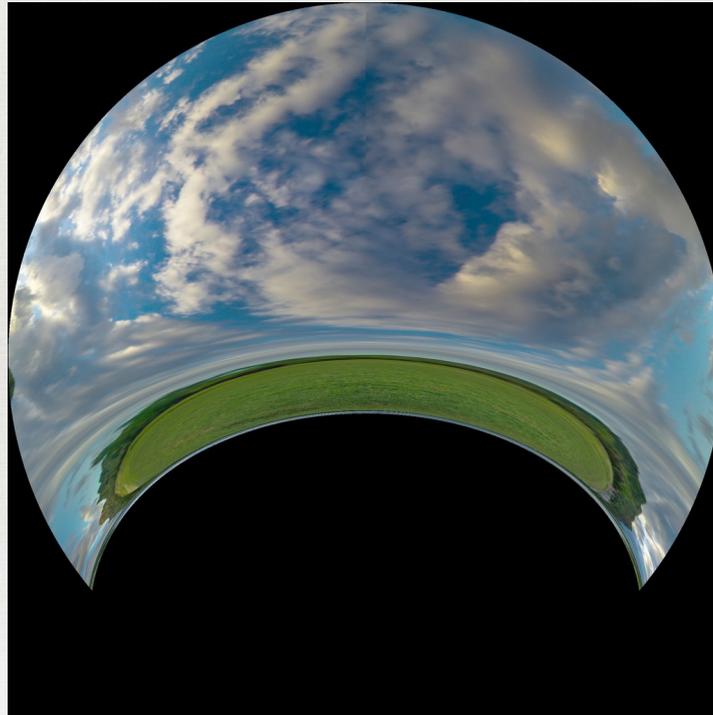
Distância ao Buraco Negro

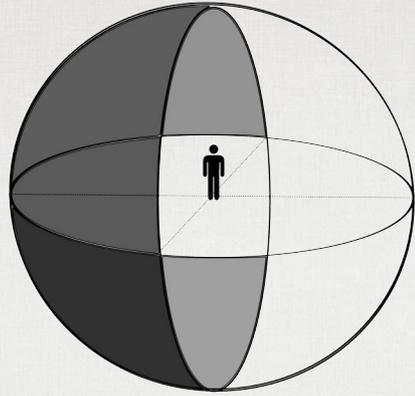




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Distância ao Buraco Negro

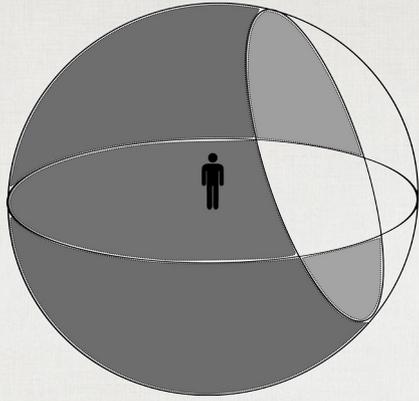




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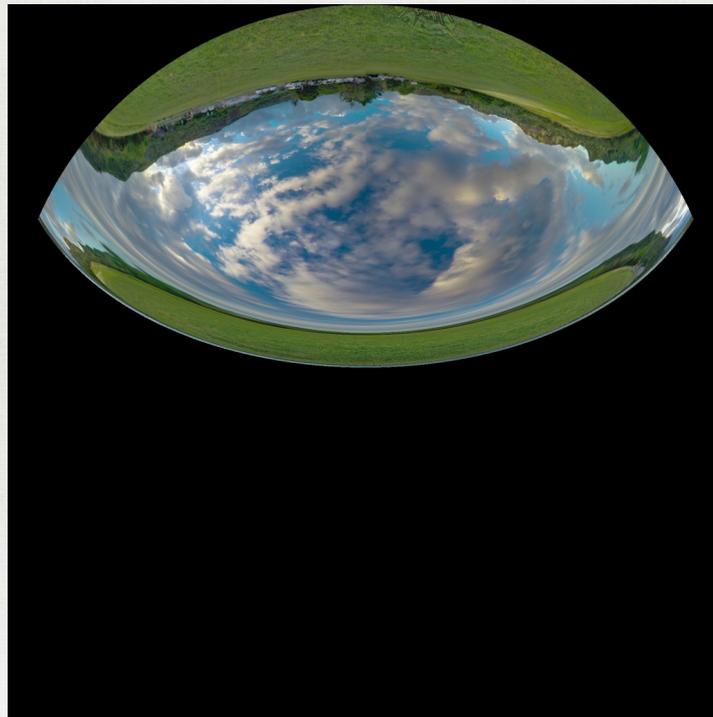
Distância ao Buraco Negro

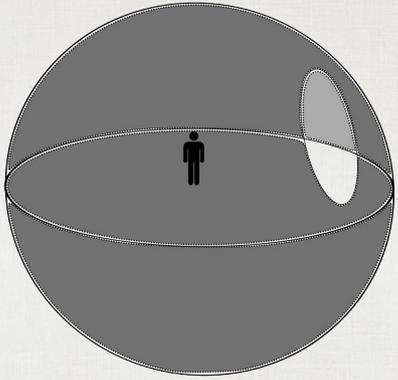




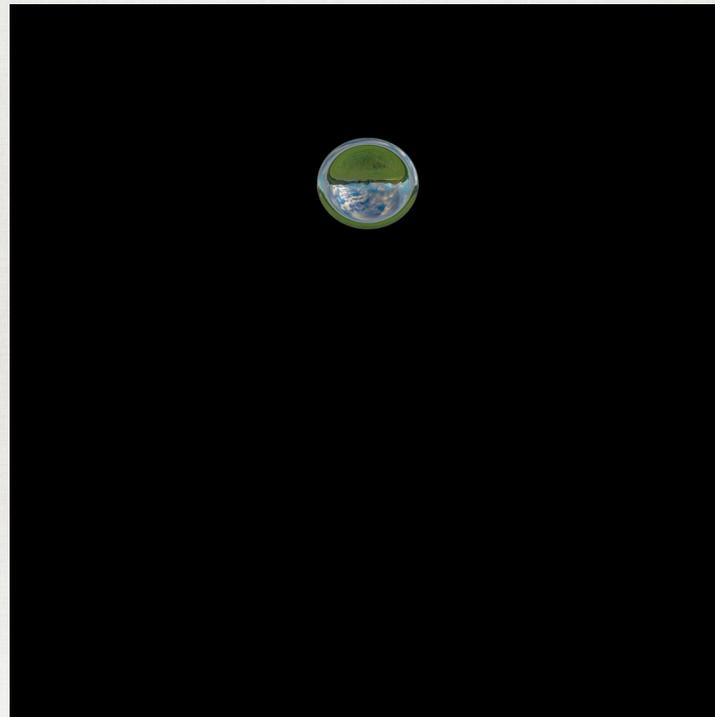
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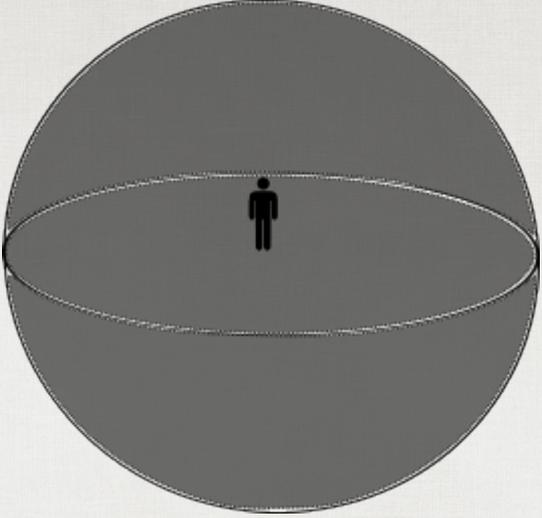
Distância ao Buraco Negro





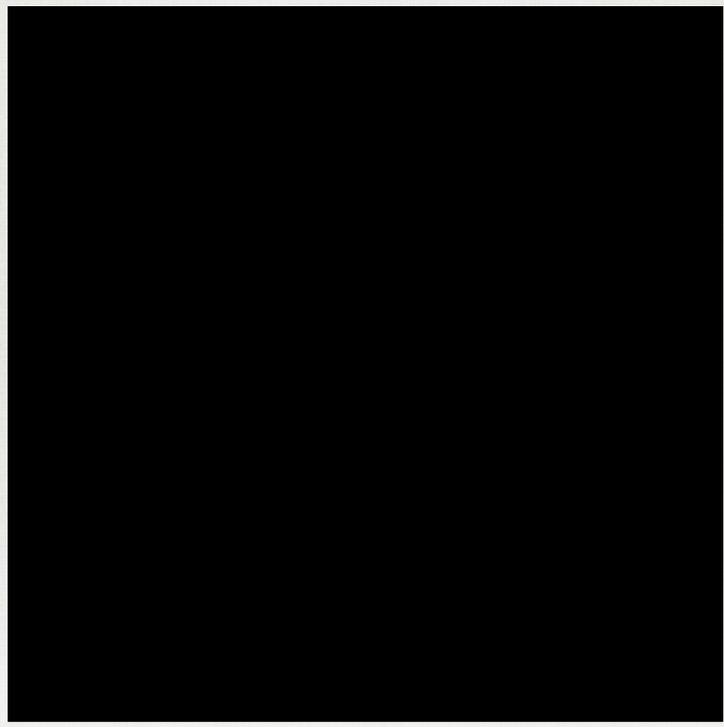
Distância ao Buraco Negro



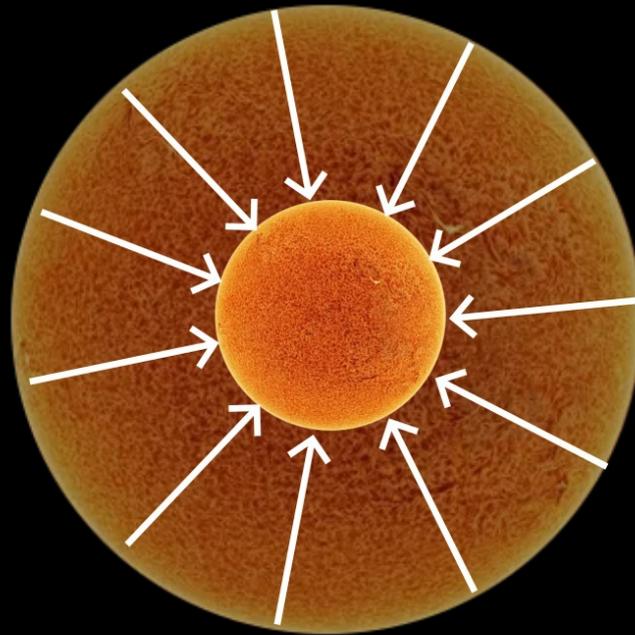


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Distância ao Buraco Negro

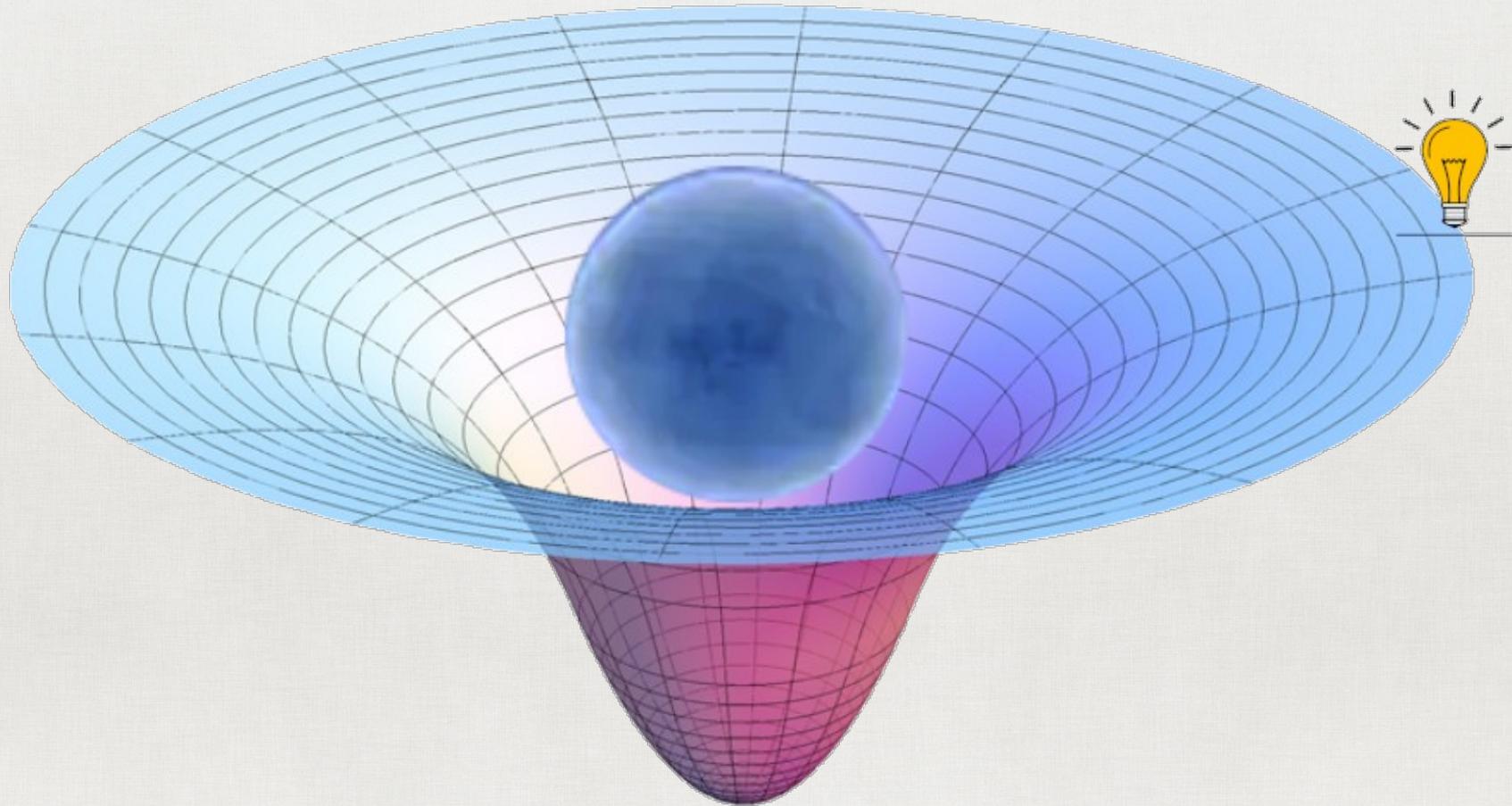


Como seria ver o colapso de uma
estrela para um buraco negro?



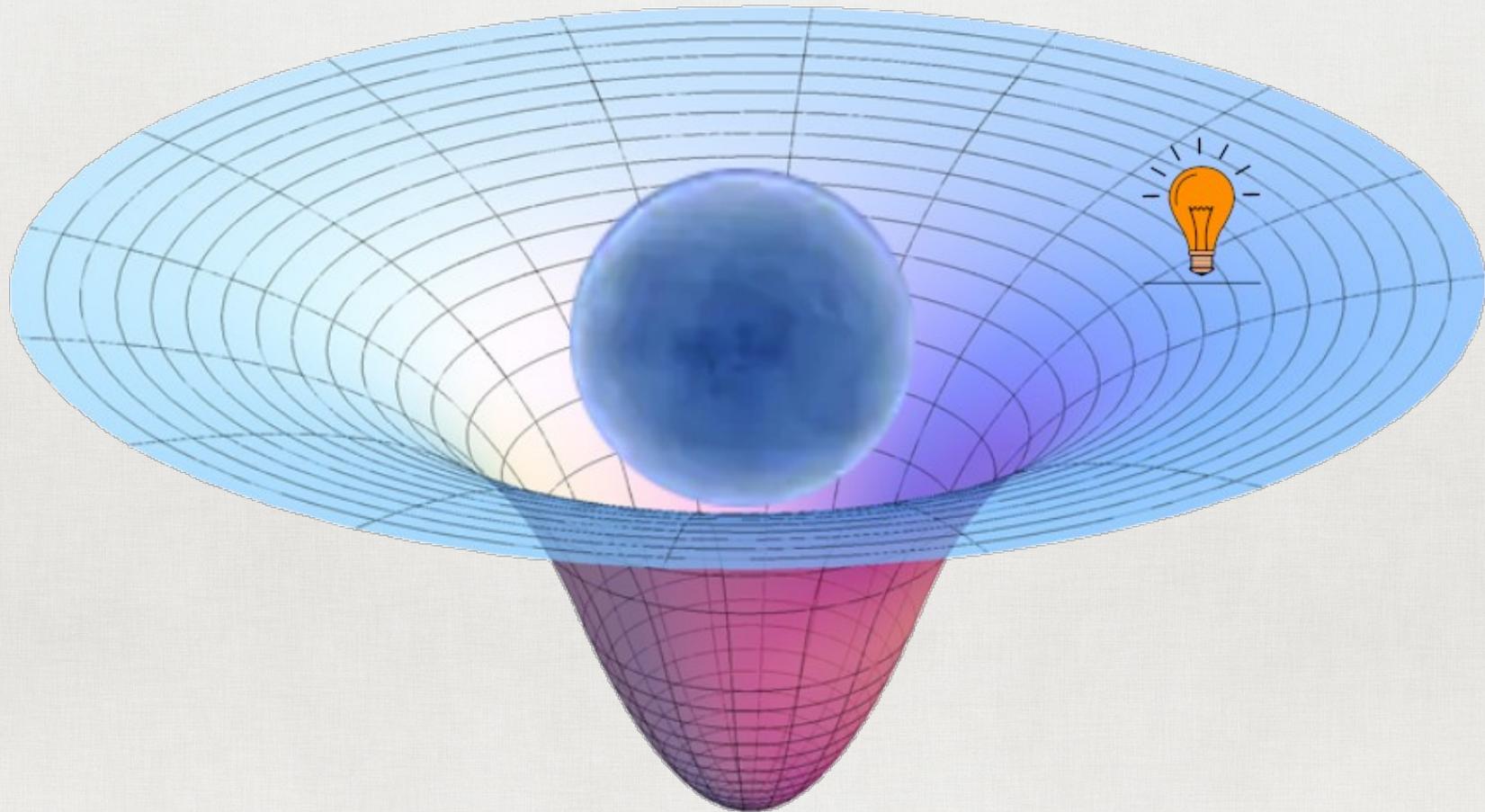
Redshift

“desvio para o vermelho” gravitacional



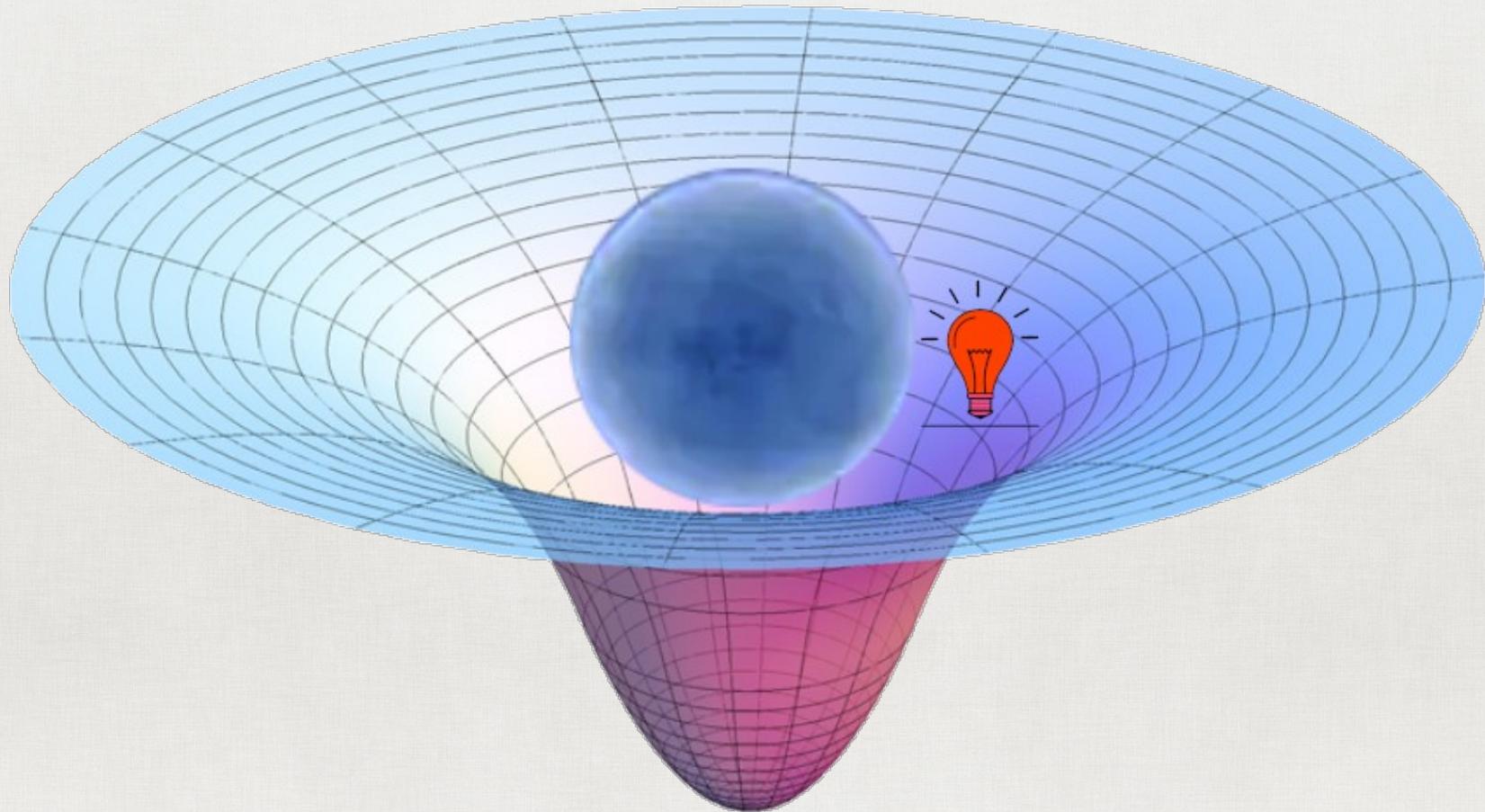
Redshift

“desvio para o vermelho” gravitacional



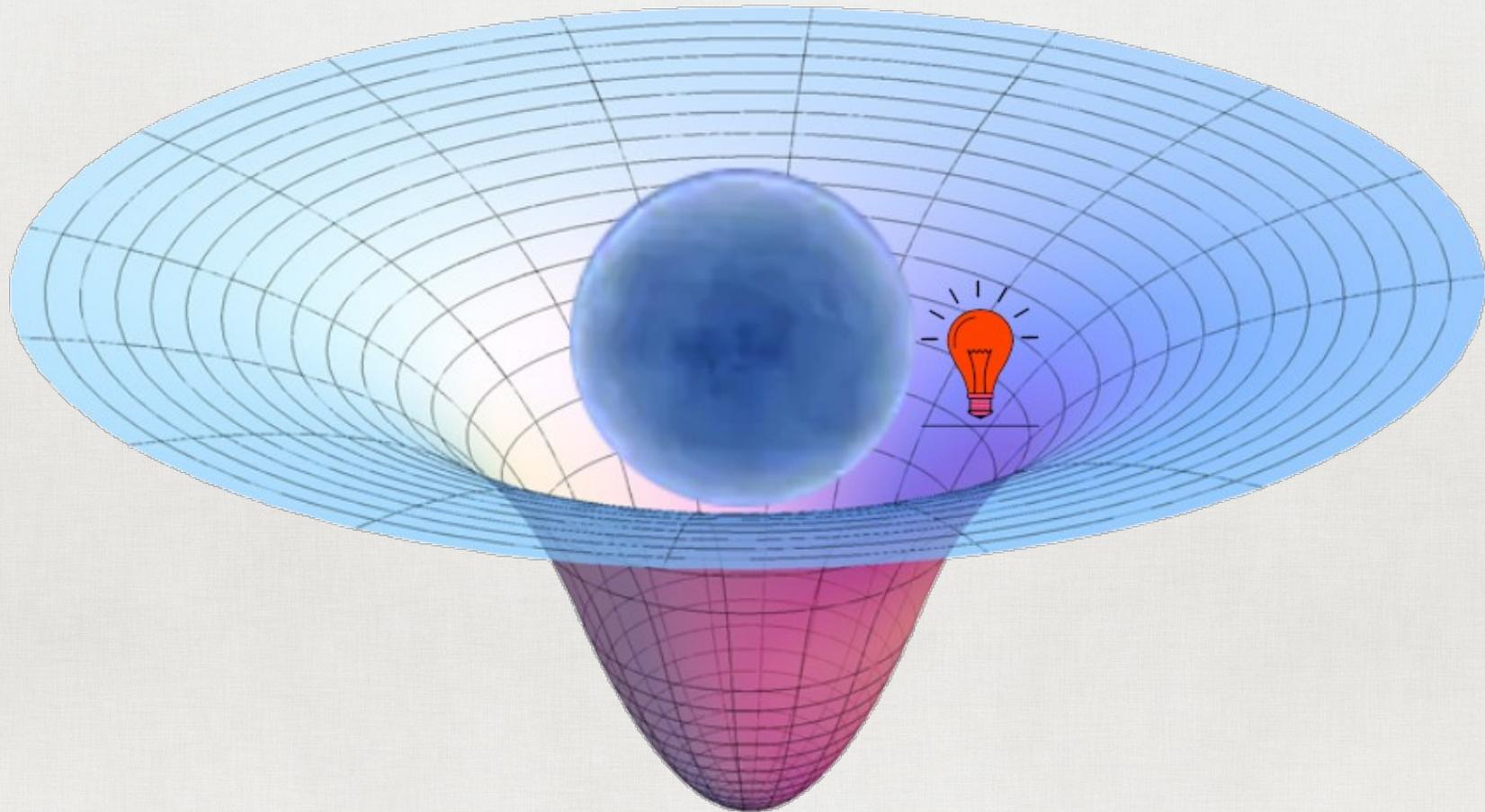
Redshift

“desvio para o vermelho” gravitacional



Redshift

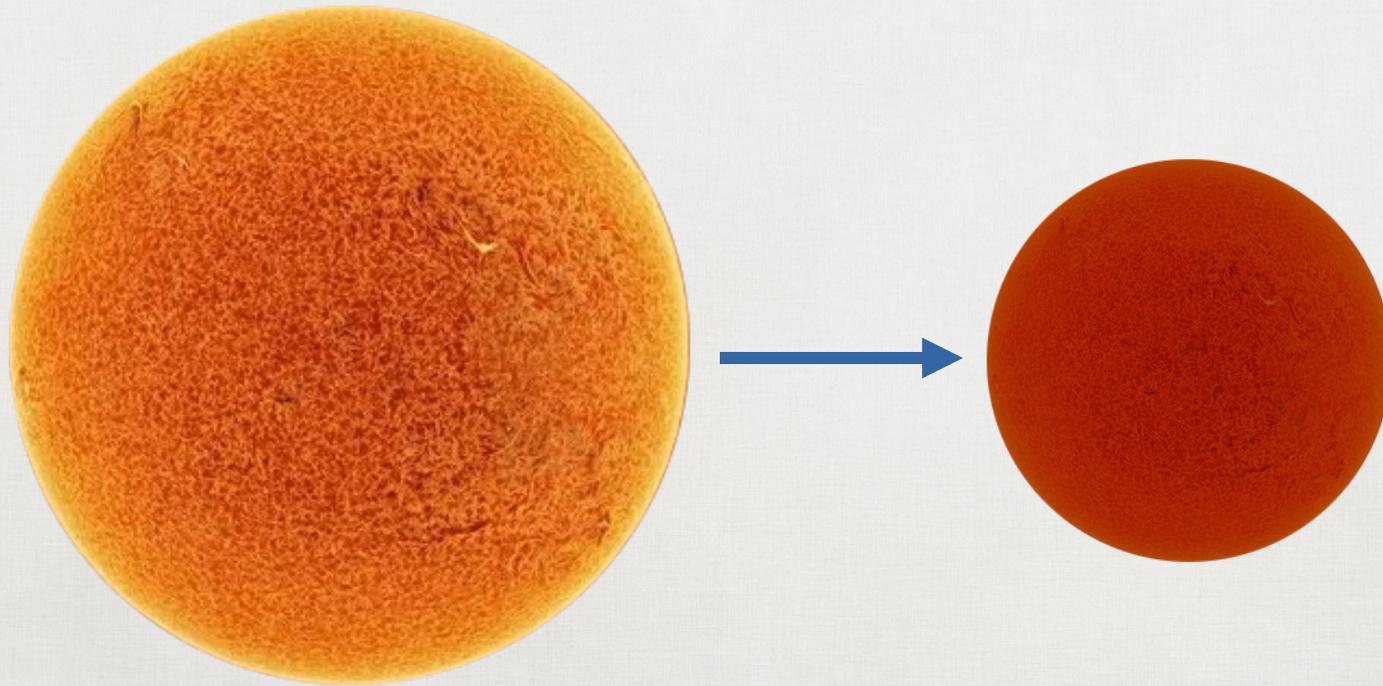
“desvio para o vermelho” gravitacional



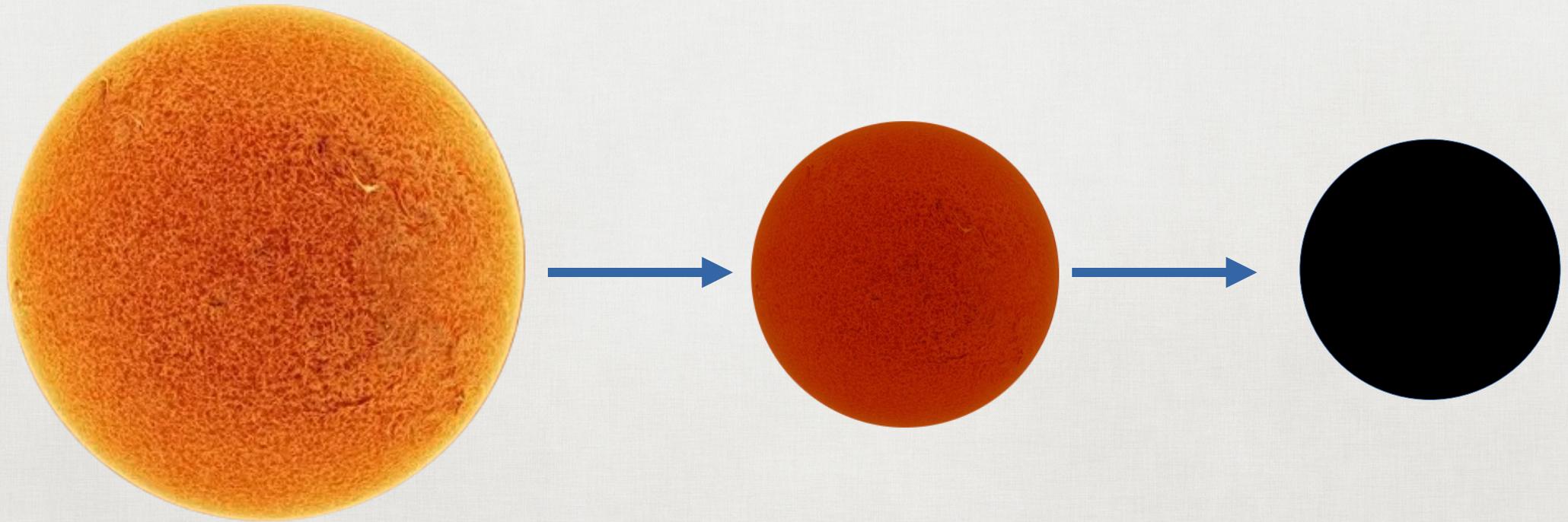
Expectativa para a imagem do colapso?



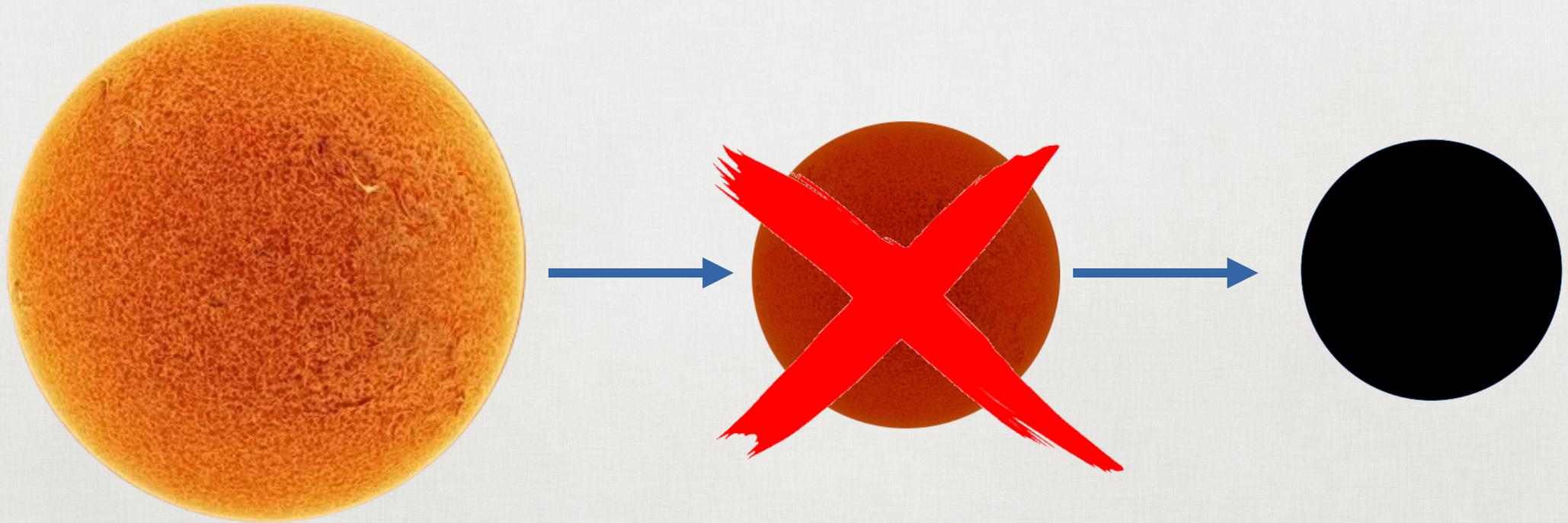
Expectativa para a imagem do colapso?



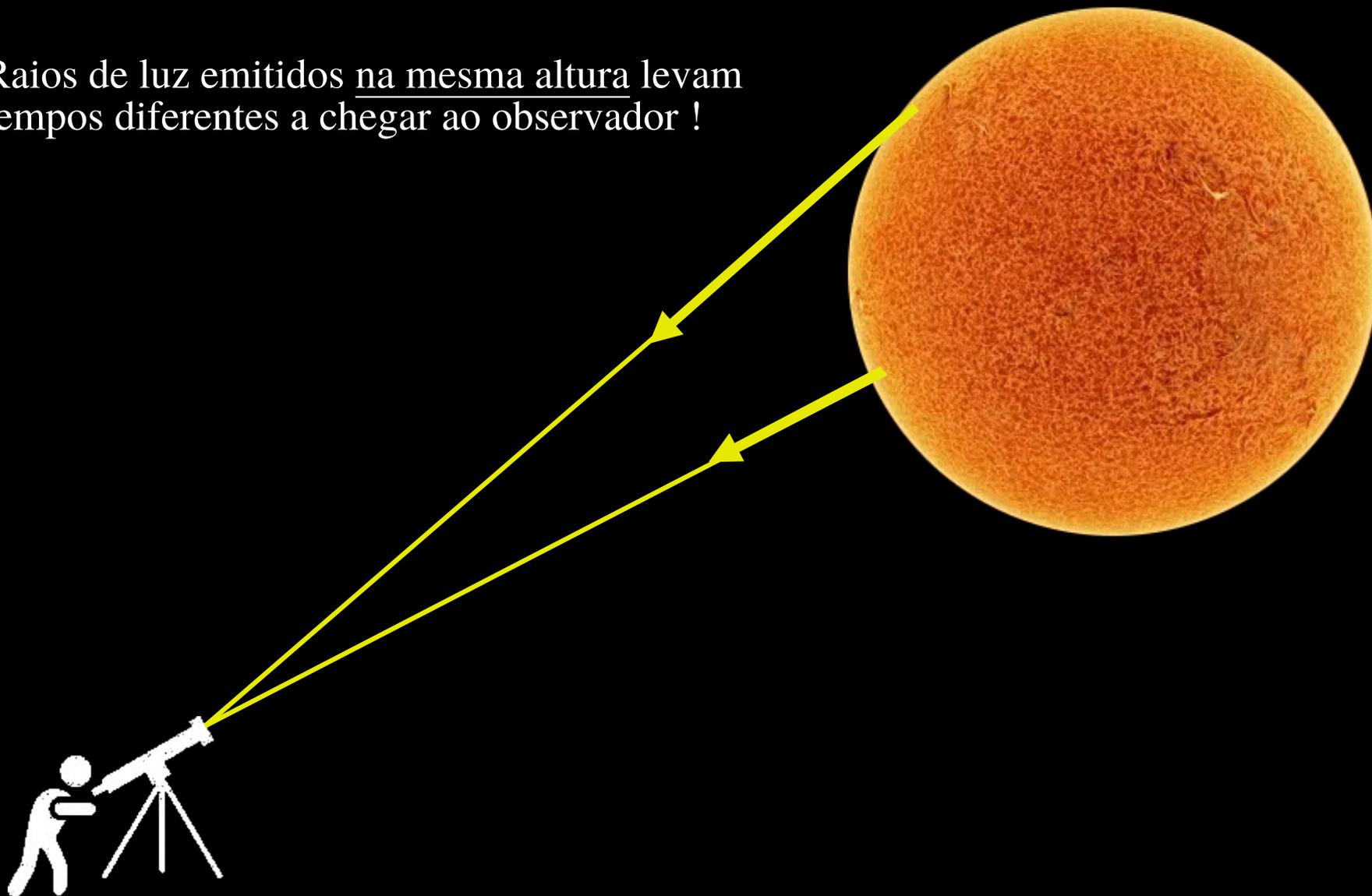
Expectativa para a imagem do colapso?



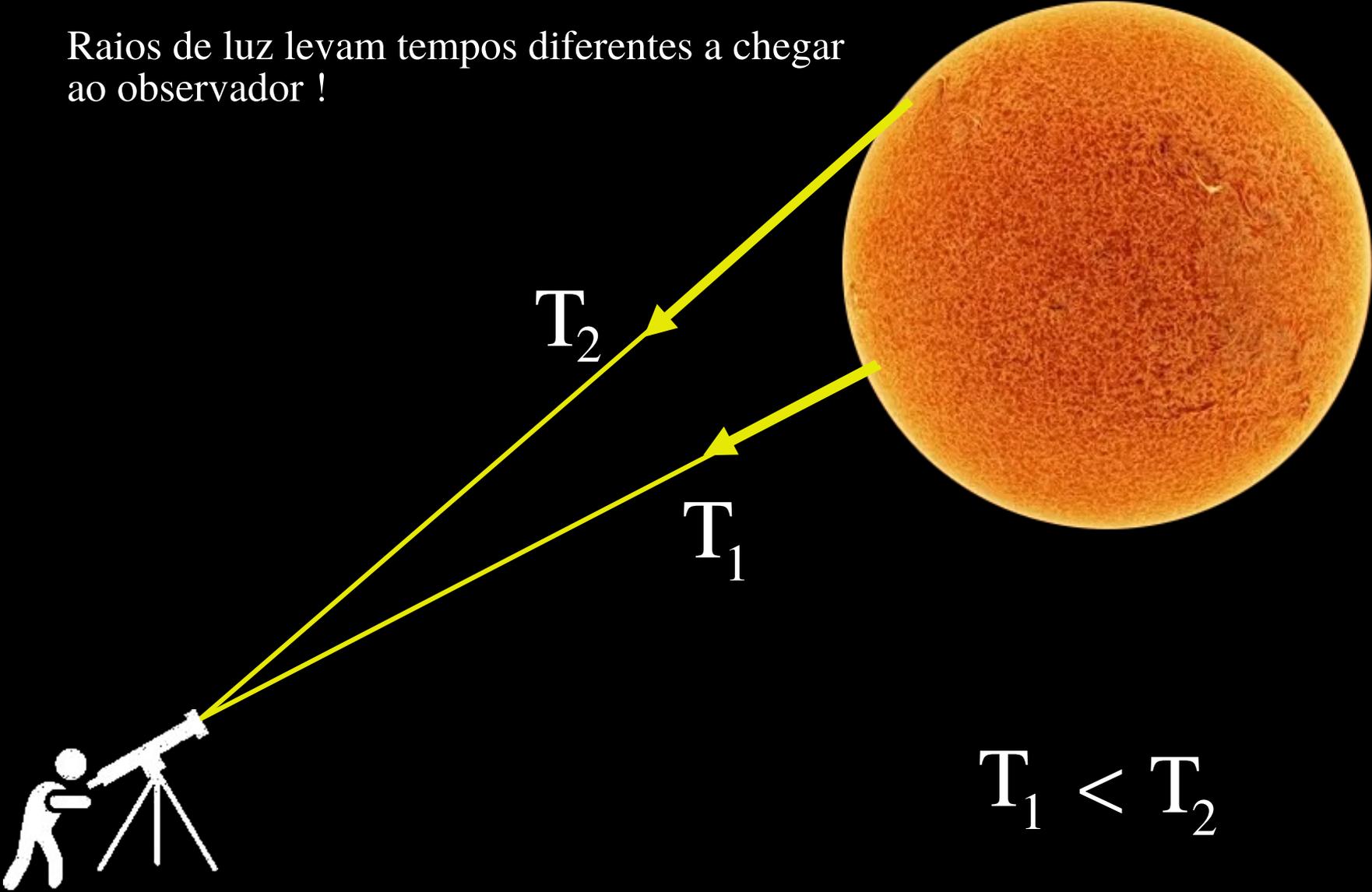
Expectativa para a imagem do colapso?



Raios de luz emitidos na mesma altura levam tempos diferentes a chegar ao observador !

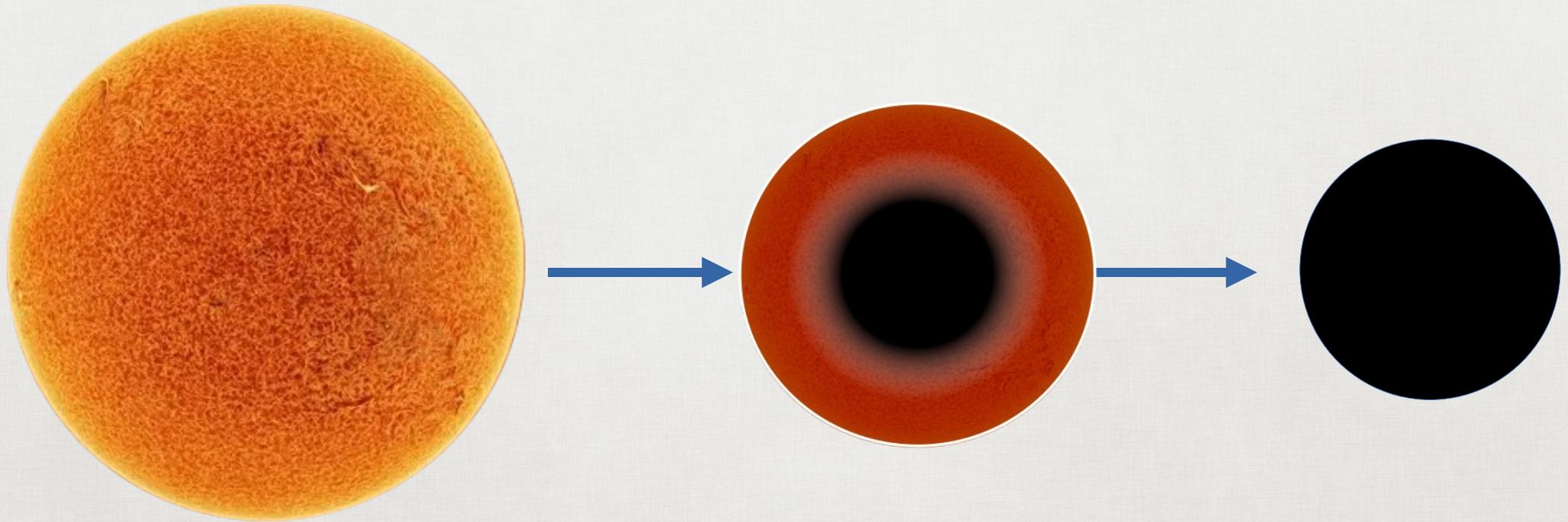


Raios de luz levam tempos diferentes a chegar ao observador !



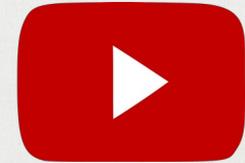
$$T_1 < T_2$$

Expectativa para a imagem do colapso



Vídeos com colapso (com pressão zero) de uma Estrela de Neutrões e com duas temperaturas:

→ $\approx 1\,000\,000\text{ °C}$ (temperatura normal)



→ $\approx 5\,000\text{ °C}$ (super-fria)



Buraco Negro no Mercado de Ver-o-Peso :)



Muito Obrigado!