Understanding Einstein’s General Relativity Equation

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Objective

Focus on gaining a better understanding of Einstein’s General Relativity equation

- Describe what a matrix is
- Describe every variable in the matrix
- Describe what each variable does

This will help us gain a better intuition of this extremely valuable tool, and how we can use it

$$G_{\mu\nu} = \begin{array}{c c} & \begin{array}{cccc} t & r & \theta & \phi \end{array} \\ \begin{array}{c} t \\ r \\ \theta \\ \phi \end{array} & \begin{bmatrix} \boxed{G_{tt}} & G_{tr} & G_{t\theta} & G_{t\phi} \\ G_{rt} & \boxed{G_{rr}} & G_{r\theta} & G_{r\phi} \\ G_{\theta t} & G_{\theta r} & \boxed{G_{\theta\theta}} & G_{\theta\phi} \\ G_{\phi t} & G_{\phi r} & G_{\phi\theta} & \boxed{G_{\phi\phi}} \end{bmatrix} \end{array}$$

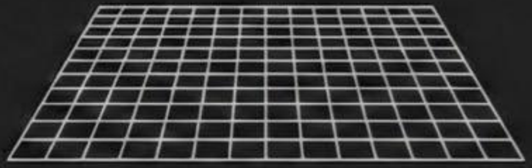
What is a Matrix: The Flat Sheet Analogy

The Matrix ($G_{\mu\nu}$)

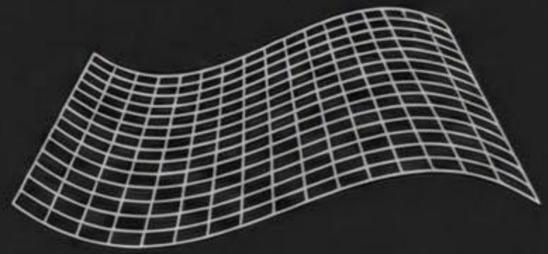
$$\begin{pmatrix} G_{tt} & G_{tr} & G_{t\theta} & G_{t\phi} \\ G_{rt} & \boxed{G_{rr}} & G_{r\theta} & G_{r\phi} \\ G_{\theta t} & G_{\theta r} & \boxed{G_{\theta\theta}} & G_{\theta\phi} \\ G_{\phi t} & G_{\phi r} & G_{\phi\theta} & \boxed{G_{\phi\phi}} \end{pmatrix}$$

Represents the geometry of spacetime.
The 'numbers' (like G_{tt}, G_{rr}) define its shape.

Flat Sheet of Paper (Flat Spacetime)



Bent Sheet of Paper (Curved Spacetime)



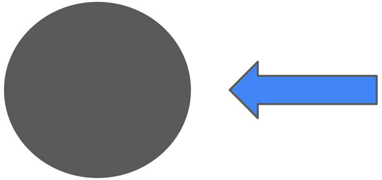
Changing the matrix numbers causes the 'paper' to bend and curve.

Matrix Columns: Dimensions of Spacetime

$$G_{\mu\nu} = \begin{array}{c} \begin{pmatrix} G_{tt} & G_{tr} & G_{t\theta} & G_{t\phi} \\ G_{rt} & G_{rr} & G_{r\theta} & G_{r\phi} \\ G_{\theta t} & G_{\theta r} & G_{\theta\theta} & G_{\theta\phi} \\ G_{\phi t} & G_{\phi r} & G_{\phi\theta} & G_{\phi\phi} \end{pmatrix} \\ \begin{array}{cccc} \textbf{4D}\text{ (Time)} & \textbf{1D}\text{ (Space)} & \textbf{2D}\text{ (Space)} & \textbf{3D}\text{ (Space)} \end{array} \end{array}$$

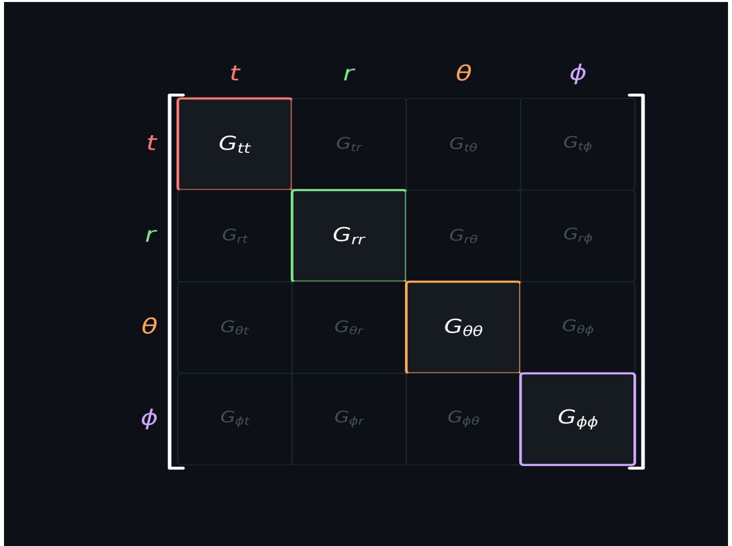
It’s a tensor. A single point in space time.

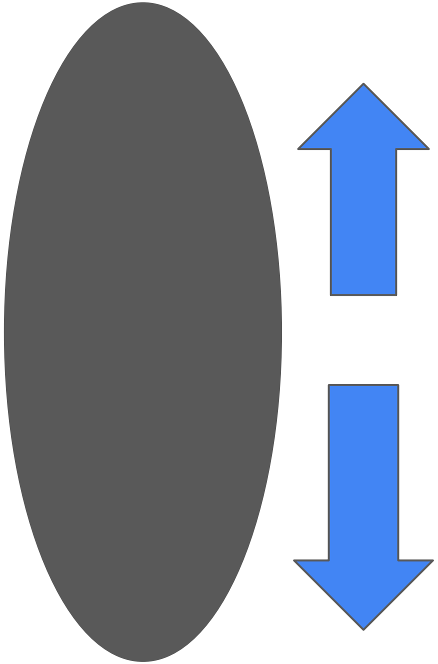
Each column of the metric tensor corresponds to a specific dimension of spacetime, with time treated as the fourth dimension.



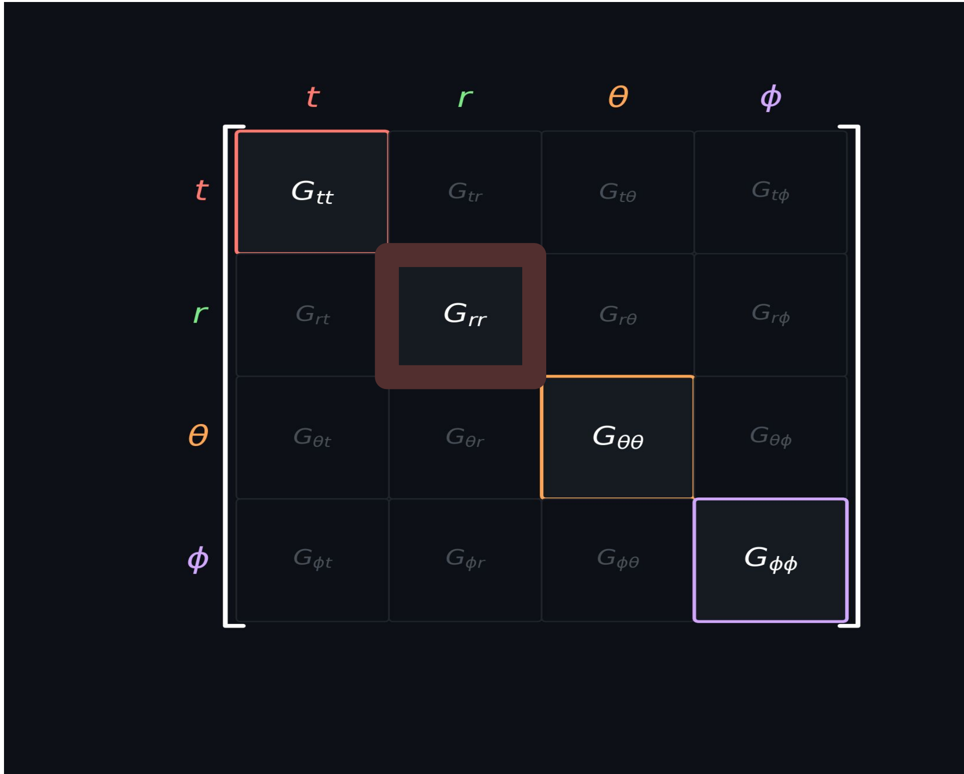
This is an example of what a tensor can look like. As the numbers in the matrix change, the tensor will warp and reshape. This gives us what space time looks like at that one point

Tensor
(Single point in space time)

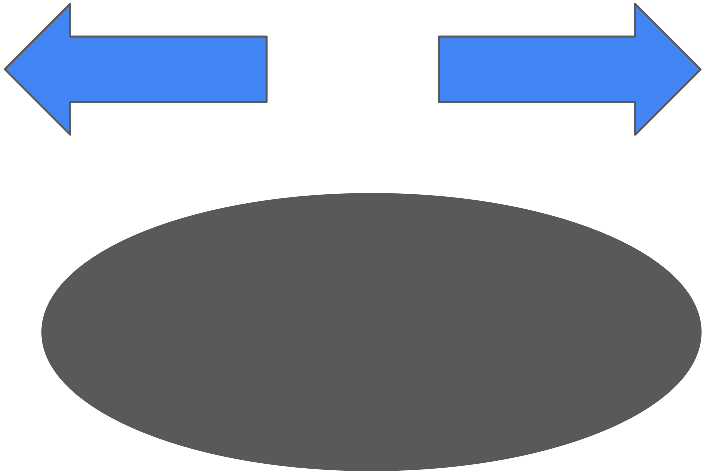




When the radial number (Grr) changes the tensor grows radially, up and down.



Tensor
(Single point in space time)

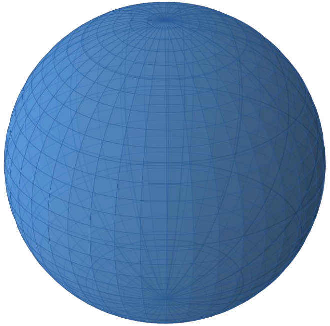


Tensor
(Single point in space time)

When the 2d number, θ (theta), changes the tensor grows horizontally left to right

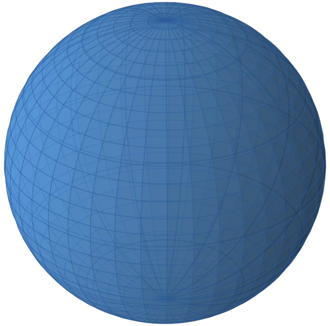
$$\begin{array}{cc} & \begin{array}{cccc} t & r & \theta & \phi \end{array} \\ \begin{array}{c} t \\ r \\ \theta \\ \phi \end{array} & \begin{bmatrix} G_{tt} & G_{tr} & G_{t\theta} & G_{t\phi} \\ G_{rt} & G_{rr} & G_{r\theta} & G_{r\phi} \\ G_{\theta t} & G_{\theta r} & \boxed{G_{\theta\theta}} & G_{\theta\phi} \\ G_{\phi t} & G_{\phi r} & G_{\phi\theta} & G_{\phi\phi} \end{bmatrix} \end{array}$$

3d Sphere



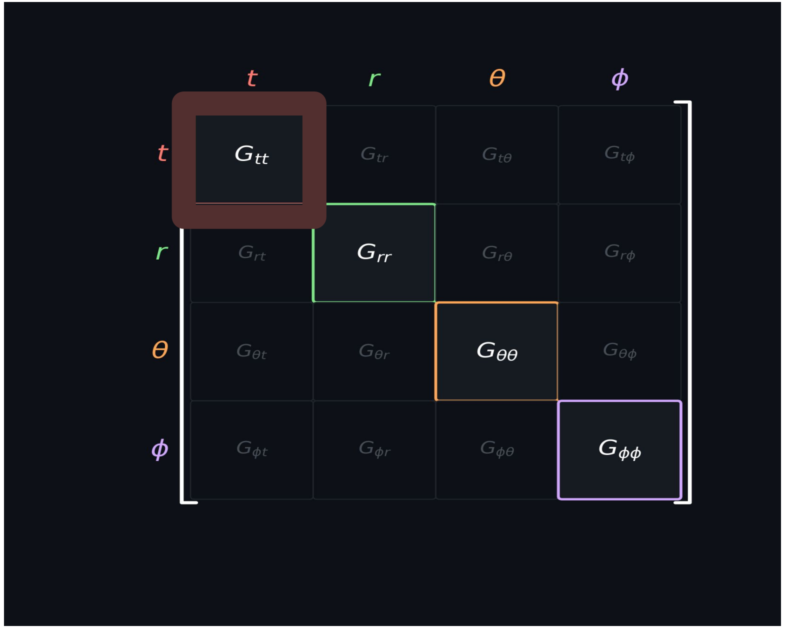
Tensor
(Single point in space time)

When, G_φφ — the azimuthal component, changes the tensor grows in 3d space as a sphere.



Time is an equation. It says the bigger the mass and the closer you are to it, time slows down. And the result of that equation goes here.

Tensor
(Single point in space time)



Summary

We have focused on gaining a better understanding of Einstein’s General Relativity equation

- We described what a matrix is
- We described every variable in the matrix
- We focused on understanding what each variable does

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