The role of the cosmological constant in gravitational lensing

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Introduction

Why this research is important

Both the cosmological constant and gravitational lensing form important parts of our understanding of the universe If there is an effect of the cosmological constant in gravitational lensing that is not accounted for, it might come important for future precision cosmology measurements.

Previous literature on the topic

Mostly analytical Islam (1983): Conventional view Rindler and Ishak (2007): Challenged the conventional view

Our project

Numerical approach Swiss-cheese model

Method

The Swiss-Cheese Model

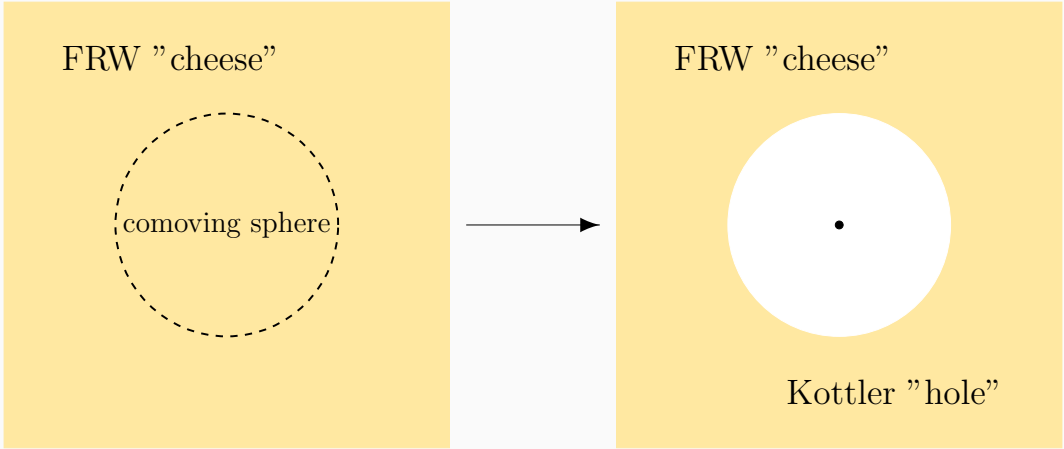


Figure 1: Illustration of a Swiss Cheese model

The Swiss-Cheese Model: Spacetime Patches

Outside the hole: Friedmann-Robertson-Walker metric (FRW)

$$ds^2 = dt^2 + a(t)^2 \left[\frac{dr^2}{1 - kr^2} + r^2(d\theta^2 + \sin^2\theta d\phi^2) \right] \tag{1}$$

Inside the hole: Kottler metric

$$ds^2 = -f(R)dT^2 + \frac{dR^2}{f(R)} + R^2(d\theta^2 + \sin^2\theta d\phi^2) \tag{2}$$

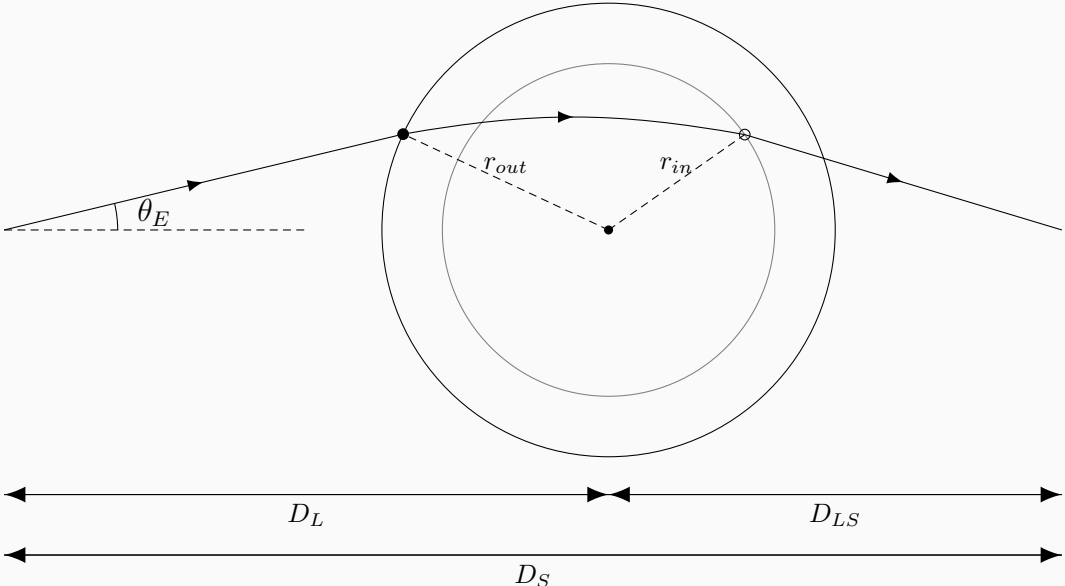
Gluing the two metrics together

A spacetime obtained by gluing two different geometries via a hypersurface Σ is well defined if it satisfies the Israel junction conditions [??].

On Σ, both geometries must induce

- the same 3-metric, and
- the same extrinsic curvature.

Propagation of light



Propagation of light: null geodesic equations

FRW null geodesics

$$\ddot{r} = (1 - kr^2)r\dot{\phi}^2 - \frac{k\dot{r}^2}{1 - kr^2} - \frac{2a_{,t}}{a}\dot{r}\dot{t}$$

$$\dot{t} = -\sqrt{\frac{a^2\dot{r}^2}{1 - kr^2} + a^2r^2\dot{\phi}}$$

$$a_{,t} = aH_0\sqrt{\Omega_M/a^3 + \Omega_k/a^2 + \Omega_\Lambda}$$

$$\dot{\phi} = \frac{L}{a^2r^2}$$

Kottler null geodesics

$$\ddot{R} = \frac{L_k^2(R - 3M)}{R^4}$$

$$\dot{\phi} = \frac{L_k}{R^2}$$

$$R_{h,t} = \left(1 - \frac{2M}{R_h} - \frac{\Lambda * R_h^2}{3}\right)\sqrt{\frac{2M}{R_h} + \frac{\Lambda R_h^2}{3}}$$

Results

Titleformats

Metropolis titleformats

METROPOLIS supports 4 different titleformats:

- Regular
- SMALLCAPS
- ALLSMALLCAPS
- ALLCAPS

They can either be set at once for every title type or individually.

Small caps

This frame uses the `smallcaps` titleformat.

Potential Problems

Be aware, that not every font supports small caps. If for example you typeset your presentation with pdfTeX and the Computer Modern Sans Serif font, every text in smallcaps will be typeset with the Computer Modern Serif font instead.

This frame uses the `allsmallcaps` titleformat.

Potential problems

As this titleformat also uses smallcaps you face the same problems as with the `smallcaps` titleformat. Additionally this format can cause some other problems. Please refer to the documentation if you consider using it.

As a rule of thumb: Just use it for plaintext-only titles.

ALL CAPS

This frame uses the `allcaps` titleformat.

Potential Problems

This titleformat is not as problematic as the `allsmallcaps` format, but basically suffers from the same deficiencies. So please have a look at the documentation if you want to use it.

Elements

Typography

```
The theme provides sensible defaults to
\emph{emphasize} text, \alert{accent} parts
or show \textbf{bold} results.
```

becomes

The theme provides sensible defaults to *emphasize* text, accent parts or show **bold** results.

Font feature test

- Regular
- *Italic*
- SmallCaps
- **Bold**
- ***Bold Italic***
- **Bold SmallCaps**
- `Monospace`
- `Monospace Italic`
- **`Monospace Bold`**
- **`Monospace Bold Italic`**

Lists

Items

- Milk
- Eggs
- Potatos

Enumerations

1. First,
2. Second and
3. Last.

Descriptions

PowerPoint Meeh.

Beamer Yeeeha.

Animation

- This is important

Animation

- This is important
- Now this

Animation

- This is important
- Now this
- And now this

Animation

- This is really important
- Now this
- And now this

Figures

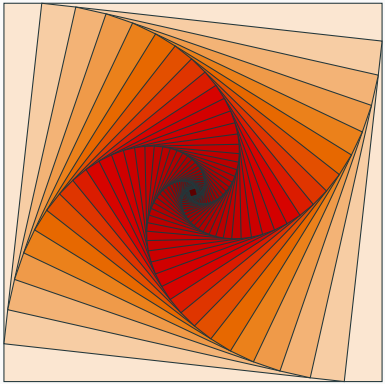


Figure 2: Rotated square from texample.net.

Tables

Table 1: Largest cities in the world (source: Wikipedia)

City	Population
Mexico City	20,116,842
Shanghai	19,210,000
Peking	15,796,450
Istanbul	14,160,467

Blocks

Three different block environments are pre-defined and may be styled with an optional background color.

Default
Block content.

Alert
Block content.

Example
Block content.

Default
Block content.

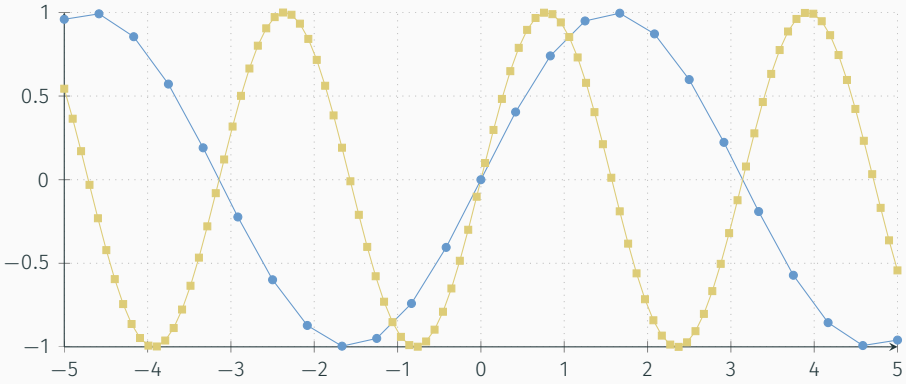
Alert
Block content.

Example
Block content.

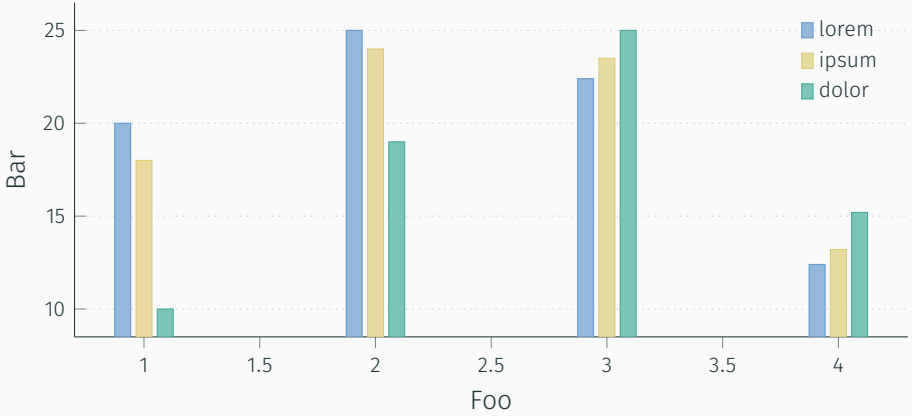
Math

$$e = \lim_{n \to \infty} \left(1 + \frac{1}{n}\right)^n$$

Line plots



Bar charts



Quotes

Veni, Vidi, Vici

Frame footer

METROPOLIS defines a custom beamer template to add a text to the footer. It can be set via

```
\setbeamertemplate{frame footer}{My custom footer}
```

References

Some references to showcase [allowframebreaks] [4, 2, 5, 1, 3]

Conclusion

Summary

Get the source of this theme and the demo presentation from

`github.com/matze/mtheme`

Questions?

Backup slides

Sometimes, it is useful to add slides at the end of your presentation to refer to during audience questions.

The best way to do this is to include the `appendixnumberbeamer` package in your preamble and call `\appendix` before your backup slides.

METROPOLIS will automatically turn off slide numbering and progress bars for slides in the appendix.

References i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A selection of problems and results in combinatorics.
In *Recent trends in combinatorics (Matrahaza, 1995)*, pages 1–6. Cambridge Univ. Press, Cambridge, 1995.


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H. Simpson.
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