Genaral Relativity

Haoran Zhou

Preface

This is my notes on General Relativity. The main reference is *A Mathematical Introduction to General Relativity* by Amol Sasane, *The Large Scale Structure of Spacetime* by Hawking & Ellis *Lectures on Mathematical Relativity* by Chruściel and *Spacetime Foundations of General Relativity and Differential Geometry* by Marcus Kriele.

Other references include 微分几何入门和广义相对论 by 梁灿彬, *Spacetime and Geometry* by Carroll and *An Introduction to Mathematical Relativity* by Jose Natario.

It is assumed that the readers are already familiar with differential geometry at a mathematical level and no additional mathematical background will be provided in this note. The mathematical background required for this note is covered by my note on Differential Geometry.

Contents

1 General Relativity **5**

1.1 Basic Concepts 5

1.2 The Axiomatic System of General Relativity 5

1.3 Observers 5

1.4 Matter Fields 5

1.5 Mass 5

1.6 Hamiltonian Formalism of General Relativity 5

2 Exact Solutions **6**

2.1 Minkowski Spacetime 6

2.2 Schwarzschild and RN Solution 6

2.2.1 Spherical Symmetry 6

2.2.2 Experimental Tests of General Relativity 6

2.3 Kerr and KN Solution 6

2.4 Vaidya Metrics 6

2.5 FLRW Spacetime 6

2.6 De Sitter Space 6

2.7 Anti-de Sitter Space 6

3 Casuality **7**

3.1 Cauchy Problem of Einstein's equation 7

4 Singularity **8**

4.1 Sigular Points 8

4.2 Sigularity Theorems 8

4.3 Gravitational Collapse 8

4.4 The Initial Singularity of Universe 8

5 Black Holes **9**

5.1 Classicification of Static Black Holes 9

5.2 Hawking Radiation 9

5.3 Black Hole Entropy 9

5.4 Thermodynamics of Black Holes 9

6 Gravitational Waves **10**

7 Astrophysics **11**

8 Cosmology **12**

Chapter 1

General Relativity

1.1 Basic Concepts

1.2 The Axiomatic System of General Relativity

1.3 Observers

1.4 Matter Fields

1.5 Mass

1.6 Hamiltionian Formalism of General Relativity

Chapter 2

Exact Solutions

2.1 Minkowski Spacetime

2.2 Schwarzschild and RN Solution

2.2.1 Spherical Symmetry

2.2.2 Experimental Tests of General Relativity

2.3 Kerr and KN Solution

2.4 Vaidya Metrics

2.5 FLRW Spacetime

2.6 De Sitter Space

2.7 Anti-de Sitter Space

Chapter 3

Casuality

3.1 Cauchy Problem of Einstein's equation

Chapter 4

Singularity

4.1 Sigular Points

4.2 Sigularity Theorems

4.3 Gravitational Collapse

4.4 The Initial Singularity of Universe

Chapter 5

Black Holes

5.1 Classicification of Static Black Holes

5.2 Hawking Radiation

5.3 Black Hole Entropy

5.4 Thermodynamics of Black Holes

Chapter 6

Gravitational Waves

Chapter 7

Astrophysics

Chapter 8

Cosmology