COSMOLOGY

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— Lecture Notes —

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NB: These lecture notes do not represent an original set of material under my authorship. Rather, they represent my personal selection of material taken from various books and other lecture notes which I have found most useful. See the literature list for explicit references.

0. INTRODUCTION

Cosmology – to some extend – can be viewed as a discipline of physics closest to the humanities, since it touches on the grand questions: "Where do we come from? Where do we go?" from the scientifically most general perspective.
As a scientific field of endeavour, it is actually a rather young field (~ 100 years), which has become a quantitative precision science field only in the recent decades. Many essential questions have still remained unanswered and the resolution of puzzles is actively worked on as we speak.
As a field of study, cosmology is particularly appealing, since it relies on almost al corner-stones of classical as well as modern physics with general relativity, thermodynamics & statistical physics, and particle / high-energy physics being most relevant.
Since the present course intends to give an overview,

there will be little room for basic introductions into all these cornerstone fields, but we will use them as resources for the present course. Whenever possible, these resources are made plausible.
In comparison to other subdisciplines of physics or science in general, quantitative cosmology has a special feature which it suffers from: we know of and have limited access to only one single "experiment", our universe.
We can neither observe multiple universes (whatever this may mean) nor study the big bang in our universe several times.
Also, our observational capabilities are constrained so far, as we only have data taken from planet Earth during the past ~ 100 years. In comparison to the presumable age of the universe (~ 13,5 by), this is like the attempt to reconstruct the timetable of the German railway system for a whole year, from a snapshot of ~ 0.2 seconds.
In view of these limitations, the qualitative and quantitative achievements of cosmology during

the past decades are truly remarkable. Nevertheless some results depend to some or a large extend on extrapolations of observations backward in time or on as of yet untested validity regimes of theoretical models. Some of these extrapolations are likely to stay with us for a long time, maybe forever. With these reservations in mind, we can also reverse this line of reasoning and consider cosmology as a unique laboratory of some regimes of physics that may not be testable otherwise. In particular, there is a fruitful interplay between cosmology and high-energy particle physics, since the conditions in the early universe can resemble those in particle collision experiments. Cross-checking results from colliders or cosmological observations has become a fertile field of fundamental physics. For those regimes that have so far remained inaccessible to colliders, cosmology can provide for the only available data so far.

Therefore, cosmology has become a field where synergies between different fields of physics (and physicists with different expertise) have arisen.

My recommendation for students thus is:
think big (cosmological scales) and think small (microscopic interactions) at the same time.