Great Debates in Galaxy Evolution

MVSem, Heidelberg University SS23
Lecturer: K. Kreckel

Open questions and problems fuel our continued research into understanding how galaxies are formed, grow and evolve over cosmic time. In the “Great Debate” of 1920 between Shapley and Curtis, they argued over the “Scale of the Universe”. Curtis argued that the Universe is composed of many galaxies like our own, which had been identified by astronomers of his time as “spiral nebulae”. Shapley argued that these “spiral nebulae” were just nearby gas clouds, and that the Universe was composed of only one big Galaxy. New observations in the 1920s and 1930s were essential to resolving this question.

In this course, we will cover a range of topics that have been posed as ‘problems’ in recent years, and the current proposed solutions.

Topics List:

1. (Historical) Shapley–Curtis Debate
2. Missing satellite problem
3. Cusp-core problem
4. G dwarf problem
5. “Impossibly early galaxy” problem
6. Missing baryon problem
7. Cooling catastrophe
8. What defines a galaxy?
9. Co-evolution (or not) of galaxies and SMBHs
10. Angular momentum problem
11. Satellite alignment problem
12. How do galaxies get their gas?
13. too-big-to-fail problem

Topics and suggested reading:

Relevant for many of the topics:
https://ui.adsabs.harvard.edu/abs/2017ARA%26A..55..343B/abstract

1. (Historical) Shapley–Curtis Debate
   - https://ui.adsabs.harvard.edu/abs/1921BuNRC...2..171S/abstract
   - https://ui.adsabs.harvard.edu/abs/1995PASP..107.1133T

2. Missing satellite problem
   - https://ui.adsabs.harvard.edu/abs/1993MNRAS.264..201K/abstract
   - https://ui.adsabs.harvard.edu/abs/1999ApJ...522...82K/abstract
   - https://ui.adsabs.harvard.edu/abs/1999ApJ...524L..19M/abstract

3. Cusp-core problem
   - https://ui.adsabs.harvard.edu/abs/1994Natur.370..629M/abstract
   - https://ui.adsabs.harvard.edu/abs/1998ApJ...502...48K/abstract
   - https://ui.adsabs.harvard.edu/abs/2012MNRAS.421.3464P/abstract

4. G dwarf problem
   - https://ui.adsabs.harvard.edu/abs/1963ApJ...137..758S/abstract
   - https://ui.adsabs.harvard.edu/abs/1997ApJ...477..765C/abstract
   - https://ui.adsabs.harvard.edu/abs/2015ApJ...808..132H/abstract

5. “Impossibly early galaxy” problem
   - https://ui.adsabs.harvard.edu/abs/2016ApJ...824...21S/abstract
   - https://ui.adsabs.harvard.edu/abs/2017Natur.544...71G/abstract

6. Missing baryon problem
   - https://ui.adsabs.harvard.edu/abs/1998ApJ...503..518F/abstract
   - https://ui.adsabs.harvard.edu/abs/2012ApJ...759...23S/abstract
   - https://ui.adsabs.harvard.edu/abs/2020Natur.581..391M/abstract

7. Cooling catastrophe
   - https://ui.adsabs.harvard.edu/abs/1994ARA%26A..32..277F/abstract
   - https://ui.adsabs.harvard.edu/abs/2006PhR...427....1P/abstract
   - https://ui.adsabs.harvard.edu/abs/2008ApJ...687..899R/abstract

8. What defines a galaxy?
   - https://ui.adsabs.harvard.edu/abs/2012AJ....144...76W/abstract
   - https://ui.adsabs.harvard.edu/abs/2014MNRAS.443.1151N/abstract

9. Co-evolution (or not) of galaxies and SMBHs
    https://ui.adsabs.harvard.edu/abs/2000ApJ...539L...9F/abstract
    https://ui.adsabs.harvard.edu/abs/2011ApJ...734...92J/abstract
    https://ui.adsabs.harvard.edu/abs/2013ARA%26A..51..511K/abstract

10. Angular momentum problem
    https://ui.adsabs.harvard.edu/abs/2001MNRAS.326.1205V/abstract
    https://ui.adsabs.harvard.edu/abs/2006ApJ...645..986R/abstract
    https://ui.adsabs.harvard.edu/abs/2002ApJ...581..799V/abstract

11. Satellite alignment problem
    https://ui.adsabs.harvard.edu/abs/2012MNRAS.423.1109P/abstract
    https://ui.adsabs.harvard.edu/abs/2013Natur.493...62I/abstract

12. How do galaxies get their gas?
    https://ui.adsabs.harvard.edu/abs/2005MNRAS.363....2K/abstract
    https://ui.adsabs.harvard.edu/abs/2009Natur.457..451D/abstract
    https://ui.adsabs.harvard.edu/abs/2008A%26ARv..15..189S/abstract

13. Too-big-to-fail problem
    https://ui.adsabs.harvard.edu/abs/2011MNRAS.415L..40B/abstract
    https://ui.adsabs.harvard.edu/abs/2017ARA%26A..55..343B/abstract