How Did The First Stars and Galaxies Form? (**Mon. 1 : 30 – 3 : 30PM**, **Spring 2017**)

Location : *B – 105*(*right from entrance*), *Center for Astrophysics*, *60 Garden Street*

Syllabus

Course Instructor

Prof. Avi Loeb

Office: P-238, Center for Astrophysics, 60 Garden St.

Individual appointments are welcome and can be arranged via: aloeb@cfa.harvard.edu

Teaching Assistant

Ms. Marion Dierickx

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Course Requirements

Weekly assignments:

(i) Students will be asked to read one original publication and a related chapter from the course book to be discussed at the Seminar

(ii) The instructor will suggest one problem every week and ask a couple of students to discuss it in a Seminar format the following week

(iii) Students will be asked to submit a short paper for mid-term and a somewhat longer paper towards the end of the term. The topic of the papers has to be related to the material covered by the Seminar and should be approved by the instructor

Course Text

Required :

⋆ Loeb, A. 2010, *How Did the First Stars and Galaxies form?* (Princeton: Princeton U Press)

Further Reading :

⋆ Schneider, P. 2006, *Extragalactic Astronomy and Cosmology* (Berlin: Springer)

Course Outline

⋆ *The discussion topic each week requires reading of the similarly titled chapter in the course book as well as the related publications listed below.*

1. The Big Picture **1/23**

In the Beginning

Observing the Story of Genesis

Practical Benefits from the Big Picture

⋆⋆⋆ *Tour to the Great Refractor Telescope at the Harvard College Observatory* ⋆⋆⋆

2. Standard Cosmological Model **1/30**

Cosmic Perspective

Past and Future of Our Universe

Gravitational Instability

Geometry of Space

Cosmic Archeology Milestones in Cosmic Evolution

Most Matter is Dark

⋆*Related publication:* Peebles, P. J. E. *Principles of Physical Cosmology*, Princeton University Press (1993), pages 62-65.

3. The First Gas Clouds ..... **2/6, 2/13, [no class on 2/20]**

Growing the Seed Fluctuations

The Smallest Gas Condensations

Spherical Collapse and Halo Properties

Abundance of Dark Matter Halos

⋆*Related publication:* Press, W. H., & Schechter, P. *Astrophys. J.* **187**, 425 (1974).

Cooling and Chemistry

Sheets, Filaments, and Only Then, Galaxies

⋆*Related publication:* Haiman, Z., Thoul, A. A., & Loeb, A. *Astrophys. J.* **464**, 523 (1996).

4. The First Stars and Black Holes **2/27, 3/6**

Metal-Free Stars

Properties of the First Stars

⋆*Related publication:* Bromm, V., & Larson, R. B. *Ann. Rev. Astron. & Astrophys.* **42**, 79 (2004).

The First Black Holes and Quasars

Gamma-Ray Bursts: The Brightest Explosions

⋆*Related publication:* Bromm, V. & Loeb, A. *Astrophys. J.* **596**, 34 (2003).

5. The Reionization of Cosmic Hydrogen by the First Galaxies[no class on 3/13], 3/20, 3/27

Ionization Scars by the First Stars

Propagation of Ionization Fronts

Swiss Cheese Topology

⋆*Related publication:* Barkana, R., & Loeb, A. *Phys. Rep.* **349**, 129 (2001).

6. Observing the First Galaxies **4/3**

Completing Our Photo Album of the Universe

Cosmic Time Machine

The Hubble Deep Field and its Follow-ups

Observing the First Gamma-Ray Bursts

Future Telescopes

⋆*Related publication:* Stark, D., et al. *Astrophys. J.* **663**, 10 (2007).

7. Imaging the Diffuse Fog of Cosmic Hydrogen **4/10**

Hydrogen

The Lyman-α Line

The 21-cm Line

Observing Most of the Observable Volume

⋆*Related publication:* Pritchard, J., & Loeb, A. *Rep. Prog. Phys.* (2012); arXiv:1109.6012

8. Future of the Universe **4/17**

End of Extragalactic Astronomy

Milky Way + Andromeda = Milkomeda

⋆*Related publication:* Loeb, A. *Phys. Rev.* **D65**, 7301 (2002).

Special Lunch and Summary **4/24**