

**How Did The First Stars and Galaxies Form? (Mon. 1 : 30 – 3 : 30PM, Spring 2013)**

Location : P – 226 (Tea Room), CfA, 60 Garden Street

**Syllabus**

**Course Instructor**

Prof. Avi Loeb

Office: P-237, Center for Astrophysics, 60 Garden St.

Phone: 617-496-6808 (office); E-mail: aloeb@cfa.harvard.edu

**Teaching Assistant**

Dr. Mark Vogelsberger

Office: P-230, Center for Astrophysics, 60 Garden St.

Phone: 617-384-7366 (office); E-mail: mvogelsberger@cfa.harvard.edu

**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** ..... **2/4**  
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** ..... **2/11**

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** ..... **2/25, 3/4**

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** ..... **3/11, 3/25**

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** ..... **4/1, 4/8**

Ionization Scars by the First Stars

Propagation of Ionization Fronts

Swiss Cheese Topology

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

<b>6. Observing the First Galaxies</b> .....	<b>4/15</b>
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	
★ <i>Related publication:</i> Stark, D., et al. <i>Astrophys. J.</i> <b>663</b> , 10 (2007).	
<b>7. Imaging the Diffuse Fog of Cosmic Hydrogen</b> .....	<b>4/22</b>
Hydrogen	
The Lyman- $\alpha$ Line	
The 21-cm Line	
Observing Most of the Observable Volume	
★ <i>Related publication:</i> Pritchard, J., & Loeb, A. <i>Rep. Prog. Phys.</i> (2012); arXiv:1109.6012	
<b>8. Future of the Universe</b> .....	<b>4/29</b>
End of Extragalactic Astronomy	
Milky Way + Andromeda = Milkomeda	
★ <i>Related publication:</i> Loeb, A. <i>Phys. Rev.</i> <b>D65</b> , 7301 (2002).	
<b>Special Lunch and Summary</b> .....	<b>5/6</b>