ASTR 610
Theory of Galaxy Formation
Lecture 1
Important Information

**Instructor:** Prof. Frank van den Bosch  (Office: 52HH#320)  
frank.vandenbosch@yale.edu

**Course Website:**  http:/campuspress.yale.edu/astro610/

**Lecture Hours:** Mon-Wed 9.00-10.15am [SPL 48]

**Textbook:** Galaxy Formation & Evolution  
Mo, van den Bosch & White (hereafter MBW)  

**Syllabus:** available on course website & canvas

**Lecture Notes:** will be made available on course website

**Grading:**  40% Final Exam (oral)  
30% Term Paper & Presentation (topic picked in class)  
30% Problem Sets
The Course

**Format:** 24 lectures (see preliminary schedule)
- 2 classes with student presentations (week 14)

**Requirements:**
- graduate student in physics or astronomy
- familiarity with astronomy nomenclature (magn, Mpc, $H_0$)
- basic knowledge of extra-galactic astronomy
  - (read chapter 2 of MBW)

**My goal for you:**
- to teach you the physics related to galaxy formation
- to teach you basic concepts & relevant nomenclature
- to prepare you for research in extra-galactic astrophysics

**What I expect from you:**
- participate actively in class (ask questions)
- hand in problem sets on time
- term paper (±8-10 pages on topic of current interest)
- presentation in class (=online) on term paper
- oral exam (1 hour, during exam period)
Good additional source of information. Somewhat less advanced than MBW. Does not cover the gastrophysical processes of galaxy formation (cooling, star formation feedback) in any detail.

One of the best graduate textbooks on cosmology. Excellent coverage of Newtonian perturbation theory. Does not cover galaxy formation in any detail, though...
Detailed coverage of structure formation in the linear regime with superb treatment of relativistic perturbation theory. Nice chapter on likelihood analysis. Does not cover non-linear collapse, or galaxy formation.

A classic! Excellent textbook on dynamics. Has detailed information on equilibria, collisions and interactions of collisionless systems.
Additional Recommended Textbooks

Brand new... an undergraduate companion to MBW. Excellent additional source of information, and very much up to date.

Good companion for MBW, with detailed treatment of reionization, first stars and 21cm cosmology.
## Preliminary Schedule

<table>
<thead>
<tr>
<th>week</th>
<th>Date</th>
<th>Topic</th>
<th>MBW</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Wed 08/31</td>
<td>Introduction; A Broad Brush Overview of Galaxy Formation</td>
<td>chapter 1</td>
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<td>1</td>
<td>Fri 09/02</td>
<td>Cosmology (Riemannian geometry, FRW metric, cosmological distances)</td>
<td>§3.1</td>
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<tr>
<td>2</td>
<td>Wed 09/07</td>
<td>Relativistic Cosmology (GR, Friedmann eqs)</td>
<td>§3.2</td>
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<tr>
<td>3</td>
<td>Mon 09/12</td>
<td>NO CLASS</td>
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<td>3</td>
<td>Wed 09/14</td>
<td>NO CLASS</td>
<td></td>
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<tr>
<td>4</td>
<td>Mon 09/19</td>
<td>Newtonian Perturbation Theory: linearized fluid equations</td>
<td>§4.1</td>
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<tr>
<td>4</td>
<td>Wed 09/21</td>
<td>Newtonian Perturbation Theory: baryonic perturbations</td>
<td>§4.1</td>
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<tr>
<td>5</td>
<td>Mon 09/26</td>
<td>Newtonian Perturbation Theory: dark matter</td>
<td>§4.1</td>
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<td>5</td>
<td>Wed 09/28</td>
<td>Transfer Function and the Cosmic Microwave Background</td>
<td>§4.3 - §6.7</td>
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<td>6</td>
<td>Mon 10/03</td>
<td>Non-linear collapse and Relaxation</td>
<td>chapter 5</td>
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<tr>
<td>6</td>
<td>Wed 10/05</td>
<td>Press-Schechter Theory, Excursion Set Formalism and Halo Mass Function</td>
<td>§7.2</td>
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<td>7</td>
<td>Mon 10/10</td>
<td>Structure of Dark Matter Halos</td>
<td>§7.3 - §7.4</td>
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<td>7</td>
<td>Wed 10/12</td>
<td>Merger Trees and Halo Bias</td>
<td>§6.1 - §6.2 - §6.5</td>
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<td>8</td>
<td>Mon 10/17</td>
<td>Structure of Dark Matter Halos</td>
<td>§7.5</td>
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<td>8</td>
<td>Wed 10/19</td>
<td>NO CLASS: October Recess</td>
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<td>Week</td>
<td>Date</td>
<td>Topic</td>
<td>Sections</td>
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<tr>
<td>9</td>
<td>Mon 10/24</td>
<td>Large Scale Structure</td>
<td>§6.1 - §6.2 - §6.5</td>
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<td>9</td>
<td>Wed 10/26</td>
<td>Halo Model and Halo Occupation Statistics</td>
<td>§7.6 - §15.6</td>
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<td>10</td>
<td>Mon 10/31</td>
<td>Galaxy Interactions &amp; Transformations</td>
<td>chapter 12</td>
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<td>10</td>
<td>Wed 11/02</td>
<td>Cooling Processes &amp; Photo-Ionization Heating</td>
<td>§8.1 - §8.3 - §8.4</td>
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<td>11</td>
<td>Mon 11/07</td>
<td>Star Formation</td>
<td>§9.1 - §9.3 - §9.5</td>
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<td>11</td>
<td>Wed 11/09</td>
<td>Supernova Feedback</td>
<td>§8.6 - §10.5</td>
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<td>12</td>
<td>Mon 11/14</td>
<td>Structure and Formation of Disk Galaxies</td>
<td>chapter 11</td>
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<td>12</td>
<td>Wed 11/16</td>
<td>Structure and Formation of Elliptical Galaxies</td>
<td>chapter 13</td>
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<td>13</td>
<td>Mon 11/21</td>
<td>NO CLASS: Thanksgiving Break</td>
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<tr>
<td>13</td>
<td>Wed 11/23</td>
<td>NO CLASS: Thanksgiving Break</td>
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<tr>
<td>14</td>
<td>Mon 11/28</td>
<td>AGN and supermassive black holes</td>
<td>chapter 14</td>
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<td>14</td>
<td>Wed 11/30</td>
<td>Numerical Simulations</td>
<td>App C</td>
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<td>15</td>
<td>Mon 12/05</td>
<td>Student Presentations</td>
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<tr>
<td>15</td>
<td>Wed 12/07</td>
<td>Student Presentations</td>
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Galaxy Formation in a Nutshell

Big Bang
Cosmic inflation
Origin of fluctuations
Particles form
Recombination
Dark ages
First stars & galaxies
Galaxy evolution
Today

0
10^{-32} seconds
10^{-30} seconds
1 second
100 seconds
1 year
100 years
380,000 years
200 million years
1 billion years
10 billion years
13.82 billion years

ASTR 610: Theory of Galaxy Formation
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Galaxy Formation in a Nutshell

- **Radiation-dominated**
- **Matter-dominated**
- **Super-horizon scales**
- **Jeans-stable**
- **Jeans-unstable**
- **Silk damping**
- **Linear growth**
- **Non-linear collapse**
- **Silk damping**
- **Stagnation**
- **Baryonic oscillations**
- **Virialization**
- **Shock cooling**
- **Cooling**

**Log[scale] vs Log[scale-factor]**

- **$\lambda$**
- **$\lambda_{H}$**
- **$\lambda_{MW}$**
- **$M_{\sim 10^{15}} M_\odot$**
- **$M_{\sim 10^{12}} M_\odot$**
- **$M_{\sim 10^{6}} M_\odot$**
- **$t_{eq}$**
- **$t_{dec}$**
- **$\tau_{bol}$**
- **$M_{\sim 10^{12}} M_\odot$**
- **$M_{\sim 10^{6}} M_\odot$**

- **AC**
- **Silk damping**
- **Baryons**
- **Dark matter**

**Galaxy Formation in a Nutshell**

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