

MASS 2023 Course:
Gravitational Lenses
(Syllabus)

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Syllabus

1. Brief introduction to cosmology (3 lectures + exercises):

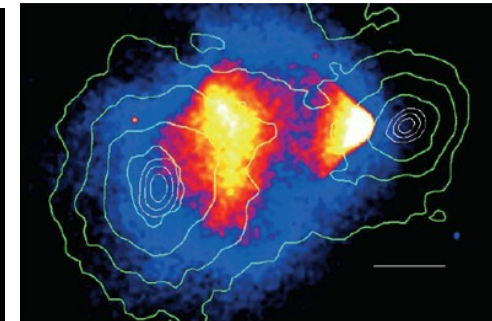
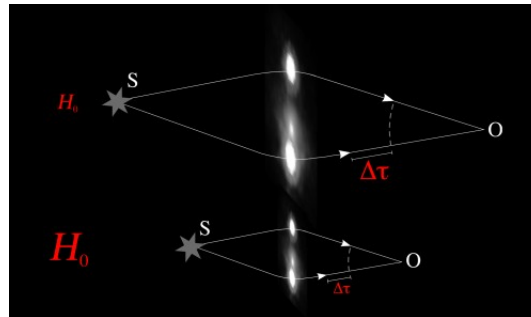
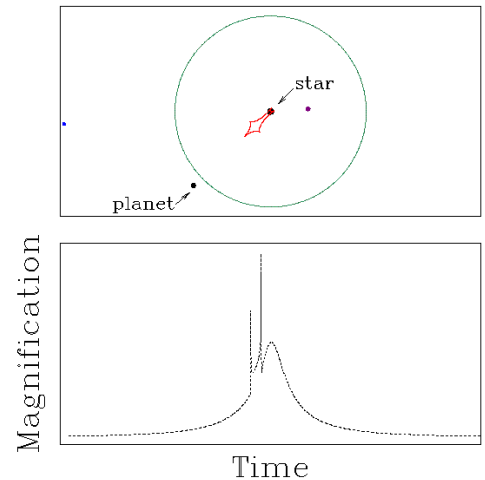
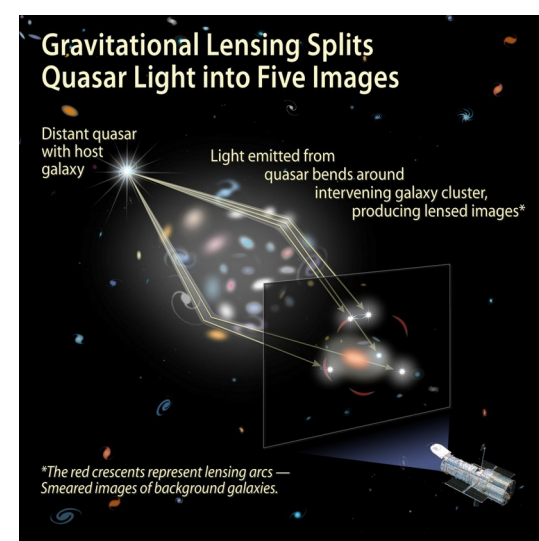
- Standard Λ CDM cosmological model
- Cosmological parameters
- Distance measures in cosmology
- Observational cosmology: SN Ia and CMBR tests for determination of cosmological parameters

2. Gravitational lenses (9 lectures + exercises):

- Basic principles: light bending in gravitational field
- Types: strong (macro, micro) and weak
- **Lensing theory** (main part of the course)
- Applications:
 - Macrolensing: detection of distant galaxies (natural telescopes), determination of cosmological parameters
 - Microlensing: detection of extrasolar planets and investigation of physics and geometry in vicinity of supermassive black holes
 - Weak lensing: detection of dark matter

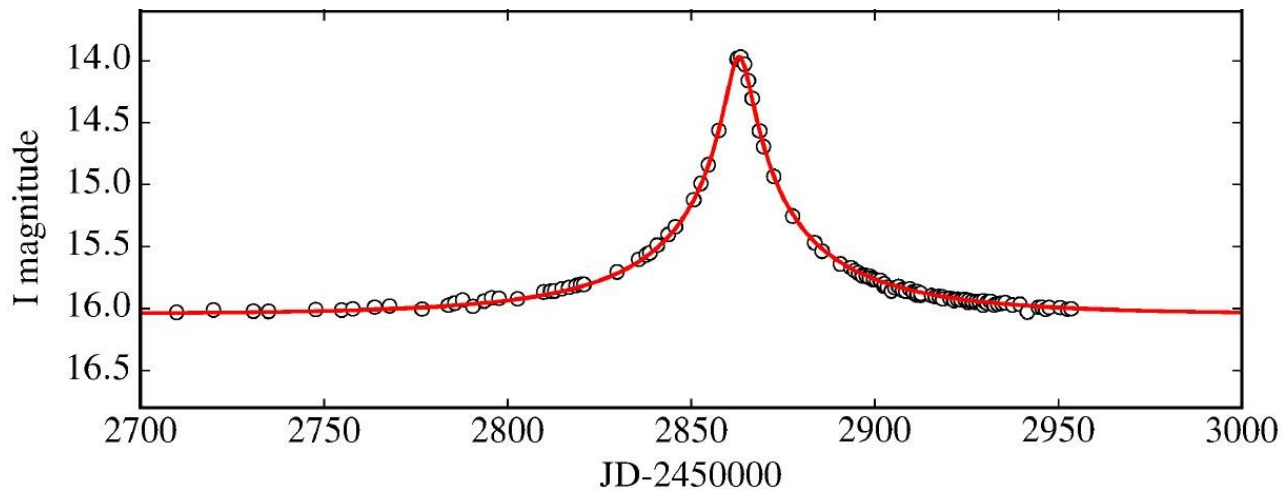
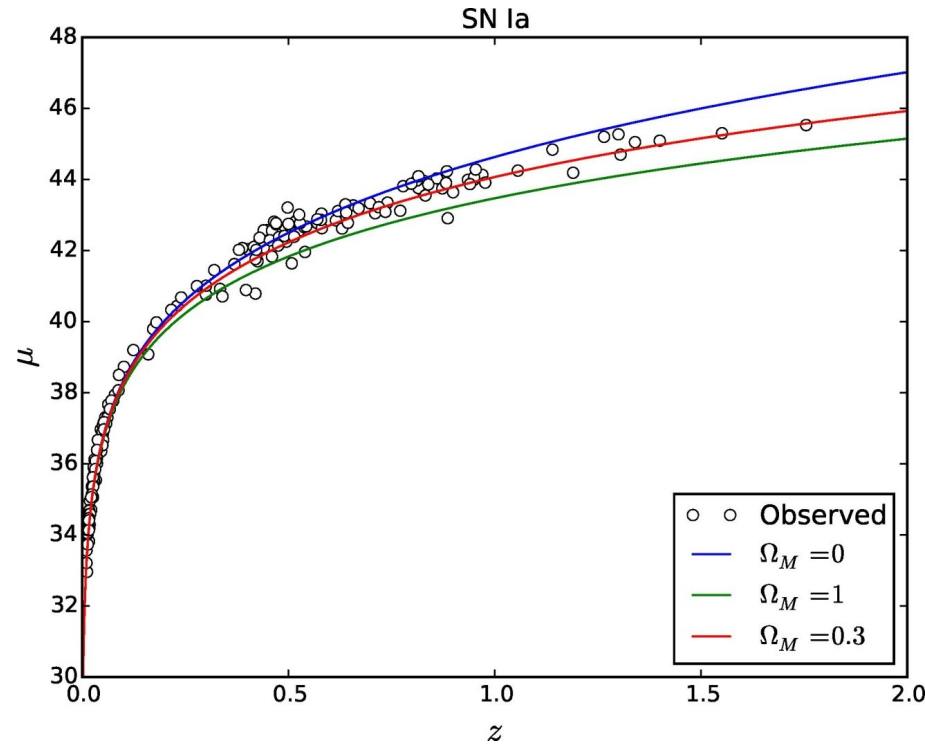
3. Final exam:

- Oral: questions to answer
- Written: problems to solve



Exercises

1. Solving problems on the blackboard
2. Comparisons of theoretical models with astronomical observations:
 - Writing scripts in Python programming language
 - You need to have installed Python 3 interpreter with NumPy, SciPy, Astropy and Matplotlib/PyLab libraries



Final exam

- Second half of December
- Test will have two parts:
 - 3-4 problems to solve
 - 2 questions to answer orally
- Problems and questions will cover both cosmology and gravitational lensing

Points	Grade
51-60	6
61-70	7
71-80	8
81-90	9
91-100	10

5 - failed
6 - satisfactory
7 - good
8 - very good
9 - excellent
10 - remarkable

Literature (Cosmology)

Articles:

1. Sean M. Carroll, 2001, *The Cosmological Constant*, Living Reviews in Relativity, 4, 1 (arXiv:astro-ph/0004075)
2. Carroll, S. M., Press, W. H. & Turner, E. L. 1992, *The cosmological constant*, ARA&A, 30, 499
3. Davis, T. M. & Lineweaver, C. H. 2004, *Expanding Confusion: Common Misconceptions of Cosmological Horizons and the Superluminal Expansion of the Universe*, PASA, 21, 97 (arXiv:astro-ph/0310808)
4. David W. Hogg, 2000, *Distance measures in cosmology*, arXiv:astro-ph/9905116v4

Online tutorials:

5. WMAP's Introduction to Cosmology: <http://map.gsfc.nasa.gov/universe/>
6. Ned Wright's Cosmology Tutorial: <http://www.astro.ucla.edu/~wright/cosmolog.htm>

Books:

7. S. Weinberg, 2008, *Cosmology*, Oxford University Press Inc., New York, USA
8. P.J.E. Peebles, 1993, *Principles Of Physical Cosmology*, Princeton University Press, Princeton, New Jersey, USA

Literature (Gravitational Lenses)

1. *Gravitational Lensing: Strong, Weak and Micro*, Book Series: Saas-Fee Advanced Courses
 - P. Schneider - *Introduction to Gravitational Lensing and Cosmology*
 - C. S. Kochanek - *Strong Gravitational Lensing*
 - P. Schneider - *Weak Gravitational Lensing*
 - J. Wambsganss - *Gravitational Microlensing*
2. J. Wambsganss - *Gravitational Lensing in Astronomy*, Living Reviews in Relativity:
<https://link.springer.com/article/10.12942/lrr-1998-12>
3. R. Narayan, M. Bartelmann - *Lectures on Gravitational Lensing*, arXiv:astro-ph/9606001v2

Lectures, exercises and main literature will be available at:

<http://pjovanovic.aob.rs/gl2023/>