

## Radiative Transfer Simulations in Astrophysics (C003939)

**Course size** *(nominal values; actual values may depend on programme)*

**Credits 6.0**

**Study time 180 h**

**Course offerings in academic year 2025-2026**

A (semester 2)

English

Gent

**Lecturers in academic year 2025-2026**

Baes, Maarten

WE05

lecturer-in-charge

**Offered in the following programmes in 2025-2026**

[Master of Science in Teaching in Science and Technology \(main subject Physics and Astronomy\)](#)

6

A

[Master of Science in Physics and Astronomy](#)

6

A

[Master of Science in Physics and Astronomy](#)

6

A

[Exchange Programme in Physics and Astronomy \(Master's Level\)](#)

6

A

**Teaching languages**

English

**Keywords**

Astrophysics, radiative transfer, numerical modeling, Monte Carlo techniques, interstellar dust

**Position of the course**

Astronomical observations are naturally limited to the two-dimensional plane of the sky. Building a computer model of the observed objects can help us understand the underlying three-dimensional structure and physical processes. These models must properly take into account the effects of radiation transport through the interstellar medium. For example, in an average spiral galaxy, one third of the stellar radiation is absorbed by interstellar dust. The Monte Carlo technique is the most popular method to accurately simulate these effects.

This course is the logical next step after "Theoretical and Numerical Astrophysics". In that course, students are initiated in simulation techniques for gravitation and hydrodynamics. This follow-up course studies simulation techniques for radiation transport, another phenomenon that is important in almost all astrophysical systems. Furthermore, the practical sessions provide a realistic setting where the student learns how to use an existing scientific code and adjust or extend it to achieve new, specific research goals.

**Contents**

- 1 The radiative transfer problem
- 2 Dust radiative transfer
- 3 X-ray radiative transfer
- 4 Random number generation
- 5 Simple monochromatic Monte Carlo radiative transfer
- 6 Weighted monochromatic Monte Carlo radiative transfer
- 7 Panchromatic Monte Carlo radiative transfer
- 8 The SKIRT code
- 9 Spatial grids
- 10 Geometric building blocks in SKIRT
- 11 Parallelisation
- 12 Radiative transfer benchmarks
- 13 The 3D structure of galaxies

- 14 The torus in active galactic nuclei
- 15 Synthetic observations for simulated galaxies

### Initial competences

Astrophysical Simulations (C002329)

### Final competences

- 1 Derive the radiative transfer equation and understand its components.
- 2 Describe the Monte Carlo photon package life cycle and related techniques for spatial discretization, sampling from three-dimensional distributions, computational optimization, and parallelization.
- 3 Describe some science cases to which radiative transfer simulations are applied and explain why they are relevant.
- 4 Apply a state-of-the-art radiative transfer code to basic science cases.
- 5 Interpret radiative transfer simulation results in a numerical and astrophysical context.
- 6 Orally convey the findings of a radiative transfer simulation project to experts.

### Conditions for credit contract

Access to this course unit via a credit contract is determined after successful competences assessment

### Conditions for exam contract

This course unit cannot be taken via an exam contract

### Teaching methods

Lecture, Independent work

### Extra information on the teaching methods

Part of the material is prepared by the student before the lecture and is reviewed during the lecture. Other parts of the material are explained in detail during the lectures.

### Study material

Type: Syllabus

Name: Radiative transfer  
Indicative price: Free or paid by faculty  
Optional: no  
Language : English  
Number of Pages : 200  
Available on Ufora : Yes  
Online Available : Yes  
Available in the Library : No  
Available through Student Association : No

Type: Slides

Name: Radiative transfer  
Indicative price: Free or paid by faculty  
Optional: no  
Language : English  
Number of Slides : 200  
Available on Ufora : Yes  
Online Available : Yes  
Available in the Library : No  
Available through Student Association : No

### References

Monte Carlo Methods, Malvin H. Kalos and Paula A. Whitlock, Second Edition, 2008 Wiley-VCH.  
Three-Dimensional Dust Radiative Transfer, Juergen Steinacker, Maarten Baes, and Karl D. Gordon, 2013, Annual Review of Astronomy and Astrophysics.  
SKIRT: An advanced dust radiative transfer code with a user-friendly architecture, Peter Camps and Maarten Baes, 2015, Astronomy and Computing.

### Course content-related study coaching

The lecturers are available for coaching during the semester.

### Assessment moments

end-of-term and continuous assessment

**Examination methods in case of periodic assessment during the first examination period**

Oral assessment, Assignment

**Examination methods in case of periodic assessment during the second examination period**

Oral assessment, Assignment

**Examination methods in case of permanent assessment**

Assignment

**Possibilities of retake in case of permanent assessment**

examination during the second examination period is not possible

**Extra information on the examination methods**

The non-periodic evaluation relates to a modest-size individual programming project.

The period evaluation relates to a project in which the student applies the SKIRT radiative transfer code to an astrophysical question. The results of this project are presented in a document and an oral presentation.

**Calculation of the examination mark**

Programming project: 30%

Radiative transfer project: 70%

**Facilities for Working Students**

The syllabus and the slides are available on Ufora. Independent work is an integral part of this course.