Department of Astronomy

Stockholm University

# Syllabus

for course at advanced level

**Late stages of stars, supernovae and gamma-ray bursts**
**Stjärnors slutstadier, supernovor och gammastrålningsutbrott**

**7.5 Higher Education Credits**
**7.5 ECTS credits**

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|---|---|
| **Course code:** | AS8002 |
| **Valid from:** | Autumn 2022 |
| **Date of approval:** | 2022-02-02 |
| **Department** | Department of Astronomy |
| **Main field:** | Astronomy |
| **Specialisation:** | A1F - Second cycle, has second-cycle course/s as entry requirements |

## Decision

This syllabus was approved by the Board of Science at Stockholm University on 2022-02-02.

## Prerequisites and special admittance requirements

Admission to the course requires knowledge equivalent to:
- A Bachelor's degree in astronomy or physics - Astrophysical gas dynamics, 7.5 credits (AS7002)
- Astrophysical spectra, 7.5 hp (AS5004)
- Stellar structure and evolution, 7.5 credits (AS5003)
- Swedish upper secondary school course English 6.

## Course structure

| Examination code | Name | Higher Education Credits |
|---|---|---|
| HELA | Late stages of stars, supernovae and gamma-ray bursts | 7.5 |

## Course content

This course addresses the late stages of stellar evolution, with focus on the massive stars which end their lives as supernovae and/or gamma ray bursts. The theory and stages of nuclear burning from helium ignition to the formation of an iron core are laid out, and the origin the elements in the periodic table is discussed. The important role of neutrino cooling for the now more rapid and qualitatively different stellar evolution is emphasized. The connection between stellar properties, such as mass and metallicity, and observational classifications are discussed in the context of the supernova that results.

The course further treats the physics of supernova explosions, and how advanced computer simulations have improved our understanding of these. We review the fundamental processes forming the light curve and spectra of the supernova, and diagnostic methods to determine the structure of the ejecta. Results from theory and observations are combined to describe the landscape of successful explosions versus failed ones leading to black hole formation, and associations between different stellar classes and supernova types.

Gamma ray bursts are reviewed, and the connection of these to the most massive and rapidly rotating stars in the Universe is discussed. We study also briefly exotic transients such as superluminous supernovae and kilonovae.

## Learning outcomes

After completing the course, the student is expected to be able to:

- describe the star's late evolutionary stages, both on microphysical and macrocopic scales, as well as the connection between stellar properties and observational classes.
- use publicly available software to make simulations of a star’s evolution, and analyse how changed assumptions affect the evolution.
- account for the different phases in a supernova explosion, observational properties of supernovae, and classifications based on these properties.
- deduce and apply analytic formulae to estimate the physical parameters of a supernova from observed light curves and spectra.
- describe fundamental phenomenology of gamma-ray bursts, models for their emission processes, and relation to the central engine.
- couple together results from observations, simulations, and theory to differentiate between well established and more speculative properties of massive stars, supernovae, and gamma ray bursts.
- argue for the origin of each element in the periodic table.

**Education**

Teaching consists of lectures, exercises and a computer lab.

The course is offered in English.

**Forms of examination**

a. The course is examined as follows: Assessment takes place through written reports of hand-in exercises, a lab report, and written and oral presentation of literature studies, including opposition on other student projects.

The examiner can decide on adapted or alternative examination formats for students with disabilities.

The examination will be conducted in English.

b. A passing final grade requires participation in laboratory and exercise sessions. If special reasons exist, following consultation with the teacher involved, the examiner may grant the student exemption from the obligation to participate in certain compulsory instruction.

c. Grading: The course’s final grade is set according to a seven-point criterion-referenced scale:
A = Excellent
B = Very good
C = Good
D = Satisfactory
E = Adequate
Fx = Fail, some additional work required
F = Fail, much additional work required

d. The course’s grading criteria are handed out at the start of the course.

e. Students who receive a failing grade on a regular examination are allowed to retake the examination as long as the course is still offered. The number of examination opportunities is not limited. Other mandatory course elements are equated with examinations. A student who has received a passing grade on an examination may not retake the examination to attain a higher grade. A student who has failed the same examination twice is entitled to have another examiner appointed, unless there are special reasons to the contrary. Such requests should be made to the board of the department. The course includes at least three examination opportunities per academic year the course is offered. For the academic years that the course is not offered, at least one examination opportunity is offered.

f. Students awarded the grade Fx are given the opportunity to improve their grade to E. The examiner decides on the supplementary assignments to be performed and the pass mark criteria. The supplementary assignments will take place before the next examination opportunity.

**Interim**

Students may request that the examination be conducted in accordance with this course plan even after it has ceased to be valid. However, this may not take place more than three times over a two-year period after the course was discontinued. Requests must be made to the departmental board. The provision also applies in the case of revisions of the course syllabus and revisions of the required reading.

**Limitations**

The course may not be included in a degree together with any of the courses Early and late stellar evolution,

15 hp (AS7011), Supernovae and gamma-ray bursts, 5hp (AS7014), Late stages of stellar evolution, supernovae and gamma-ray bursts (AS7016), or with equivalent courses.

**Misc**

The course is part of the master programme in astronomy but can also be taken as a separate course.

**Required reading**

The required reading is decided by the board of the department and published on the course page in the online course catalogue at least 2 months before the start of the course.