# . – Introduction to astronomy and astrophysics

## Prof. Massimo Della Valle

***COURSE AIMS AND INTENDED LEARNING OUTCOMES***

The course is addressed to second/third-year students in Mathematics and/or Physics intending to deepen their knowledge of Astronomy and Astrophysics. Astronomy is probably the oldest science. The paintings in *Lascaux* caves, in the department of Dordogne in southwestern France, show that our ancestors began to study the sky as soon as 20 thousand years ago. After providing a short historical introduction, we will approach the study of stars in their most relevant aspects: their structure, composition, mechanisms for energy production, and building chemical elements on which our life is based. We will also describe in some details the final stages of the life of a star, which ends through *Supernova* and *Gamma-ray Burst* explosions. Particular attention will be paid to the final products of stellar evolution, such as *Neutron stars* and *Black Holes* and the recent class of astrophysical objects labelled as *Kilonovae*, i.e. the electromagnetic counterparts of gravitational wave sources. We will illustrate an updated overview of the observational facilities operating from ground, such as the large telescopes of the European Southern Observatory in Chile, from space (e.g. *Hubble space Telescope*) or ready to become operational (*James Webb Space Telecope* and *LSST*). The final part of the course will address basic notions on our Solar System and the discovery of extrasolar planets and the probability to find life in other worlds.

***COURSE CONTENT***

**Module 1 : The Roots of Modern Astronomy (2h)**

The Astronomy of Greece; The Ptolemaic Universe; Islam and Astronomy; The Puzzle of Planetary Motion; The Copernican Revolution; The Tycho Supernova; Galileo and Benedetto Castelli; Kepler's Three Laws of Planetary Motion.

**Module 2: The Sky as it appears (3h)**

Constellations; The Names of the Stars; The Brightness of Stars; Magnitude and Intensity; The Sky and Its Motion; The Celestial Sphere; Precession and Nutation; The Annual Motion of the Sun; The Seasons; The Motion of the Planets; Astronomy vs. Astrology.

**Module 3: Light and Telescopes (3H)**

The Electromagnetic Spectrum; brief notes on Radiative Process in astrophysics (Black Body, Bremsstrahlung Synchrotron); Optical Telescopes; New-Generation Telescopes; Active and Adaptive Optics; Interferometry; The Spectrograph; Radio Telescopes; Infrared Astronomy; Ultraviolet Astronomy; X-Ray Astronomy; Gamma-Ray Telescopes; The Hubble Space Telescope.

**Module 4: Measuring the star parameters (4h)**

Distances to Stars; Intrinsic Brightness; Brightness and Distance; Absolute, Apparent and bolometric Magnitudes; Pogson Formula; photometric systems; Luminosity; The Sizes of the Stars; Luminosity, Radius, and Temperature relation; The H-R Diagram; Giants, Supergiants, and Dwarfs; Luminosity Classification; the Saha and Boltzmann equations; the Masses of Stars; the density of Stars; the binary stars.

**MODULE 5: Interstellar Medium (2h)**

Nebulae; Extinction and Reddening; Interstellar Absorption Lines; 21-cm line; Molecules in Space; Infrared Radiation from Dust; X Rays From the Interstellar Medium; Ultraviolet Observations of the Interstellar Medium; The Interstellar Cycle.

**MODULE 6: Stellar Evolution (14h)**

1. THE FORMATION OF STARS

Star birth in giant molecular clouds; Proto-stars; the star structure (hydrostatic equilibrium, energy transport, conservation of mass, conservation of energy) energy production: Proton-Proton chain; the Bethe Cycle; energy transport: radiative vs. convection; the pressure-temperature thermostat.

2. THE MAIN SEQUENCE

Why There Is a Main Sequence; the end of the Main Sequence; the life of a Main-Sequence star;

the post-Main-Sequence evolution, expansion into a giant and supergiant; degenerate matter;

Helium fusion; fusing elements heavier than Helium (3-alpha reaction); the role of neutrinos.

3. FINAL STAGES OF STELLAR EVOLUTION

Nova and Supernova Explosions; the building of heavy elements ( r- and s-process); Gamma-ray Bursts; Kilonovae and Gravitational wave emissions.

**MODULE 7: The Residuals of Stellar Evolution (6h)**

White dwarfs; degenerate electron pressure: mass-radius relation, luminosity source of white ; Neutron Stars; theoretical prediction of Neutron Stars; the discovery of Pulsars; Black Holes; escape velocity; the energetic of Schwarzschild and Kerr Black Holes; the search for Black Holes.

**MODULE 8: Our Backyard and Life in Other Worlds (6h)**

Planet Earth; The Moon; The Sun; Mercury; Venus; Mars; Jupiter; Saturn; Uranus; Neptune; Asteroids, Comets, Dwarf Planets, Kuiper Belt ; The structure of our Galaxy (The Milky Way); Life in Our Solar System; Life in Other Planetary Systems; extrasolar planets; Communication with Distant Civilizations; Travel Between the Stars; Radio Communication ;How Many Inhabited Worlds? (Drake Equation)

***READING LIST***

**“Lecture Notes”** provided by the lecturer

***Consulting Books:***

**“Astrophysics in a Nutshell” “ Maoz, D.,** Princeton University Press, 2016

**“Introduction to High Energy Astrophysics”** S. Rosswog, M. Brüggen, Cambridge University Press

**“The Cosmos: Astronomy in the New Millennium”** Jay M. Pasachoff, Alex Filippenko,

Cambridge University Press

**“Lezioni di Astronomia”**, Rosino L., Edizioni CEDAM

***TEACHING METHOD***

Each module consists of about 2-14 hours of lectures which include the corrections and discussions of homework. We also plan a training session at the Asiago Astrophysical Observatory (INAF-Padova and Padova University).

***ASSESSMENT METHOD AND CRITERIA***

Oral Exam. Discussion of three topics - two of which will be assigned in advance by the teacher. The third one will be choose by the student and be presented as a short seminary. The evaluation will be done on the basis of: i) the general degree of knowledge of the subject (40%); ii) the ability to answer related topics (30%); iii) homework (30%).

***NOTES AND PREREQUISITES***

The understanding of the course requires knowledge of basics of Mathematics and Physics, usually acquired in the courses of Analysis 1 – 2 and Physics 1 – 2.

Covid-19

In case the current Covid-19 health emergency does not allow frontal teaching, remote teaching will be carried out following procedures that will be promptly notified to students.

The lecturer will be available by appointment. All appointments are preferably arranged via email ([massimo.dellavalle@inaf.it](mailto:massimo.dellavalle@inaf.it)).