TEACHING GUIDE ON

Origin and Evolution of the Chemical Elements in the Universe

<table>
<tr><td>MASTER MODULE</td><td>SEMESTER</td><td>CREDITS</td><td>COURSE TYPE</td></tr>
<tr><td>Particle Physics and Astrophysics</td><td>2</td><td>6</td><td>Optative</td></tr>
<tr><td>PROFESSOR(S)</td><td colspan="3">CONTACT DETAILS</td></tr>
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<tr><td colspan="3">TUTORIALS TIMETABLE</td></tr>
<tr><td colspan="3">L,M: 17-19 h X: 9:30-11:30 (Abia)
X: 16 -19 V: 11- 14h (Domínguez)
L, X: 17:30-19:30 (Vilchez)</td></tr>
<tr><td colspan="4">MASTER DEGREE</td></tr>
<tr><td colspan="4">University Master in Physics: Radiations, Nanotechnology, Particles and Astrophysics, University of Granada</td></tr>
<tr><td colspan="4">TEACHING DATES AND TIMES</td></tr>
<tr><td colspan="4">2nd semester: see master webpage</td></tr>
<tr><td colspan="4">PRE-REQUISITES FOR REGISTRATION</td></tr>
<tr><td colspan="4">Basic knowledge in astrophysics is recommended</td></tr>
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BRIEF CONTENTS DESCRIPTION

Modern Astrophysics and Cosmology are based of the development of the most advanced astronomical instrumentation - which made possible accurate astronomical observations - and on theoretical physcial models and numerical simulations to test observations. In this course we will study the role played by stars in the chemical evolution of the interstellar medium within galaxies; with a particular emphasis in the concomitant nucleosynthesis associated to thermonuclear reactions which determine the stellar evolution, including explosive events as novae, supernovae and gamma/X ray bursts. Finally, by using all the necessary input physics and the most recent observations and numerical simulations, we will analyze the chemical evolution of the galaxies, from the Big-Bang up to our local neighbourhood.

PROGRAM

- 1. Evolution of low and intermediate mass stars. The equations of stellar structure. Energy sources and energy transport. The main sequence, RGB and AGB evolutionary phases. Mass loss. Nucleosynthesis. Initial-final mass relationship. Comparisons with observations. Rotation and non- standard mixing processes.

- **2. Massive stars and core collapse supernovae.** Central H and He combustion. Advanced nuclear combustion phases: neutrino losses, statistical nuclear equilibrium and neutronization. Gravitational collapse and explosion mechanisms. *The mass-cut*. Nucleosynthesis. The role of mass loss and rotation.

- **3. Close binary systems: novae, thermonuclear supernovae and X-ray bursts.** Acretion on compact objects. Progenitors of thermonuclear supernovae. Explosions mechanisms and nucleosynthesis. Thermonuclear supernovae and cosmology. Novae, nucleosynthesis and *yields.*. X-ray bursts and associated nucleosynthesis.

- **4. Chemical evolution of the galaxies.** Diferential equations and main parameters. Analytical simple solutions. The IRA approximation. The G-dwarf problem. Migration. Multidimension approximations.

- **5. Star formation in galaxies.** The star formation rate in the Milky Way and other galaxies. HII regions: physical and chemical properties. Determination of chemical abundances in the insterstellar medium: methods. Chemo-dynamical evolution of galaxies.

- **6. Observational results and implications.** Abundance distribution of the elements in the local neighbourhood, Milky Way and distant galaxies. The history of the star formation rate. Chemical gradients in galaxies. Chemical evolution of galaxies within the evolution of the Universe.

BIBLIOGRAPHY

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- Kippenhahn, R. Weigert, A. (1990): Stellar structure ans evolution. A&A Library
- Hansen, C.J., Kawalet S.D., Trimble V. (2005) Stellar Interiors: Physical Principles, Structure and Evolution. Springer Verlag, 2nd edition
- Maeder, A. (2009): Physics, formation and evolution of rotating strs. A&A library

- Pagel, B. E. J. Nucleosynthesis and Chemical Evolution of the Galaxies, Cambridge Eds. 1997
- Sparke, L. S., Gallagher III, J.S.: Galaxies in the Universe: An introduction. Cambridge Eds. 2000
- Recchi, S. Chemodynamical Simulations of Dwarf Galaxy Evolution. Advances in Astronomy especial issue "Metals in 3D: A cosmic view form integral field spectroscopy", Iglesias-Paramo, Vilchez, Papaderos & Roth Eds. 2013.
- Osterbrock, D., Ferland, G., Astrophysics of Gaseous Nebulae and AGNs, CA: University Science Books, 2006

RECOMMENDED LINKS

- Digital Library portal for researchers in Astronomy and Physics
  http://adsabs.harvard.edu/abstract_service.html

- Models and nucleosynthesis of low and intermediate mass stars
  http://fruity.oa-teramo.inaf.it/

- Models and nucleosynthesis of massive stars
  http://www.iasf-roma.inaf.it/orfeo/public_html/

- Main properties of galaxies
  http://ned.ipac.caltech.edu/level5/