Introduction to the Fundamental Astrophysics Course

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This course is part of the Master 2:
Physique Théorique et Mathématique, Physique des Particules et Astrophysique

Cours de septembre à décembre :

Physique Théorique et Mathématique, Physique des Particules et Astrophysique (Master M2 - P3TMA)

Version mise à jour des intervenants (26/11/2012):

Septembre à décembre: September → December		Intervenants	
Cours sur les méthodes mathématiques pour la physique (3 ECTS - 30h)			
Méthodes Mathématiques et Théorie des Groupes	CMN1	O. Ogievetsky	
Méthodes Mathématiques et statistiques pour la physique	CMN2	J.-P. Ernenwein (14h)	C. Schimd (16h)
Cours fondamentaux (6 ECTS - 40h: 32h cours + 8h TD)			
Astrophysique fondamentale	CF1	P. Amram	D. Burgarella
Cosmologie relativiste	CF2	C. Marinoni	
Mécanique quantique avancée	CF3	J. Asch**	P. Briet**
Mécanique statistique	CF4	T. Martin	
Phénomènes non linéaires: systèmes dynamiques et chaos	CF5	S Vaienti**	M. Pettini
Physique des particules	CF6	M. Talby	
Relativité Générale	CF7	T. Schücker	
Théorie des champs quantiques relativistes	CF8	L. Lellouch*	

Parcours *'Astrophysics & Cosmology'*

Cours de janvier à février :

Janvier à Février: January - February			
Programmation en informatique pour la physique (3 ECTS - 26h + stage)			
Cours + Projet informatique	CMN3	A. Crepieux	J. Brunner* (IR)
Cours de spécialité et d'option (3 ECTS - 20h)			
Parcours théorie (CPT)			
Chaos hamiltonien, transport et physique des plasmas	CS1	X. Leoncini	
Dynamique Hamiltonienne et mécanique statistique	CS2	M. Pettini	
Géométrie et théorie de jauge	CS3	S. Lazzarini	
Introduction à la thématique des réseaux complexes	CS4	A. Barrat*	
Le Modèle Standard de la physique des particules	CS5	T. Krajewski	
Physique des trous noirs	CS6	A. Perez	
Théorie quantique des champs avancée	CS7	M. Knecht*	
Théorie quantique du solide	CS8	T. Martin	
Parcours physique des particules (CPPM)			
Astroparticules	CS9	J. Busto	H. Costantini
Physique des particules expérimentale et tests du Modèle Standard	CS10	J.-P. Ernenwein	A. Duperrin* (8h)
Recherches de nouvelle physique et physique des neutrinos	CS11	J. Busto	L. Vacavant* (12h)
Parcours astrophysique et cosmologie (LAM)			
Physique des galaxies	CS12	V. Buat	O. Ilbert (CNAP)
Physique des structures cosmiques	CS13	A. Cattaneo	C. Adami
Physique des systèmes planétaires, exoplanètes	CS14	M. Deleuil	P. Barge (CNAP)
Cosmologie physique	CS15	C. Schimd	S. Escoffier

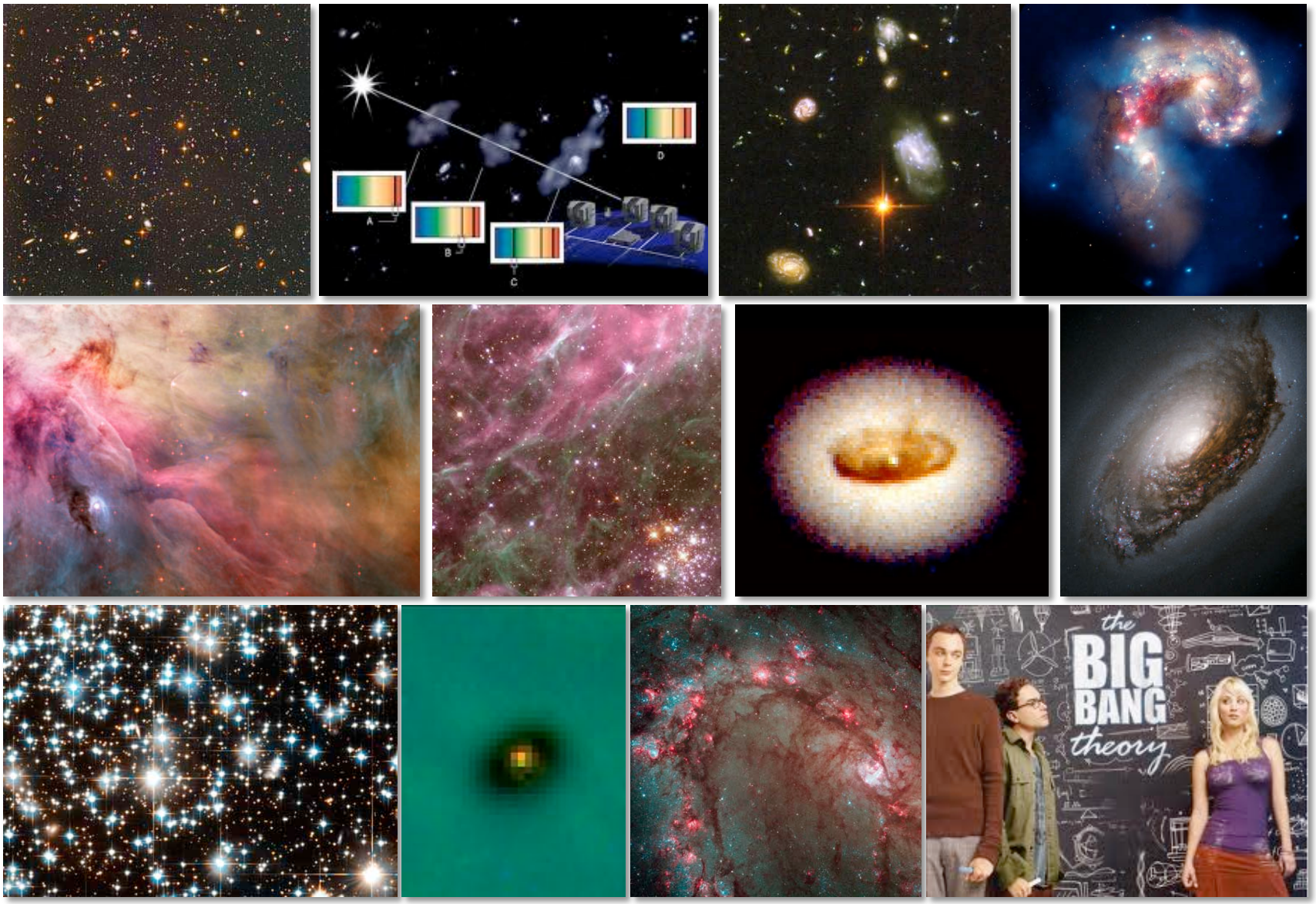
Report on
How many new PhD thesis in 2013

- **11 new PhD thesis will start in LAM in Sept./Oct. 2013**
- **Various origins for fundings: CNES-INSU, ED352, LabEx OceVu, ESO, IAC-INSU grant, embassies, internal resources and ERC.**
- **The LAM science council will meet in October 2013 to prepare the next campaign and annoucements for next year.**

Fundamental Astrophysics

- *Fundamental Astrophysics* is meant to bring you the basics or fundamentals to understand the main (astro)physical phenomena in the Universe at all scales from the largest (Universe itself) to the smallest (Stars)
- *Warning:* in case you wish to study the Pre-Big-Bang era, this course might no be perfectly suited to your goals...

Illustrations



Quick Summary of the Course

- InterGalactic Medium
- Interstellar Medium
- Star Formation
- Stellar Evolution
- Stellar Structure
- Stars, Gas & Dust in Galaxies
- Stellar Death

Being more specific … the IGM

- The InterGalactic Medium (IGM) is a sparse gas that extends between the galaxies of the universe.
- It takes on a cosmic filamentary structure, with thin wisps and walls separating vast void areas.
- The intergalactic medium connects galaxies together.
- The average density of the universe as a whole is about one hydrogen atom per cubic meter, with the intergalactic medium having about 10 to 100 atoms per cubic meter.

Being more specific … the ISM

- The interstellar medium (ISM) is the material that fills the space between the stars.
- The interstellar regions are have very low densities and consist mainly of gas (99%) and dust.
- In total, approximately 15% of the visible matter in the Milky Way is composed of interstellar gas and dust.
- Of the gas in the Milky Way, 90% by mass is hydrogen, with the remainder mostly helium.
- This gas appears primarily in two forms:
  - cold clouds of atomic or molecular hydrogen
  - Hot ionized hydrogen near hot young stars
- The clouds of cold molecular and atomic hydrogen represent the raw material from which stars can be formed in the disk of the galaxy if they become gravitationally unstable and collapse.

Being more specific … Star Formation

- Star formation is the process by which dense regions within molecular clouds in interstellar space, commonly referred to as "stellar nurseries", collapse into spheres of plasma to form stars.
- As a branch of astronomy star formation includes the study of the interstellar medium and giant molecular clouds (GMC) as precursors to the star formation process and the study of young stellar objects and planet formation as its immediate products.
- Star formation theory, as well as accounting for the formation of stars today but also at high redshift and, ultimately, for the first generation of stars.

Being more specific … Stellar Evolution

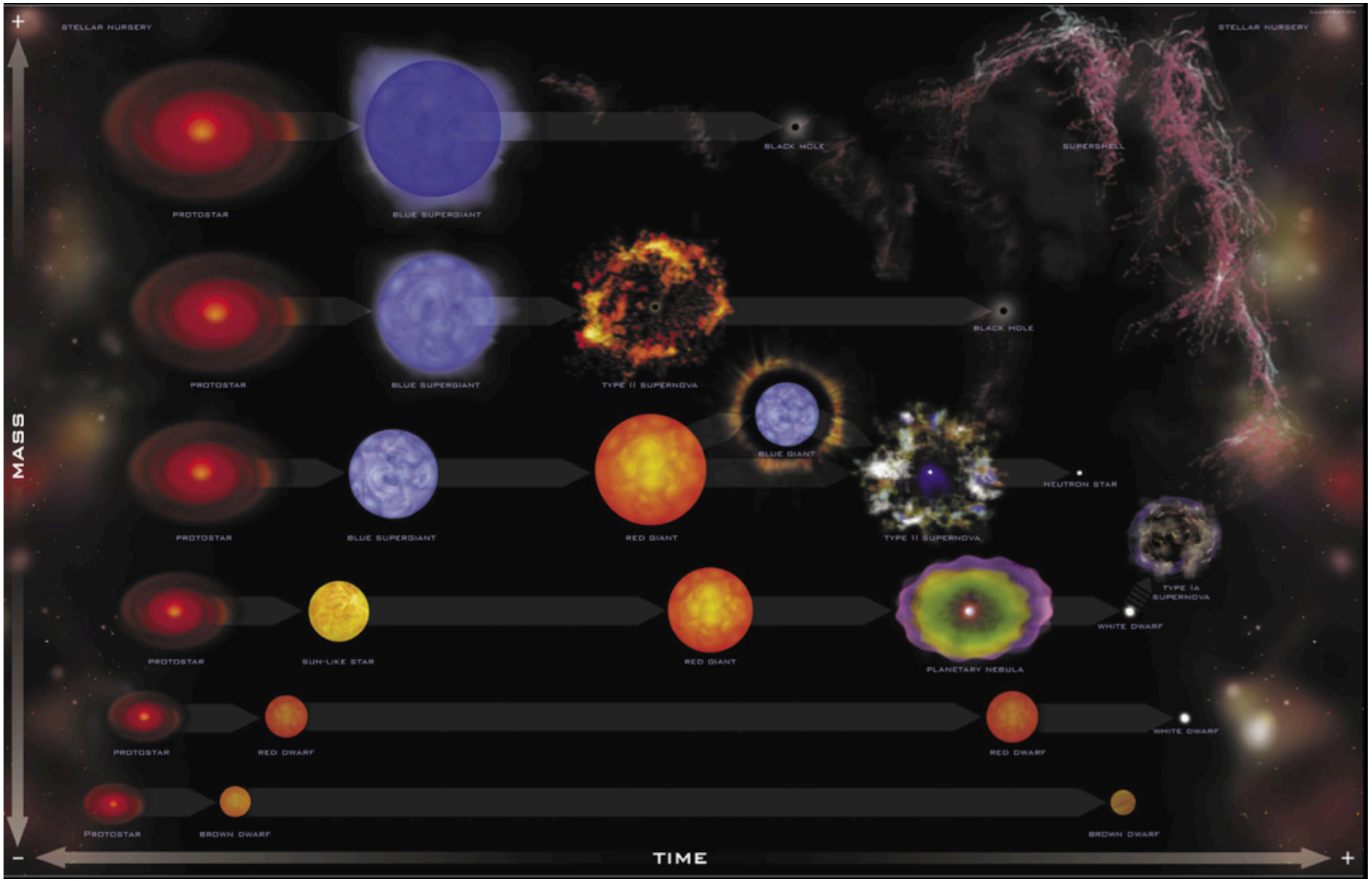
- Stellar evolution is the process by which a star undergoes a sequence of radical changes during its lifetime.
- Depending on the mass of the star, this lifetime ranges from only a few million years for the most massive to trillions of years for the least massive, which is considerably longer than the age of the universe.
- All stars are born from collapsing clouds of gas and dust, often called nebulae or molecular clouds.
- Over the course of millions of years, these protostars settle down into a state of equilibrium, becoming what is known as a main sequence star.

Being more specific … Stellar Stucture

- Stars of different mass and age have varying internal structures.
- Stellar structure models describe the internal structure of a star in detail and make detailed predictions about the luminosity, the color and the future evolution of the star.
- The simplest commonly used model of stellar structure is the spherically symmetric quasi-static model, which assumes that a star is in a steady state and that it is spherically symmetric.
- It contains four basic first-order differential equations:
  - two represent how matter and pressure vary with radius
  - two represent how temperature and luminosity vary with radius.

Being more specific … Stars, Gas & dust in Galaxies

- Understanding galaxy formation and evolution is at the heart of modern astronomy.
- Central to that goal is the necessity to improve our understanding of star formation, and thus the evolution of the interstellar medium (ISM) of galaxies.
- This requires an understanding of phenomena spanning vast spatial scales, which must be gained through observations across the electromagnetic spectrum as well as state-of-the-art numerical simulations.
- One therefore needs to focus on:
  - the detailed properties of the molecular clouds where stars are born,
  - the fuel and tracers of star formation,
  - the quantification of star formation,
  - its effects on galaxy evolution.
- Implicit to this quest will be the use of physical and chemical diagnostics exploiting the latest telescopes on the ground or in space.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STELLAR NURSERY
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PROTOSTAR
BLUE SUPERGIANT
BLACK HOLE
SUPERSHELL
PROTOSTAR
BLUE SUPERGIANT
TYPE II SUPERNOVA
BLACK HOLE
MASS
PROTOSTAR
BLUE SUPERGIANT
RED GIANT
BLUE GIANT
NEUTRON STAR
TYPE II SUPERNOVA
PROTOSTAR
SUN-LIKE STAR
RED GIANT
PLANETARY NEBULA
TYPE Ia SUPERNOVA
WHITE DWARF
PROTOSTAR
RED DWARF
RED DWARF
WHITE DWARF
PROTOSTAR
BROWN DWARF
BROWN DWARF
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TIME
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Being more specific … Stellar Death

In addition to the stellar evolution point of view, stellar death have important implications on several astrophysical fields:

- Cosmological Standard Candles SNIa that allow to constrain the cosmology
- Supernovae throw much of the material from their parent star back out into the interstellar medium, changing its chemical composition. This adds many elements to the interstellar medium which were not present before, or were only present in trace amounts. This is especially true for all element heavier than iron.

Preliminary Agenda of the Course

Day	Date	Time	Who
~~Thursday~~	~~Sept. 13~~	~~9h00-12h00~~	~~Ph. Amram~~
~~Tuesday~~	~~Sept. 12~~	~~9h00-12h00~~	~~Ph. Amram~~
~~Tuesday~~	~~Sept. 24~~	~~9h00-12h00~~	~~D. Burgarella~~
Tuesday	Oct. 01	9h00-12h00	D. Burgarella
Tuesday	Oct. 08	9h00-12h00	D. Burgarella
Tuesday	Oct. 15	9h00-12h00	Ph. Amram
Tuesday	Oct. 22	9h00-12h00	D. Burgarella
Tuesday	Oct. 29	9h00-12h00	D. Burgarella
Tuesday	Nov. 05	9h00-12h00	Ph. Amram
Tuesday	Nov. 12	9h00-12h00	Ph. Amram
Tuesday	Nov. 19	9h00-12h00	Ph. Amram
Tuesday	Nov. 26	9h00-11h00	Ph. Amram
Tuesday	Dec 03	9h30-12h00	D. Burgarella
Tuesday	Dec 10	9h00-11h00	D. Burgarella

Reminder

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End of the Introduction