

# *Ecole doctorale Astronomie & Astrophysique d'Ile-de-France* (ED127)

OBSERVATOIRE DE PARIS (SIEGE DE L'ECOLE DOCTORALE)  
UNIVERSITES PIERRE-ET-MARIE-CURIE (PARIS VI),  
DENIS-DIDEROT (PARIS VII), PARIS SUD XI (ORSAY),  
VERSAILLES-ST QUENTIN

&

PARTENARIATS: ECOLE NORMALE SUPÉRIEURE (ULM)  
ECOLE NATIONALE DES SCIENCES GÉOGRAPHIQUES  
DIRECTION DES SCIENCES DE LA MATIERE (CEA)

## *Doctoral lectures/ Cours Doctoral-2022*

*for PhD students, post-docs, and all interested*

*Registration required to [ed127.formations@ias.u-psud.fr](mailto:ed127.formations@ias.u-psud.fr)*

*Site : Institut d'Astrophysique de Paris (IAP).*

*DATES : 2022 May 30-June 3, Virtual (+ PhD exercises @IAP if possible)*

### *Distant $z>4$ galaxies: Observations and models, up to dark ages* *Galaxies Lointaines à $z>4$ : Observations et modèles, jusqu'aux âges sombres*

**Proposed by**

**on Observations by Dr François Hammer (Obs.Paris) [francois.hammer@obspm.fr](mailto:francois.hammer@obspm.fr)**

**on Models by Prof Brigitte Rocca-Volmerange (IAP & U. Paris-Saclay) [brigitte.rocca@iap.fr](mailto:brigitte.rocca@iap.fr)**

#### **Summary :**

Distant Galaxies ( $z>4$ ) are keys to galaxy formation and epoch, re-ionization of the universe, galaxy environments (DM haloes, clusters, IGM,..), up to the primeval fluctuations (Nobel Prizes 2006, 1978) as clarifying their star formation histories as their links with AGN/quasars,  $\gamma$ -ray-bursts,... The future UV-to-farIR-submm observations of individual sources as populations from deep large surveys, extended to the whole ElectroMagnetic and Gravity Wave domains, are fascinating perspectives of the future telescopes. Models (semi-empirical) based on basic physics laws are needed for their interpretations as well to improve the coherency of their results with numerical simulations as machine-learning modeling (not discussed here).

The present lectures propose reviews, talks, exercises and discussions to help the young researchers, as PhD students, postdocs or others, for their future orientation (research or others?) and to complete their general galaxy backgrounds.

1. *General principles on stellar mass growth, evolution of metals and dust, distance effects with basic dynamics*
2. *Future observations with the perspectives of JWST, Euclid and e-ELT (sensitivity, resolutions)*
3. *Models of spectro-photometrical evolution (SED, magnitudes, colors, mass, distance/z, environments).*

**Résumé:** Les galaxies lointaines à  $z>4$  sont essentielles pour découvrir la physique et l'époque de leur formation, la ré-ionisation de l'Univers et les effets d'environnements (halos de matière sombre, amas de galaxies) jusqu'aux fluctuations primordiales, mais aussi leurs liens avec les noyaux actifs de galaxies et quasars ou les sursauts  $\gamma$ , et même les ondes gravitationnelles. Les futures observations (sources individuelles et relevés profonds et larges) seront multiples avec les futurs télescopes, de l'UV à l'IR/submm, étendu rayons X et à l'émission synchrotron. Les modèles (semi-empiriques ou simulations numériques), limités à  $z=6$  et incompatibles entre eux, nécessitent de nouveaux experts en urgence. Les simulations numériques (une expertise spécifique) ne seront pas discutées ici.

Le programme (talks, exercises) est :

1. Principes généraux sur la croissance de la masse stellaire, l'évolution des métaux et de la poussière, les distances.
2. Les observations actuelles dans la perspective des télescopes JWST, Euclid et e-ELT
3. L'évolution spectrale et photométrique (SED, magnitudes, couleurs et masses, distance/z et environnement.

\*) "*Studying Distant Galaxies: Methods and Analyses*" Hammer et al. , <https://arxiv.org/abs/1701.03794>  
ou <http://www.worldscientific.com/worldscibooks/10.1142/q0016>

\*\*\*) *Code Pégase.3 (Fioc & Rocca-Volmerange 2019, A&A) et arXiv 2019 documentation*  
[www.iap.fr/users/fioc/Pegase/Pegase.3](http://www.iap.fr/users/fioc/Pegase/Pegase.3)

## Lundi/Monday, IAP, May 30, 2022

### **9h30-12h30 Morphology and basic kinematics: distant galaxies**

Kinematics spatially solved by field integrals. Morpho-kinematics classification. mergers versus rotating disks & The Tully-Fisher relation), **Francois Hammer, Astronome, Observatoire de Paris**  
lunch

**14h00-15h15 The UV-farIR spectrophotometric evolution of galaxies with code PEGASE.3** (Versions Python and Fortran95) Evolution parameters: SFR, gas, stars, SN, stellar BH, metals, dust, attenuation/emission), **Michel Fioc, IAP, Assistant-Professor Sorbonne U.**

**15h30 -17h30 TP 1:** Initiation to code Pégase: SED, colours, scenarii, **Pégase members**

## Mardi/Tuesday, IAP, May 31, 2022

**9h30-10h30 Reference templates by types** (spiral/elliptical/burst)

**10h30-11h30 Distance/age effects-Cosmology**

**Brigitte Rocca-Volmerange, IAP & Prof. U. Paris-Saclay**

**11h45-12h45 Photometric redshifts (ZPeg)**

**Damien Le Borgne, IAP, Assistant Professor Sorbonne U. (tbc)**

lunch

**14h00 -17h30 TP 2 Spectroscopy/Photometry of distant galaxies Pégase members**

## Mercredi/Wednesday, IAP, June 1, 2022

**9h30-10h45 Properties and evolution of grains in the Universe Frédéric Galliano , CEA**  
break

**11h00-12h00 Polarized dust foregrounds from Planck2018, Karim Benabed, IAP,(tbc)**

**12h-13h Optically invisible galaxies in the early universe, David Elbaz, CEA**

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Lunch, free afternoon

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## Jeudi/Thursday, IAP, June 2, 2022

**9h30-11h15 Large SURVEYS , galaxy selections :** CANDELS, VUDS, 3D-HST.

Luminosity and Mass functions, SED and multi- $\lambda$  photometry and star formation rate **Francois Hammer**  
break

**11h30-12h30: Extremely deep multi- $\lambda$  imaging surveys Pascal Oesch, Geneva U. (tbc)**  
lunch

**14h00-15h30 Performances of MUSE and the future blue MUSE on high-z galaxies,**  
**Johan Richard, CRAL, Obs. Lyon**

**15h30-16h45 High-z Galaxies in absorption Pasquier Noterdaeme Astronome, IAP**

## Vendredi/Friday, IAP, June 3, 2022

**9h30- 10h30 Galaxies and AGN, N. Nesvadba Obs Nice ,**

**10h45-12h45: TP3 Finalization and summary of Exercises, Pegase Members**  
lunch

**14h00-15h15 Photometric Accuracy for distant sources, Nathan Secrest, (tbc)**

**15h15-16h15 Star formation and turbulence, Pierre Guillard, IAP, Sorbonne U.**

**16h30-17h30 Galaxies vs GRB/Gravitationnal waves Frédéric Daigne/Irina Dvorkin, IAP**

**17h30-18h00 Discussion and conclusion,**