SORBONNE UNIVERSITÉ

PROGRAMME INSTITUTS ET INITIATIVES

Appel à projet – campagne 2021

Proposition de projet de recherche doctoral (PRD)

Intitulé du projet de recherche doctoral (PRD):

Understanding Galaxy Evolution by the Intermittence of their Histories of Star Formation and Black Hole Growth

Directeur.rice de thèse porteur.euse du projet (titulaire d'une HDR) :

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Unité de Recherche :

Intitulé : Institut d'Astrophysique de Paris

Code *(ex. UMR xxxx)* : UMR 7095

École Doctorale de rattachement de l'équipe (future école doctorale du.de la doctorant.e) ED 127

Doctorant.e.s actuellement encadré.e.s par la.e directeur.rice de thèse (préciser le nombre de doctorant.e.s, leur année de 1e inscription et la quotité d'encadrement) : Eduardo Vitral, 2019-2022

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Co-encadrant.e :

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Unité de Recherche :

Intitulé : Laboratoire d'Etudes du Rayonnement et de la Matière en Astrophysique et Atmosphères (LERMA)

Code *(ex. UMR xxxx)* : UMR 8112

École Doctorale de rattachement : ED 127

Doctorant.e.s actuellement encadré.e.s par la.e co-directeur.rice de thèse (préciser le nombre de doctorant.e.s, leur année de 1e inscription et la quotité d'encadrement) :

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Unité de Recherche :

Intitulé : Institut d'Astrophysique de Paris

Code *(ex. UMR xxxx)* : UMR 7095

École Doctorale de rattachement :

Ou si ED non Alliance SU :

Doctorant.e.s actuellement encadré.e.s par la.e co-directeur.rice de thèse (préciser le nombre de doctorant.e.s, leur année de 1e inscription et la quotité d'encadrement) :

Cotutelle internationale : Non

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Selon vous, ce projet est-il susceptible d'intéresser une autre Initiative ou un autre Institut ?

Oui

Description du projet de recherche doctoral *(en français ou en anglais) :*

Ce texte sera diffusé en ligne : il ne doit pas excéder 3 pages et est écrit en interligne simple.

Détailler le contexte, l'objectif scientifique, la justification de l'approche scientifique ainsi que l'adéquation à l'initiative/l'Institut.

Le cas échéant, préciser le rôle de chaque encadrant ainsi que les compétences scientifiques apportées. Indiquer les publications/productions des encadrants en lien avec le projet.
Préciser le profil d'étudiant(e) recherché.

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Context: Stars are observed to form in Giant Molecular Clouds in the disks of galaxies. Some of the gas in these clouds is consumed by star formation (SF), but is replenished by the infall of external gas. The SF can be suppressed (quenched) if this infall is prevented by the environment or if the disk gas is expelled by stellar explosions (supernovae) or by powerful outflows from central supermassive black holes (AGN), with a recent consensus that AGN regulate and quench the SF in massive galaxies. The life of a galaxy can be resumed in the buildup of its stellar mass (summed over the galaxies that previously merged into the present one), which is directly related to its star formation history (SFH). Galaxy SFHs can be roughly estimated from their spectral energy distributions (SEDs) derived from broad-band magnitudes or extracted more precisely from their spectra. These approximate SFHs confirm that currently massive galaxies tend to be passive and formed the bulk of their stars at early times, while star formation in lower mass galaxies tends to be more spread out in time and presently ongoing.

Motivations: But the details behind this picture are uncertain. Which galaxies enjoy a continuous SFH and which go through a small number of bursts of SF, i.e. does the intermittence of SFH depend only on final stellar mass and SF class, or also on environment and other factors? Which present-day galaxy properties depend on the intermittence of their SFH? In particular, do the cuspy vs. cored inner distributions of dark matter in galaxies simply reflect continuous vs. bursty SFHs or black hole growth histories? Can current codes or new ones understand these questions by performing galactic archeology with an accurate extraction of SFHs from the combination of optical spectra and SEDs of galaxies in the local Universe? What are the physical processes related to the answers to these questions? More generally, do low- mass satellites quench their SF when their gas is removed by the ram pressure from the hot gas of their environment or could internal processes such as supernovae as well as AGN play a major role? Why do the few (~1%) very young galaxies in the local Universe form the bulk of their stars in the last billion years and not earlier?

Methods: Luckily, our understanding of galaxy histories can be improved thanks to new much more realistic hydrodynamical simulations of large portions of the Universe with cosmological initial conditions (e.g. ILLUSTRIS-TNG and NewHorizon), as well as more focussed zoom-in simulations (e.g. NIHAO), all of which are the first large such simulations to resolve the thin disks of galaxies and capture the essential evolution of galaxies. The student will analyze the outputs of these simulations, extract the SFHs and black hole growth histories, and study how their intermittence affects the observed properties of present-day galaxies. The student will then analyze the physical processes at work related to the questions above, by digging deeper into the simulation outputs and by physical modeling.

Strengths of supervisors & laboratories:

Gary Mamon (IAP - Sorbonne Université) is a world expert in both dynamical modeling and galaxy formation and evolution. Concerning the proposed thesis topic, he has developed simple analytical models for galaxy merger rates and tidal stripping (Mamon 1992, 2000; Gonzalez-Casado, Mamon & Salvador-Solé 1994). He supervised a postdoc on predicting the fraction of very young galaxies in the present-day universe, as a function of their current stellar mass (Tweed et al. 2018), and measured the same from the star formation histories extracted from the spectra of 400 thousand galaxies (Mamon et al. 2020). With former postdoc E. Tollet, he is finishing a study of galaxy evolution in clusters in the Horizon hydrodynamical simulations, and supervised with J. Silk the recent theses of R. Bieri and G. Dashyan on AGN feedback from hydrodynamical simulations (Bieri et al. 2015, 2016, 2017) and analytical modeling (Dashyan, Silk, Mamon et al. 2018).

Andrea Cattaneo (Observatoire de Paris / LERMA) is a leader in physical modeling of galaxy formation and evolution. With A. Dekel he explained galaxy bimodality and downsizing from a simple model of a threshold in maximum galaxy mass (Cattaneo et al. 2006, 2008). He wrote an influential review on the role of black holes on galaxy formation and evolution (Cattaneo et al. 2009, *Nature*). With G. Mamon, he developed a simple galaxy formation model to make the first precise prediction of the role of mergers in the growth of galaxy stellar mass (Cattaneo et al. 2011). With student E. Tollet, he analyzed the NIHAO hydrodynamical simulations to quantify the role of supernova explosions in the galaxy baryons cycle (Tollet et al. 2019).

Joseph Silk (IAP & Johns Hopkins) is an undisputed leader in galaxy formation and evolution. He pioneered the role of supernovae in the evolution of dwarf galaxies (Dekel & Silk 1986) and that of AGN in high-mass galaxies (Silk & Rees 1998). After launching these ideas, he showed their limits, by establishing the importance of positive feedback from AGN (Silk 2013) and the unexpected role of AGN in dwarf galaxy evolution (Silk 2017). He wrote many reviews on galaxy formation (the most notable being Silk & Mamon 2012). He has been awarded many prestigious prizes, among which the Gold medal of the Royal Astronomical Society (2008), the Henry Norris Russel Lectureship of the American Astronomical Society (2018) and the Gruber Prize in Cosmology (2019).

The **Institut d'Astrophysique de Paris** hosts one of the strongest collection of world experts in galaxy formation and evolution, with hydrodynamical simulations (Dubois & Pichon), spectral synthesis codes (Charlot, Fioc, Le Borgne & Rocca-Volmerange), black holes (Dvorkin & Volonteri) and thirteen other internationally-renown permanent faculty and staff working in this field.

Keywords: galaxies, galaxy evolution, groups and clusters of galaxies, star formation, black holes, hydrodynamical simulations, dark matter

National collaborations

* Yohan Dubois (CNRS scientist, IAP)

* Jonathan Freundlich (Postdoc, Strasbourg)

* Sebastien Peirani (CNRS scientist, OCA, Nice)

International collaborations

* Avishai Dekel (Professor, Hebrew University, Jerusalem, Israel)

* Mojtaba Raouf (Postdoc, KASI, Daejeon, South Korea)

* Justin Read (Professor, Univ. of Surrey, UK)

* Marina Trevisan (Professor, UFRGS, Porto Alegre, Brazil)

Bibliographic references

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Mahajan, Mamon & Raychaudhury 2011, *The velocity modulation of galaxy properties in and near clusters: quantifying the decrease in star formation in backsplash galaxies*, MNRAS 416, 2882, https://ui.adsabs.harvard.edu/abs/2011MNRAS.416.2882M

Mamon, Trevisan, Thuan et al. 2020, *The frequency of very young galaxies in the local Universe - II. The view from SDSS spectra*, MNRAS 492, 1791, https://ui.adsabs.harvard.edu/abs/2020MNRAS.492.1791M

Pontzen & Governato 2012, *How supernova feedback turns dark matter cusps into cores*, MNRAS 421, 3464, https://ui.adsabs.harvard.edu/abs/2012MNRAS.421.3464P

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Wetzel, Tinker & Conroy 2012, *Galaxy evolution in groups and clusters: star formation rates, red sequence fractions and the persistent bimodality*, MNRAS 424, 232, https://ui.adsabs.harvard.edu/abs/2012MNRAS.424..232W

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cd_instituts_et_initiatives@listes.upmc.fr avant le 20 février.