MSFR Research Training Network

Contributions from Observatoire Astronomique de Marseille-Provence

1 Applicants

List of Senior Staff at OAMP, co-signing this proposal

- **Alessandro Boselli**
  Multifrequency analysis of star-forming galaxies, Statistics of star forming galaxy populations
  Percentage of research time to be invested : **30%**
- **Véronique Buat**
  Multifrequency analysis of star-forming galaxies, Dust obscuration in star forming galaxies
  Percentage of research time to be invested : **10%**
- **Denis Burgarella**
  Relationship between galactic winds, Lyman alpha emission and Lyman continuum escape
  Percentage of research time to be invested : **30%**
- **Lise Deharveng**
  HII regions, dust, formation of massive stars
  Percentage of research time to be invested : **20%**
- **Jean-Michel Deharveng**
  Relationship between galactic winds, Lyman alpha emission and Lyman continuum escape
  Percentage of research time to be invested : **20%**
- **Bruno Milliard** *Statistics of star forming galaxy populations, Tracers of star formation, UV imaging and spectroscopy*
  Percentage of research time to be invested : **30%**

- **Laurence Tresse**
  Tracers of star formation, Statistics of star forming galaxy populations, Optical spectroscopy, Halpha emission
  Percentage of research time to be invested : **20%**

- **Marie Treyer**
  Tracers of star formation, Multifrequency analysis of star-forming galaxies,Statistics of star forming galaxy populations
  Percentage of research time to be invested : **20%**

- **Annie Zavagno**
  HII regions, dust, formation of massive stars
  Percentage of research time to be invested : **20%**

List of postdocs, working in the field of the RTN:

- **Jean-Claude Bouret**
  Physics of massive stars, stellar winds and spectral synthesis
  Percentage of research time to be invested : **50%**

- **Jorge Iglesias-Paramo**
  Multifrequency analysis of star-forming galaxies, Statistics of star forming galaxy populations
  Percentage of research time to be invested : **30%**

List of relevant publications :

- Bouret et a., 2003, ApJ (in press), astro-ph/0302207
- Deharveng L., Zavagno A. et al., 2003, A&A, 399, 1135
- Buat V., Boselli A., et al., 2002, A&A, 383, 801
- Gavazzi G., Boselli A., et al., 2002, A&A, 396, 449
- Tresse et al., 2002, MNRAS, 337, 369

2 Project Objectives

The expertise offered at the Observatoire Astronomique Marseille-Provence includes several themes covered by the RTN "Violent Star Formation". In this section, we provide detailed abstracts of those which will be worked on in the framework of the MSFR network.

2.1 Understanding massive star formation in HII regions

The physical processes leading to the formation of massive stars are still poorly understood. Such stars are often found at the centres of dense clusters, where the high star and/or gas density seems to favour the formation of massive objects, either by coalescence of intermediate mass protostars or by accretion. Our research is focussed on systematic studies of galactic HII regions and young stellar clusters to test these scenarii. This work is based on various observational techniques, from imaging and photometry to spectroscopy, at several wavelengths, and involves both ground (CFHT, ESO, IRAM, etc...) and space (ISO) instruments. We concentrate particularly on the stellar content of star forming regions as well as the evolutionary status of the observed sources, the star formation efficiency and the IMF.

We now plan to focuss our research on sequential star formation as observed at the periphery of HII regions and triggered by the expansion of the ionized material. Models show that the compressed layer of shocked dense neutral material surrounding an HII region may become gravitationally unstable and fragment, this process leading to the formation of massive objects, stars or clusters. We are involved in a systematic search for and study of such clusters found around HII regions. It is true that this process of 'sequential star formation' is in a way the opposite of 'violent star formation'. However, understanding of the former process should lead to a better understanding of the latter.

Finally, we'll study the consequences of massive star formation on the evolution of their surrounding medium: photo-ionization of the interstellar medium, shocks propagating star formation throughout the initial molecular cloud, dust distribution and properties in HII regions, etc...

Progress on these topics will benefit from collaborations with other network nodes specialized in star formation processes (IoA, St-Andrews and Sheffield) and stellar evolution, such as the Geneva group (ongoing collaboration with D. Schaerer).

2.2 Towards Understanding Massive Stars in Star-Forming Galaxies

Aside from the pure stellar physics point of view, massive stars also play a pivotal role in the starburst problem, because the prime diagnostic of the star formation rate - the UV flux or (indirectly) the H-ionizing flux - are produced almost exclusively by young, massive stars. We are therefore engaged in a project aimed at understanding the physics and evolution of massive stars, in various environments (essentially different metallicities). The adopted approach is to progress from individual stars in starbursts, to super star clusters in local galaxies and finally to high-redshift galaxies with extra-ordinary star formation rate. This is achieved through the analysis and modelling of FUSE, HST and ESO or AAT spectra of massive stars and starbursts. In this way, we can test and validate the stellar physics before going on to the next step. This approach allows us to better understand the influence of stellar properties - rotation, surface abundances, clumping in the wind, shock-generated X-rays and their effects on the ionization structure of the wind - on the stellar spectra. This also helps us towards or mail goal which is to derive the physical properties of local starbursts from their UV spectra. Understanding these objects is important since starburst galaxies seem to be the closest analogues to high-Z galaxies.

Our expertise essentially concerns the modelling of stellar atmospheres and winds and the computation of synthetic stellar spectra. We have very powerful tools at our disposal, including state-of-the-art codes that we have modified and refined for our own purposes. These codes are used to model spectra obtained on a great variety of instruments, ESO/UVES, HST/STIS, FUSE, in order to determine the fundamental parameters and properties of massive stars in a number of clusters including NGC 346 (SMC), R136a (LMC), NGC 3603 (Milky Way). More recently, we have used these codes to model the nebular emission of tens of galactic HII regions observed with ISO, which, among other results, allowed us to place contraints on the EUV flux distribution of the synthetic spectra.

In the framework of the RTN, we propose to collaborate to the development of a new code whose purpose would be to generate synthetic integrated spectra of starbursts galaxies. To construct a model of the UV spectrum of a galaxy with active star formation, representative stellar spectra are needed from all regions of the HR diagram that contribute significantly to the UV flux. In practice, we will never get spectra of stars at all masses, ages, compositions, and rotation rates. We therefore have to use refined stellar models (both evolutionary models and spectral synthesis models) to explore unobserved domains theoretically. We are therefore computing extensive grids of stellar spectra, covering the whole OB domain, for different metallicities, representative of the conditions prevailing in galaxies at different redshifts.

For all these topics, collaborations with the Geneva (D. Schaerer & G. Meynet), Sheffield and U.C.L nodes (P. Crowther, L. Smith) are expected. Arguably, this part of the network will play a dominant role in the field because of the very high complementarity of our expertises.

2.3 Star formation history in galaxies

The Star Formation Rate (SFR) in various locations and at different scales in the Universe is a crucial quantity for understanding the star formation process and its most extreme aspect, the Violent Star Formation.

There are three sub-topics for which we would like to enhance our present expertise through cooperation within the network and are expecting new data (ground-based IR imaging, multi-wavelength observations, multi-object spectroscopy in visible, UV GALEX survey).

1) At small scale (star cluster, sites of star formation) and at intermediate scale (spiral arms, bursting regions) there is a need to identify and quantify the physical parameters that, for a given quantity of gas, make the star formation process so variable in terms of efficiency.

2) The determination of the SFR is known to be hampered by the limited knowledge of a number of factors, such as dust extinction, IMF, history of star formation, environment, not to speak of uncertainties affecting the measurements of the various tracers. Multi-wavelength studies are essential to circumvent these difficulties; they provide intercomparison of various tracers and shed light on the respective systematics. The most crucially missing data are in the UV and the GALEX survey is expected to satisfy this need.

3) The time efficiency of star formation (duty cycle) is buried into the two previous items and deserve study on its own. The UV to Halpha flux ratio is a well recognized tool that may be supplemented by spectroscopy and abundance determinations.

2.4 Stellar and galactic winds

The stellar winds and galactic winds are important processes associated with Violent star formation; among other things, they provide kinetic energy into the interstellar medium, the galactic halo and the intergalactic medium, and play a role in the dispersion of metals into the cosmic web. They are at the heart of a general and important phenomenon refered to as feedback. The specific aspect we are interested in, which would benefit collaboration with nodes members, is the escape of Lyman emission favoured by the velocity of the neutral gas resulting from galactic winds and the escape of ionizing radiation through holes in the neutral gas distribution, also created by winds. In complement of existing data on Lyman break galaxies and data expected from spectroscopic surveys at high spectral resolution and at high redshift, the GALEX survey should provide the statistics of Lyman-alpha emitting galaxies that is missing at low redshift.

3 Research projects for PhD students and postdoctoral fellows

3.1 The violent star formation activity of cluster BCD galaxies

Advisors: A. Boselli (OAMP) & J.M. Vilchez (IAA-Granada)

In collaboration with J.M. Vilchez (IAA-Granada) and G. Gavazzi (Universita di Milano, Italy), we collected multifrequency data for 50% (30 galaxies) of the BCD brighter than M_B=-13 in the Virgo cluster. The dataset has a unique wavelength coverage, including Halpha, UBV, HK, ISOCAM 7-15 mic calibrated and fully reduced images, ISOPHOT 60-100-170 μ aperture photometry and 20 cm radio continuum data. Spectroscopic data relative to the most important visible emission (Hα, Hβ, [NII], [OIII], [OII], [SII]..) and absorbtion (underlying Hβ..) lines, as well as radio data of the atomic hydrogen (HI at 21 cm) and CO (2.6mm) are also available. 1500 and 2500 A images will be soon available from the GALEX survey.

We would like to use this unique set of data to study the present day and the history of star formation activity of cluster BCD galaxies and compare it to that of isolated objects of similar type in order to understand the role of the environment on the formation and evolution of these morphological class.

The present day star formation activity of these BCDs will be estimated from Hα and UV data, once corrected for dust extinction using the Balmer decrement and the UV/FIR flux ratio. These data, combined with optical and near-IR imaging data, tracing respectively the distribution of the intermediate and old stellar population, will be used to construct the stellar spectral energy distribution (SED) of the target galaxies.

By comparing the SED, the different present day star formation tracers and the atomic and molecular gas indicators (principal feeders of star formation) with the prediction of stellar population synthesis models, we will be able to reconstruct the pattern of the star formation activity of these cluster dwarf galaxies during their evolution with a unique accurate temporal resolution.

3.2 Lyman Alpha emission from galaxies

Advisors: D. Burgarella (OAMP) & D. Schaerer(Geneva Observatory)

We will observe two or three fields (HDFS, CDFS, AXAF) with GIRAFFE on VLT (PI : Denis Burgarella) to detect the Lyman alpha emission of starbursting galaxies in two redshift ranges around z=2.5 and z=3.5. The Lyman alpha line is produced during intense star formation phases and it will be an opportunity to detect galaxies undergoing violent star formation in the remote universe and compare it with starbursts in the nearby universe (connexion with the GALEX all-sky survey mission whose Denis Burgarella is a Science Team member). From each field we should harvest R 5000 spectra of about 50 galaxies. The objective is to try to detect and analyse the properties of the Lyman alpha emission from these galaxies. The originality of this program is that 1) we will use GIRAFFE in a high spectral resolution mode to study the line profile which contains a lot of information on the emission area and 2) we should have a large sample of ¿ 100 galaxies detected (conservatively assuming that 50% of galaxies show Lyman alpha in emission but recent works suggest that it could be more in the faint regime). Daniel Schaerer developped models for primordial galaxies (pop.III) for Lyman alpha and Lyman continuum that we will compare to these observations. These models cover metallicities from 0 to solar and are therefore adapted to the observations. Moreover, several population synthesis codes can be used by Daniel Schaerer

(Staburst99+), with the advantage of offering several results to compare with. Information at other wavelengths for these galaxies are available and they will be used to complete our analysis. In this context, a post-doc would cooperate and contribute significantly to the analysis of the data and their interpretation.

4 The Observatoire Astronomique de Marseille-Provence

The Observatoire Astronomique de Marseille-Provence (OAMP) is the largest public research institute in the Marseille region; it combines fundamental research in astronomy with technological research in instrumentation. OAMP has 45 researchers; 100 engineering, technical and administrative personnel; 12 thesis students and 7 postdocs. A number of OAMP staff (several node members) teach in the Marseille's universities and OAMP is also involved in a DEA (equivalent to a M.Sc.) on plasmas physics and astronomy.

Research at OAMP includes cosmology, galaxy evolution and stellar populations, massive stars formation and the interstellar medium, circumstellar disks and exoplanets, comets and the Sun. In addition, OAMP is involved (PI or Co-I) in several ground-based and space projects, like VLT/VIRMOS, FUSE, GALEX, HERSCHEL or COROT, to name a few. In the context of this RTN, FUSE and GALEX data are of special interest. Indeed FUSE gives access to unique informations on the SED star forming galaxies, which is known to be determined by the star formation history, initial mass function and dust extinction. Therefore, the far-UV observations of galaxies are of fundamental importance to understand the very recent star formation history in the universe and to interpret the spectra of high-z galaxies. Concerning GALEX, this satellite is entirely devoted to map the star formation history of the universe. The goal of the mission will be to produce several surveys and among them an all-sky map in two bands down to about mAB = 21 at an angular resolution of the order of 4-5 arcsecs. GALEX will investigate how star formation in galaxies evolved from the early Universe (80 percent of the way back to the Big Bang) up to the present. As a CoI of the GALEX mission, the team in OAMP will have prioritary access to GALEX data before their public release.

5 Management experience at Observatoire Astronomique de Marseille-Provence

Our institute has a large experience in managing large research project, especially concerning the design and development of instruments for national or international projects. These projects are managed in the framework of large consortia including, academic laboratories and industry, as well as national or international agencies (CNES, ESA, ESO, NASA, etc...); to name a few in the very last few years:

- Participation in GALEX (UV imaging and spectroscopy)
- Partipation in the VLT/VIRMOS Deep Survey (VVDS)
- Participation in HARPS at ESO (High Accuracy Radial velocity Planet Searcher)
- Participation in the EMIR (near-infrared JHK multi-object spectrograph for the Grantecan) building consortium

- Participation in HERSCHEL (imaging and spectroscopy from 60 to 600 microns)
- Participation in FUSE (Far UV Spectroscopic Explorer)

6 Computing facilities

All researchers, including PhD students have access to local computing resources, built thanks to subsidies from the aforementionned projects. In addition, the GRAPE cluster of the Dynamic of Galaxies team is also available for very specific use. At the prsent stage, this cluter is made of a handwired GRAPE-3A board coupled to a Sparc-10/412 (sustained speed 2 Glops), a set of five GRAPE-3AF boards coupled to an Ultra-2/200 (sustained speed 20 Gflops), a GRAPE-4 board coupled to an Alpha 500/500 box (sustained speed 28 Gflops), and six GRAPE-5 boards coupled to two coupled Compaq DS20's (231 Gflops in total).

7 List of ongoing collaborations with other members of the RTN

- A. Boselli:
  - Hensler, Gerhard: Giant outflows in Virgo cluster late-type galaxies: 1 paper submitted
  - Vilchez, Jose M.: SFR in different environments; SFR in BCD galaxies in the Virgo cluster: 6 papers in common
  - Boissier, Samuel: Comparison of 2D models of galaxy evolution with multilambda observables; Schmidt law in spiral galaxies; 2D models of dust extinction in late-type galaxy (now on GALEX data): 1 accepted paper + 1 submitted paper
  - Prantzos, Nicolas: Comparison of 2D models of galaxy evolution with multilambda observables; Schmidt law in spiral galaxies; 1 accepted paper + 1 submitted paper
  - Stasinska, Grazyna: Spectroscopic properties of late-type galaxies: 1 paper in preparation

- J.C. Bouret:
  - Schaerer, Daniel & Christophe Morisset: Mid-IR observations of galactic HII regions; modelling of the ionizing spectra of massive stars and study of the nature of the observed excitation sequences (1 paper submitted)
  - Smith, Linda: Quantitative spectroscopy of main-sequence O stars at low metallicity (1 published paper)

- D. Burgarella:
  - Schaerer, Daniel & Kunth, Daniel: Lyman Alpha emission galaxies

- L. Deharveng:
  - Heydari-Malayeri, Mohammad: Study of compact star forming regions in the LMC and SMC

- J. Iglesias:
  - Muñoz-Tunón, Casiana: Evolution of HII regions in spiral galaxies
  - Vilchez, Jose M.: SFR in different environments; SFR in BCD galaxies in the Virgo cluster

- L. Tresse:
  - Contini, Thierry: Low and high resolution spectroscopy on the VVDS