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Radio galaxies with Gaia

The starburst-AGN duality

B. Rocca-Volmerange

Institut d'Astrophysique de Paris, 98bis Bd Arago, 75014 Paris, France
e-mail: rocca@iap.fr

Abstract. Among thousands of AGNs, Gaia will detect radio galaxies with an unprecedented astrometry accuracy at a high statistical level. Signatures of star formation and nucleus in radio galaxies might be simultaneously detected by Gaia, allowing to find a possible link between these two activities. To show evidences of a possible coupling could have implication in cosmology and galaxy formation theories. The powerful radio galaxies discovered at the earliest epochs (z>4), get already high stellar mass (10^{12} $M_\odot$) and moreover are hosting supermassive black holes (10^9 $M_\odot$). They might be considered as nearly primeval galaxies. Finding such high masses when the Universe was only 1Gyr old, does not not favor the most popular model of galaxy evolution which would require a time-scale of about 10 Gyrs to form massive galaxies. So that Gaia will bring clues on the physics of galaxy evolution.

Key words. Galaxies: stellar populations – Galaxies:formation – Galaxies: evolution – AGN: Torus– Cosmology: baryonic mass

1. Introduction

Radio galaxies are the most luminous stellar populations observed at cosmological distances, amplified by the embedded active nucleus. At the earliest epochs of the universe (z>4), they are considered as primeval galaxies with surprising huge masses requiring a rapid baryonic mass accumulation process.

However they are sites of complex physics where coupled signatures of various processes are hard to disentangle. Past and present star formation, jet and accretion-disk emissions, feedback and dust absorption/emission, relation with environmental densities, all these processes require a complete coherent scenario of evolution making difficult the analysis of observations.

Simultaneously splendid numerical simulations of the 3D-Universe tentatively aim to reproduce the statistical observations of large galaxy surveys and structures. They are based on galaxy formation theories narrowly depending on the initial conditions and on the physics of galaxy formation and evolution. Following the initial famous CDM model (Blumenthal et al, 1986), most of these simulations are based on the popular hierarchical evolution scenario modulated by various versions of dark matter (warm, ΛCDM). However due to an unsufficient numerical resolution, unprecise initial conditions or inadequate physics of evolution,

Send offprint requests to: B. Rocca

models would require further developments to reproduce the galaxy populations and individual galaxies observed at all redshifts.

On the other side, to prepare the arrival of the huge amount of Gaia data on galaxies, we built synthetic galaxy libraries firstly adapted at the low resolution of the BP/RP instruments (Tsalmantza et al, 2009 and references therein) with the help of our evolution model PÉGASE.2 (www.iap.fr/pegase) computing predictions for evolution scenarios by types. Extended to larger ranges of parameters, this large library is used to educate the Support Vector Machine in charge to automatically select on board the variety of observed sources. A version at high spectral resolution PÉGASE-HR2 is in preparation. It will be used to interpret the data from the Radial Velocity Spectrograph (RVS).

Our objectives for radio galaxies with Gaia are to predict signatures identifing the variety of processes at works. These targets could be classified in a new class to derive their key evolution parameters.

2. Multiple components of distant RG

Gaia will observe radio galaxies with an excellent astrometry mainly due to the nucleus. Gaia will also detect, when in active phase, all evidences of intense starburst or HII region which could be triggered in the closed environment of the nucleus. So that definite clues on the starburst-AGN duality might be derived from local observations of active galaxies.

One of the main difficulties is to disentangle the respective signatures of nucleus and of old versus recent star formation activities.

2.1. The massive evolved stellar component

To interpret the famous bright limit in the K magnitude -redshift (K-z) Hubble diagram, the space of galaxy evolution parameters has been explored with the code PÉGASE. Adopting the standard cosmological parameters and correction for distance modulus, we successively analysed the parameter set: star formation laws, IMF, stellar mass. Reference templates by types are built from the best fits of local data spectral energy distributions and colors.

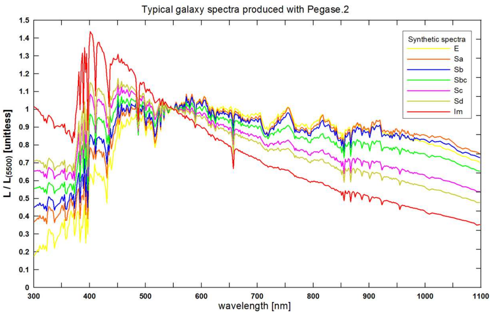

Fig. 1. Spectral Energy Distributions of various galaxy types computed with the code Pégase at age of 13Gyrs.

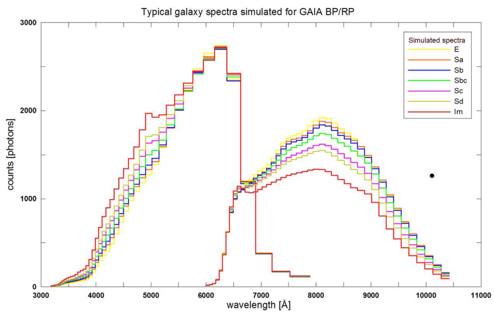

Fig. 2. Spectral Energy Distributions of various galaxy types at 13Gyrs simulated through the BP/RP filtersof Gaia.

When k- +e- corrections (expansion and evolution) are applied to templates, predictions are compared to the high-z observational data. As main result, the K-z diagram at high redshift appears brightly limited by the luminous powerful radio galaxies (Fig. 1). Amplified by the underlying AGN, the K-luminosity of radio galaxies are systematically brighter by $\tilde{2}$ mag compared to normal field galaxies. The best model for distant radio galaxies follows the elliptical scenario, at any age, formed from a progenitor cloud of $M_{baryon}= 10^{12}\ M_{\odot}$. This result differs from the initial fluctuations of $M_{in}= 10^{5}\ M_{\odot}$ predicted by the CDM and would imply a mass accumulation time-scale of less than

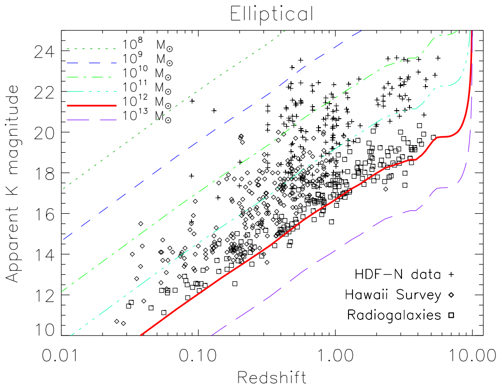

Fig. 3. The observed K-z Hubble diagram shows a sharp cut from z=0 to 4. With the evolution scenario of elliptical galaxy,the code Pégase predicts galaxies of $M_{baryon}= 10^{12}\ M_{\odot}$ (red line), already formed at z=4 (Rocca-Volmerange et al, 2004)

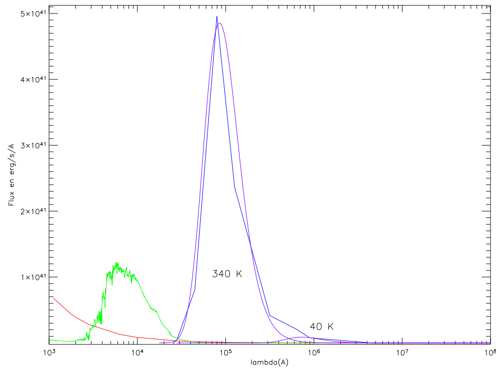

Fig. 4. The three main fluxes contributing to the radiative energy distribution of the 3CR radio galaxy sample: the elliptical SED (green line), the synchrotron power law (red line) and the two blackbody laws (pink lines) of respectively 340 K ± 50 K and 40 K ± 16 K. The dust emission (blue line) is derived from the observations after subtraction of stellar + synchrotron emissions.

1Gyr, an important constraint for galaxy evolution models.

As an example, from the visible to IR spectral energy distribution (SEDs) of 3CR galaxies, the typical stellar mass $10^{12} M_{\odot}$ of the elliptical evolved population and a synchrotron power-law could be substracted to the continuum. The rest is mainly attributed to hot dust emitting in the mid-IR emission at ≃ 340K. This likely traces the optically thick dusty torus illuminated by the embedded AGN (Rocca-Volmerange & Remazeilles, 2005). Gaia is indirectly concerned by the absorption factor related to this IR emission.

2.2. The AGN component

As AGNs, nuclei of radio galaxies will be detected with the high accuracy of astrometry of Gaia, and so will be useful for the reference systems. Moreover emission lines may bring information on the source of ionization either by photoionization and/or shocks. The best way to disentangle the two sources of ionization is to analyze the line ratios. In the visible, results of 3D spectroscopy with OASIS/CFHT on the FR-II radio galaxy 3C171 (z=0.238) are presented in Rocca-Volmerange & Moy, 2003. The [OIII]λ5007/Hβ map shows the intense photoionisation in the nuclear zone around the AGN and the boundaries of the ionized cocoon with the intergalactic medium suffering ionizing shocks.

3. The activity of Star Formation

At all redshifts, radio galaxies are sites of star formation. The essential parameter to constraining evolution theories is the ratio of re-

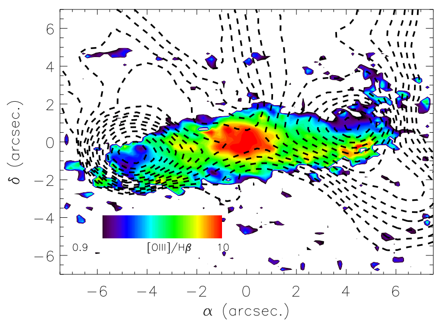

Fig. 5. The map of line ratio [OIII]λ5007/Hβ confirms the central zone is photoionized by the AGN while the ratio traces shocks at the boundaries of the cocoon (Rocca-Volmerange & Moy, 2003)

cent/old star masses defining the star formation law as a function of age (redshift). However the stellar mass calibration is subject of debate. Firstly the mass of young stars (O-star continua, emission lines, dust emission) depends on instrumental apertures, extinction, HII region evolution, Lyman continuum photons and others. Secundly evolved stars are depending on observations and interpretation with metal abundance, internal structure and extinction.

At high redshift, models of galaxy evolution as PÉGASE are generally used in the comoving frame. They are based on templates SED of nearby galaxies, after k+e corrections, after a possible substraction of the AGN component. A consortium HzRG (High redshift Radio galaxies) develop a large program of observing multi wavelength SEDs from the visible to the IR-submillimetric and radio (Spitzer, Herschel, APEX, ALMA) domain on a sample of 70 radio sources. For local sources at low redshifts, Gaia aims to observe nearby radio galaxies with the two instruments BP/RP and RVS. Star formation tracers are continua, metallic absorption lines, emission lines while nucleus is precisely identified. Among the local active galaxies, NGC 1068 is one of the nearest and probably the most studied Seyfert 2 galaxy, becoming an excellent laboratory to study the interaction between black holes, the jets that they can produce and the medium in which they propagate. The recent detection of star formation (Esposito et al, 2011) allows to trace young stellar population found at at 100 pc south of the nucleus Intermediate-age stellar population contributes significantly to the continuum, especially in the inner 200 pc (Martin et al. 2010).

Another fascinating active galaxy is NGC1275, the brightest cluster galaxy in Perseus, The spatial resolution of Gaia based on contrast detection separating the nucleus and starburst locations with a high accuracy is well adapted to constrain star formation activity in this atypical galaxy. Among the many fascinating features of NGC1275, the brightest cluster galaxy in Perseus, is the high velocity optical emission line system (HVS) discovered by Minkowski 50 years ago. Even if in rapid progress, the details of this situation have remained elusive .

Statistics and coherent calibrations of old/young star formation activities will be significatly approached by the Gaia mission and its instruments.

4. Conclusions

Gaia will observe active galaxies not only for reference systems but also to identify the star formation zones in relation with the radio jet and accretion activities. The AGN modeling will be considered in parallel with star formation activities, in particular from astrometry, continua and emission lines. Moreover statistics on the local sources as well as number density properties from the luminosityand mass functions will complete the quasars counts.

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