SF2A 2007
J. Bouvier, A. Chalabaev, C. Charbonnel (eds)

MODELLING SPECTRA OF N-BODY SIMULATIONS OF GALAXY MERGERS

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Abstract. We present an efficient approach to model spectra for N-body simulations of galaxy mergers (Horizon GalMer project) using the PEGASE.HR synthetic populations. Using the pre-computed grid of PEGASE.HR simple stellar populations (SSP) spectra and/or colours, as well as the kinematics of the particles on the line of sight, we are able to make on-the-fly computation of spectra and/or colours for any region of the simulated galaxies as seen from any direction.

1 The GalMer Database

The Horizon GalMer database contains results of N-body simulations of mergers of galaxies (Di Matteo et al. 2007, Di Matteo et al. this volume) of different morphological types. To model the galaxy evolution, we use a Tree-SPH code, where gravitational forces are calculated using a hierarchical tree method and gas evolution is followed by means of smoothed particle hydrodynamics. The code describes interstellar medium using hybrid particles and allows to trace the star formation and metal enrichment histories for every particle at any given snapshot of the simulation.

The first release of the data contains about 900 simulations (with limited inclination angles of the orbits), in 50 to 70 snapshots each, representing mergers of giant galaxies of different morphological types (E0 to Sd).

Apart from the data discovery and retrieval capabilities, we provide a set of data processing/analysis tools useful to compare the results of the simulations with observed data:

- On-the-fly generation of synthetic spectra of stellar populations of galaxy mergers
- On-the-fly generation of synthetic images of galaxy mergers
- On-the-fly computation of the luminosity weighted line-of-sight velocity distribution

These tools exploit the PEGASE.HR code (Le Borgne et al., 2004) to model stellar populations and account for contributions of stars of different ages and metallicities to the properties of the merging galaxies.

2 The Algorithm for Computation of Spectra

Running the PEGASE.HR code for each hybrid particle participating in the N-body simulations is a very expensive procedure in terms of computational time. In addition, some modifications need to be introduced into the PEGASE.HR code in order to model complex star formation histories.

We have developed an approach that allows to avoid executing the PEGASE.HR code at the time of computation of the synthetic spectra of N-body simulations, but we are still able to deal with star formation histories of individual particles. The algorithm comprises several steps.

1. We pre-compute a grid of Simple Stellar Populations (SSPs) for the Miller-Scalo (Miller & Scalo, 1979) IMF (the IMF is used in our simulations) for a set of ages from 50 Myr to 12 Gyr with a step of 50 Myr and metallicities between Z=-2.5 and Z=1.0. The resulting grid contains spectra from 4000A to 6800A with a logarithmical rebinning in the wavelength, corresponding to the step of 10 km/s. It is stored as a 3-dimensional (wavelength, age, metallicity) FITS file with a size of 220 Mb. This grid has to be done only once for all the simulations with a given IMF.

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2. For every hybrid particle we compute a star formation (SFH) and metal enrichment (MEH) histories as a 2-dimensional histogram, containing mass fractions of stars of given ages and metallicities. This 2-dimensional histogram contains exactly the same grid of age and metallicity values that are used in the SSP grid – this allows to avoid interpolation while extracting a spectrum for a given (age, metallicity) pair. This step of algorithm needs to be done once per N-body experiment (merger event). When a synthetic spectrum needs to be computed, a user is asked to provide a location of an "observer" and a distance from the point of origin in the coordinate system of the simulations, as well as the sizes and shapes of the regions of interest (RoI) in the plane of view to compute spectra for. The original N-body particles are selected inside RoIs and sorted along a line of sight.

3. Spectrum for every particle is computed on-the-fly using its 2D SFH/MEH and the SSP grid as a linear combination of simple stellar populations having weights corresponding to the values contained in the 2D SFH/MEH. The only mathematical operations needed at this step are multiplication of vector (representing a spectrum) by a constant and co-adding these vectors. This operation can be run in several computational threads and it takes one to several milliseconds on a modern PC.

4. Computed spectrum of every particle is red- or blueshifted according to its line-of-sight radial velocity. The spectra are logarithmically rebinned in a wavelength so Doppler shifting requires only to shift the elements in the array by the same (eventually floating-point) value, so no complex and time consuming resampling procedure is needed.

5. The resulting SED is computed by co-adding generated spectra for every particle. Kinematics of points on the line-of-sight is accounted automatically, because of step (4). Dust extinction is taken into account using a column density of the ISM. Since the points are sorted along a line of sight, this can be done in an incremental way while computing the resulting SED.

Depending on the number of particles, included in the RoI, the total time to generate a spectrum is from a fraction of to a few seconds.

3 Generating Synthetic Images and LOSVD

Broadband colours can be computed in a similar way to spectra – one needs to supply an SSP grid containing broadband fluxes in given photometric bands instead of spectra. Step (4) is excluded, and due to much smaller number of points in the vectors the time of computation decreases to milliseconds per RoI, or about a second for a complete 2D synthetic image of a snapshot.

Luminosity weighted Line-of-Sight Velocity Distribution (LOSVD) can be generated using exactly the same algorithm as one used for spectra generation. An additional parameter, a working wavelength, is needed because the contributions of different stellar populations will not be the same at different wavelength, changing the LOSVD shape.

4 Possible Applications

There are numerous astrophysical applications for the tools provided in a frame of the Horizon GalMer database. We identify some of them:

1. Simulating observations (direct images, 3D spectroscopy) of merging galaxies at different redshifts. This can be very useful for preparing observational proposals as well as for comparing results of observations to the N-body modelling.

2. Studying the dynamics of mergers and merger remnants by making LOSVD analysis.

References

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