Astrophysics & Cosmology at IAS during the Planck era. Scientific computer training.

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1 Pratical aspects

The projects will take place at IAS, from Monday April 4th to Friday, April 15th, from 9:30am to 18:00 each day.

Students will work in the computer room 208.

A few lectures will be given during about the science context as well as the computer tools.

It's not necessary to have taken the NPAC cosmology class to attend the IAS computer training projects !

The evaluation will be based on: 1) the written report due the 2nd Thursday evening; 2) the oral public presentation; 3) the initiatives during the 2-week project; 4) the robustness of the approach; 5) the critical look on the approach and the litterature.

2 Computers

Students will be using terminals in the computer room. They will have to connect to the **edu-calcul2** computer. Login and passwords will be given. Computer accounts will be closed 1 month after the end of the training: make sure you backup your programs elsewhere at the end of your project.

We will be using IDL. A tutorial will be given. Online introduction and material is available at: `http://www.ias.u-psud.fr/projets/idl/`

Data and some programs will be available through the directory: `~hdole/master2` . You can start using IDL with the program `example_m2.pro` .

Let's meet monday, Apr 4th at 10h00 at l'IAS !

3 Discovering new clusters of Galaxies in X-rays with Rosat (Project 1)

3.1 Introduction

The Rosat satellite surveyed the sky in X-ray domain and provided us with a full-sky map. Clusters contain hot gas that emits in X-ray with bremstralung effect. They should thus appear as compact sources in the maps. The goal is to find clusters in the Rosat map and measure their flux. The direct application will be to use them in the Planck data (not during this project).

This project, as is, has never been published before.

3.2 Outline

- familiarisation with the galaxy clusters, map and the signal
- cross correlation of cluster external catalogues and bright/faint Rosat point source catalogues
- closer look at bright/faint sources with no cluster counterparts in catalogues
- measure of signal-to-noise ratio of detection of clusters
- measure of the flux of the clusters
- project synthesis, report writting, preparation of 10 slides for the oral presentation

4 Clusters of Galaxies: measurements of the Sunyaev-Zeldovich effect on simulated maps; applications to Planck (Project 2)

4.1 Introduction

Planck is currently surveying the sky and observing galaxy clusters through their SZ effect (distorsion on the CMB signal by hot gas in clusters). The goal is to measure the flux of clusters by using match filters and aperture photometry on simulated maps matching well Planck data properties.

This project, as is, has never been published before.

4.2 Outline

- familiarisation with the galaxy clusters, SZ effect, maps and the signal
- familiarisation with filters and comparison
- derive the relation between filters
- apply filters in pixel space and Fourier space
- measure the cluster fluxes
- project synthesis, report writting, preparation of 10 slides for the oral presentation

5 Cosmic Microwave Background Fluctuations: Measurements with the method Internal Linear Combination with Monte-Carlo Markov Chains (MCMC) (Project 3)

5.1 Introduction

WMAP was a NASA satellite dedicated to the measure of the fluctuations of the Cosmic Microwave Background. Current available data correspond to seven years of integration on the sky.

The goal of this project is to extract a map of the CMB fluctuations in intensity, from the public maps corresponding to the sky observed at 5 different frequencies in the millimetric and radio range. The goal is also to measure an angular power spectrum of the map, which gives insights on the early universe.

5.2 Outline

• learn about millimetric and radio spectral ranges, WMAP, IDL, the data and their unit and format (Healpix), and how to visualize them.
• Download the 7-yr intensity WMAP maps from the `lambda` web site and vizualize them with the IDL Healpix library (`mollview` or `orthview`)
• understand wuch astrophysical component(s) are dominating in each frequency map
• get a map of the CMB intensity fluctuation from the 5 frequeny maps, e.g. with the internal linear combination (ILC). You can use the MCMC to converge to your solution and/or estimate the error bars
• compare your map to the WMAP team ILC map
• how robust are your parameters ? Compare to the litterature
• use `anafast` to get an angular power spectrum of the intensity fluctuations of the CMB, and study the influcence of the Galactic cut.
• compare your power spectrum to the one published by the WMAP team, and also the SPT team, and provide some interpretation
• project synthesis, report writting, and preparation of 10 slides for the oral presentation

5.3 Documentation

• `http://map.gsfc.nasa.gov`
• `http://lambda.gsfc.nasa.gov`
• Hinshaw et al, 2007, ApJ, in press
• Bennett et al, 2003, ApJS, 148, 1
• Bennett et al, 2003, ApJS, 148, 97
• Eriksen et al, 2004, ApJ, 612, 633
• Hivon et al, 2002, ApJ, 567, 2
• `http://healpix.jpl.nasa.gov`

6 Statistical analysis of galaxies newly detected by Planck: number counts and spectral shape (Project 4)

6.1 Introduction

Planck, while observing the whole sky with unprecedented angular resolution and sensitivities between the frequencies of 30 to 857 GHz (centimetric to submillimetric spectral domains) detected many "compact sources" (mainly galaxies, but also galaxy clusters and Galactic objects). This catalog is public since 3 months, and is called ERCSC (Early Release Compact Source Catalog).

The goal of the project is to statistically characterize the galaxies of this all-sky sample. Some (actually many) galaxies remain unidentified, i.e. don't have an obvious already known identification.

This whole catalog will likely tell us about star formation and the radiogalaxies in the low redshift universe. However, this sample being new and poorly studied, here is a rare opportunity to work on a hot topic where almost nothing has been published yet.

The goals of the project in more details are: 1) get an estimate of the galaxy number by flux bin (called number counts) and to compared to existing models and interpret; 2) sort the galaxies by spectral shape (or Spectral Energy Distributions, SED) and study some of their physical characteristics (type of emission, luminosity) and extract some extreme types.

Notice that the ERCSC catalog by itself doesn't allow a clean statistical study since we're missing there important informations about completeness for instance that can introduce selection effects. So the interpretation on this topic will be light. But the methods developped during this project could be used later with more informations to allow a proper statistical work.

Note: this project can be split into 2 different projects: one for number counts, and the other one for the galaxies SEDs. This project, as is, has never been published before.

6.2 Outline

- get used to the infrared and submillimetric range, Planck, the 6 HFI frequencies, IDL, the ERCSC (how to read it), and litterature about number counts and galaxies SEDs.
- Download a few WMAP maps for illustration; Download the ERCSC from the ESA web site.
- Overplot ERCSC sources selected at one frequency and overplot them on the WMAP data
- understand the emission processes in the galaxies, and its dependance on frequency
- start at 857 GHz and use aperture fluxes. Exlcude from the analysis any extended sources using the appopriate keyword
- use an IRAS mask (e.g. 100 micron IRIS map, and select all sky regions below 2.5 MJy/sr). justify why. Try also 5 MJy/sr.
- counts: plot histograms of the flux distributions and guess at which fluxes you might want to cut the sample; justify why.
- counts: compute number counts at 857 GHz, and compare with models (e.g. Béthermin et al., 2011 to start with) and Herschel (Oliver et al., or Clements et al., 2010)
- counts: compute counts at other frequencies, and compar with models (links to models: `http://www.ias.u-psud.fr/irgalaxies/model.php`)
- SEDs: use the 857 GHz catalog, which also gives the fluxes in all other bands; select galaxies that are peaking at 857 GHz, and others at 545, and 353 etc.. make the difference between dusty-like sources and flat-spectrum radio-sources.
- SEDs: construct a few color-color diagrams: e.g.: 857/545 vs 545/353
- SEDs: get an estimate of the relative fraction of each population.
- SEDs: identify possible extreme source in color-color diagrams
- analyze and critics of your results
- project synthesis, report writting, and preparation of 10 slides for the oral presentation

6.3 Documentation

- Planck ERCSC catalog and documentation: `http://www.sciops.esa.int/index.php?project=planck&page=Planck_Legacy_Archive`
- Practical Statistics for Astronomers, J. V. Wall; C. R. Jenkins, Cambridge, 2003

7 Angular correlation function of bright infrared galaxies observed by Planck (Project 5)

7.1 Introduction

The angular correlation function $w(\theta)$ allows to quantify the clustering of the objects (galaxies or galaxy clusters) and is a widely used tool to characterize the structuration of matter in the Universe. $w(\theta)$ has been extensively studied in the visible and radio ranges, but much less in the infrared and the submillimeter.

The goal of this project is to measure for the first time $w(\theta)$ on the Planck all-sky data (using the first catalog, the ERCSC, see project 4), allowing to probe star formation at relatively low redshift.

You can use either the classical estimator of $w(\theta)$, the LS estimator (see below), and (if you hav etime) a new estimator using the stacking technique. This last method is bieng developped at IAS. The results will be compare dto the litterature, in particular IRAS, Akari and Herschel results.

Notice that the ERCSC catalog by itself doesn't allow a clean statistical study since we're missing there important informations about completeness for instance that can introduce selection effects. So the interpretation on this topic will be light. But the methods developped during this project could be used later with more informations to allow a proper statistical work.

Note: this project can be split into 2 different projects: one for galaxies, and the other one for galaxy clusters. This project, as is, has never been published before.

7.2 Outline

• get used to the infrared and submillimetric range, Planck, the 6 HFI frequencies, IDL, the ERCSC (how to read it), and litterature about angular correlation function of galaxies and clusters
• Download a few WMAP maps for illustration; Download the ERCSC from the ESA web site.
• Overplot ERCSC sources selected at one frequency and overplot them on the WMAP data. We'll start with 857 GHz sources.
• start at 857 GHz and use aperture fluxes. Exlcude from the analysis any extended sources using the appopriate keyword
• use an IRAS mask (e.g. 100 micron IRIS map, and select all sky regions below 2.5 MJy/sr). justify why. Try also 5 MJy/sr.
• counts: plot histograms of the flux distributions and guess at which fluxes you might want to cut the sample; justify why.
• develop and implement an algorithm to measure the angular correlation function $w(\theta)$ with the Landy & Szalay (1993) estimator.
• test the algorithm on simulations
• measure $w(\theta)$ on the Planck 857 GHz catalog (cleaned from extended sources, and outside Galactic contamination, and on an homogeneous sample in flux)
• compute also at all other Planck HFI frequencies
• compare to the litterature (IRAS, Akari, Herschel), discussion and criticism.
• optional: test the stacking method on simulations, and validate it; then apply it at 857 GHz.
• analyze and critics of your results
• project synthesis, report writting, and preparation of 10 slides for the oral presentation

7.3 Documentation

• `http://www.planck.fr/`
• Practical Statistics for Astronomers, J. V. Wall; C. R. Jenkins, Cambridge, 2003
• Planck ERCSC catalog and documentation:
`http://www.sciops.esa.int/index.php?project=planck&page=Planck_Legacy_Archive`
• Landy & Szalay, 1993
• Overzier, 2003, A&A