Observational cosmology: the RENOIR team

Master 2 session 2014-2015
Observational cosmology: the RENOIR team

Outline

- A brief history of cosmology
- Introduction to cosmological probes and current projects at CPPM
- Future surveys at CPPM
A brief history of cosmology
The expanding Universe

To tell if an object is moving towards or away from Earth, astronomers study the light emitted by these objects. This light has a characteristic frequency (color), depending on the object itself and what gets absorbed or not.

When matter is moving away from us, these frequencies appear shifted towards the red, or lower-frequency, part of the spectrum (redshift), and when matter is moving towards us, these frequencies are shifted towards the blue, higher-frequency, part of the spectrum (blueshift).

In the 1920s, Georges Lemaître and Edwin Hubble found that the light emitted by galaxies was red-shifted, which later helped them elaborate a landmark paper in cosmology today that claimed the **Universe is expanding**.
The expanding Universe

In 2D, it is like a balloon inflating: each point on the balloon is drifting away relative to each other point on the balloon as it inflates, so there is no center of the Universe.
In 1933 the Swiss astrophysicist Fritz Zwicky studied clusters of galaxies.

- A galaxy is a collection of billions of stars.
- A cluster of galaxies contains hundreds to thousands of galaxies.

When Zwicky applied the virial theorem to the Coma cluster of galaxies, he obtained evidence of unseen mass, i.e., lots of additional mass which doesn't emit much light.

Today, galactic, galaxy cluster/supercluster and cosmologic observations show that roughly 90% of matter is dark (no-luminous).

From primordial nucleosynthesis, CMB, lensing and formation of large scale structures, we know that 84.5% of the matter is non-baryonic = dark matter.
Finally, in 1998, published observations of Type Ia supernovae by the High-z Supernova Search Team and the Supernova Cosmology Project show that the expansion of the universe is accelerating.

Total mass-energy of the Universe is dominated by a cosmic fluid called **dark energy** in opposition to the attractive force of matter.

Nobel Prize 2011 in Physics was awarded for this work to S. Perlmutter, B. Schmidt & A. Riess
The concordance model = $\Lambda$CDM
where $\Lambda$ is the cosmological constant
And CDM the Cold Dark Matter

According to latest Planck results, the energy content of the Universe is:

5% ordinary matter
27% dark matter
68% dark energy
Towards the understanding of dark matter and dark energy

Cold Dark matter

- CDM candidates are: WIMPs, axions, sterile neutrinos, LSP in supersymmetric models, LKP in Kalusa-Klein multidimensional models
- Modified gravity model (MOND theories which adjusts Newton's laws, TeVeS theories based on General Relativity)

Dark energy

- Cosmological constant $\Lambda$
- Quintessence (dynamical field)
- A failure of General Relativity on very large scales
- Other ideas have come from string theory, brane cosmology, homogeneity assumption, ...... or that acceleration of expansion is just an illusion ....

☐ Need to constrain cosmological parameters and their evolution with time
Introduction to cosmological probes
Type Ia supernovae

Type Ia supernovae produce consistent peak luminosity because of the uniform mass of white dwarfs that explode via the accretion mechanism.

The stability of this value allows these explosions to be used as **standard candles** to measure the distance to their host.
Two main projects:

**SNLS (SuperNovae Legacy Survey)**

Between 2003 and 2008, the Legacy Survey detected and monitored about 1000 supernovae with Megaprime at the Canada-France-Hawaii telescope. Definitive results expected soon (2014)

**SNFactory (Nearby SN Factory)**

Initiated to study a large sample (approximately 300) of nearby (0.03<z<0.08) Type Ia supernovae in detail in order to refine their use as cosmological calibrated standard candles. Phase I (2005-2010) and Phase II (2010-2015)
The Cosmic Microwave Background (CMB) is the thermal radiation left over from the "Big Bang". This snapshot, of the oldest light in our Universe, imprinted on the sky when the Universe was just 380,000 years old.

It shows tiny temperature fluctuations that correspond to regions of slightly different densities, representing the seeds of all future structure: the stars and galaxies of today.
Baryon acoustic oscillations (BAO)

The Baryon Acoustic Oscillation (BAO) method relies on the imprint left by sound waves in the early universe to provide a feature of known size in the late-time clustering of matter and galaxies.

This comparison can in theory distinguish between the different forms of Dark Energy. The patterns of galaxy clustering contain information about how cosmic structure is amplified from initial small fluctuations. This clustering encodes a robust ‘standard ruler’ between galaxies which could be used to map out the expansion history of the Universe.
The galaxy clustering at CPPM

**BOSS (Baryon Oscillation Spectroscopic Survey)**

Between 2009 and 2014, BOSS surveys about 1.5 millions Luminous Red Galaxies at $z < 0.8$ on 10,000 deg$^2$, with the **Sloan Digital Sky Survey** (SDSS-III).

**eBOSS (extended-BOSS)**

Starting in July 2014 and up to 2019, eBOSS will survey the Universe at $0.6 < z < 3.5$ (SDSS-IV).

**US projects with French participation**

Strong collaborations with LAM

A lot of data to analyze, based on the galaxy clustering: BAO, Redshift Space Distortions (RSD), …
CPPM team is working on combination of data from different cosmological probes

Necessary condition to break degeneracies between cosmological parameters

- Original statistical tool developed on the CPPM grid combination of SNe + CMB + BAO + WL
- Collaboration with CPT/LAM/Saclay
- Collaboration with China
Future surveys at CPPM
LSST

Large Synoptic Sky Telescope (LSST) is a ground based telescope (dedicated 8 meter), with first lights in 2020.

Roughly 103 supernovae have been discovered in the history of astronomy.

In comparison, LSST will discover over 1 million supernovae during its ten-year survey (up to 500,000 for cosmology).

LSST is designed to achieve multiple goals in four main science themes: Taking an Inventory of the Solar System, Mapping the Milky Way, Exploring the Transient Optical Sky, and Probing Dark Energy and Dark Matter.
LSST at CPPM

- Responsibility for the filter system
- Responsibility for the data processing and algorithm in the French team
- Preparation of data analysis
- Simulation, specifications and optimization
LSST Computing and analysis at CPPM

- LSST Computing is the realm of BIG DATA
- A strong and growing interest in participating in the LSST challenging software developments has started since two years in France
- CPPM is now responsible for the coordination of data processing and algorithm in the French team.
- The development of LSST algorithm is tested on real data of already existing (CFHTLS/SDSS) or currently observed (DES/HSSC) images and offer the possibility of publications of analysis on real data
Euclid space mission

Euclid was approved by ESA in 2011 and will be launched in 2020.

Euclid will provide multiple probes of dark energy (WL, BAO, clusters).

SDSS (BOSS) today  EUCLID tomorrow

Euclid will directly map the dark matter distribution in the Universe through weak gravitational lensing by imaging 1.5 billion galaxies.

At the same time, it will carry out a spectroscopic redshift survey of 50 million galaxies.
Euclid at CPPM

- Implication in the NISP instrument (spectro-photometer in infrared)
- Preparation of data analysis and data processing
- Simulation of spectroscopic images
- IR detectors responsible
- Calibration and observation strategy.
Euclid detector activities at CPPM

CPPM is in charge of the reception of the 16 flight detectors that will be received from NASA from 2014 to 2016.

CPPM team will do
- their characterisation at CPPM
- their integration in the NISP instrument at LAM.

The instrument will then be sent to ESA.

A large technical-scientific group in Marseille is in charge of testing the performance of the detector for science (simulation, analysis etc..)
Euclid simulation activities at CPPM

CPPM team is in charge of Euclid infrared spectro-photometer’s simulator.

Simulations are needed to:

- understand the instrument
- predict its performances
- anticipate some technical issues

Simulation tools allow to set up the data analysis chain and train the data analysis.
Conclusions

You wonder what is the ultimate fate of the universe..

and / or

You’d like to be part of the experimental team which will bring evidences for a deviation of the Einstein’s laws, one century after their discovery ...

and / or

You want to contribute to the understanding of Dark Matter and Dark Energy

join us,
join the RENOIR team.
Practical information
The RENOIR team

**Permanent staff:**
9 researchers (CNRS, University)

+ several engineers for technical support

**Non-permanent staff:**
1 student in 2nd year (Euclid)
2 students in 1st year (eBOSS, LSST)
3 postdocs on Euclid
1 postdoc on BOSS/eBOSS

(7 PhD defended since 2004)
Training for M2 students

Seminars (1st semester) and computer projects (2nd semester) will be proposed by the RENOIR team

Research internship (2nd semester) followed by a PhD thesis will be proposed on:

- BAO/RSD with BOSS/eBOSS
- Supernova with LSST(+CFHT/DES)
- Euclid

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### M2 specialized lecture in second semester

**M2 specialized lecture: Physical cosmology**  
given by C. Schimd & S. Escoffier

<table>
<thead>
<tr>
<th>Interpretation</th>
<th>Cosmological probes</th>
</tr>
</thead>
<tbody>
<tr>
<td>. The cosmic acceleration</td>
<td>. Large scale structures (BAO, RSD)</td>
</tr>
<tr>
<td>. Dark energy</td>
<td>. Cosmic Microwave Background (CMB)</td>
</tr>
<tr>
<td>. Dark matter</td>
<td>. Weak gravitational lensing</td>
</tr>
<tr>
<td></td>
<td>. First lights, intergalactic medium (IGM), reionization,</td>
</tr>
<tr>
<td></td>
<td>and Lyman-α forest</td>
</tr>
</tbody>
</table>

**Combination**

. Statistical analysis