Gravitational Lensing: The beginning of a new era for the study of the dark universe?

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TEXAS symposium
Sao Paulo dec 2012
Cosmic Microwave Background $z \sim 1100$

Large scale structures $z \sim 0$

$\sim 13$ billion years separate the two
The most convincing proof of the existence of dark matter:

**The cosmic microwave background**

Dark matter crisis

Baryons crisis
Where are the Baryons?

Were they expelled from galaxies or did they ever fall in galaxies?

Warm-Hot gas dominates Mass at low z

Courtesy: F. Nicastro (Sydney 2009)
Scale dependence of the missing baryon problem (Dai et al. 2010)
What is dark matter?
Where is dark matter?

There is no dark matter (modified gravity, f(R), etc...)

Microlensing

Dark matter distribution from Small to large angular scales (Weak and strong lensing)
CFHTLenS (PIs: Van Waerbeke & Heymans)

- The state-of-the-art cosmological survey with 155 sq degrees, ugriz to $i < 24.7$ (7$\sigma$ extended source)
- Uses 5 yrs of data from the Deep, Wide and Pre-survey components of the CFHT Legacy Survey
Gravitational lensing: lensed galaxies mapping foreground matter
Galaxy - galaxy lensing:

THE HALO MODEL
CFHTLenS measurement on red (early type) galaxies

Velander et al., 2012
DM halo mass to baryon (L,M) scaling

CFHTLenS: Velander et al. 2012
What lensing is teaching us about galaxy formation?

Also indicative of the satellite fraction per type, redshift, mass range.
Cosmic Shear two-points Statistics and mass Power Spectrum

Shear correlation function at separation $\Theta$:

$$\langle \gamma(r) \gamma(r+\theta) \rangle_r = \frac{1}{2\pi} \int_0^\infty dk \, k \, P_k(k) \, J_0(k\theta)$$

$$P_k(k) = \frac{9}{4} \Omega_0^2 \int_0^\infty dz \, P_{3D} \left( \frac{k}{D_L(z)} ; z \right) \mathcal{F}[z, z_{\text{source}}]^2$$
CFHTLenS: shear correlation function and systematics tests

P(k) analysis underway
Cosmological parameters
Analysis done

Kilbinger et al 2012
Different source redshifts give consistent results.

Non-linear clustering gives consistent results.

Benjamin et al. 2012
Marginal tension between CFHTLenS and WMAP/BAO that could be indicative of massive neutrinos. Similar to SDSS (Mandelbaum et al 2012)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>flat $\Lambda$CDM</th>
<th>curved $\Lambda$CDM</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Omega_m$</td>
<td>0.27 ± 0.17</td>
<td>0.28 ± 0.17</td>
<td>CFHTLenS</td>
</tr>
<tr>
<td></td>
<td>0.288 ± 0.010</td>
<td>0.285 ± 0.014</td>
<td>WMAP7+BOSS+R11</td>
</tr>
<tr>
<td></td>
<td>0.2762 ± 0.0074</td>
<td>0.2736 ± 0.0085</td>
<td>CFHTLenS+Others</td>
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<td>$\sigma_8$</td>
<td>0.67 ± 0.23</td>
<td>0.69 ± 0.29</td>
<td>CFHTLenS</td>
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<td>0.828 ± 0.023</td>
<td>0.819 ± 0.036</td>
<td>WMAP7+BOSS+R11</td>
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<tr>
<td></td>
<td>0.802 ± 0.013</td>
<td>0.795 ± 0.013</td>
<td>CFHTLenS+Others</td>
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<tr>
<td>$\Omega_{\Lambda}$</td>
<td>1 − $\Omega_m$</td>
<td>0.38 ± 0.36</td>
<td>CFHTLenS</td>
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<tr>
<td></td>
<td>1 − $\Omega_m$</td>
<td>0.717 ± 0.019</td>
<td>WMAP7+BOSS+R11</td>
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<td>1 − $\Omega_m$</td>
<td>0.7312 ± 0.0094</td>
<td>CFHTLenS+Others</td>
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<tr>
<td>$\Omega_K$</td>
<td>0</td>
<td>0.19 ± 0.43</td>
<td>CFHTLenS</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>−0.0020 ± 0.0061</td>
<td>WMAP7+BOSS+R11</td>
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<td></td>
<td>0</td>
<td>−0.0042 ± 0.0040</td>
<td>CFHTLenS+Others</td>
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<tr>
<td>$h$</td>
<td>0.84 ± 0.25</td>
<td>0.81 ± 0.24</td>
<td>CFHTLenS</td>
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<tr>
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<td>0.692 ± 0.0088</td>
<td>0.694 ± 0.012</td>
<td>WMAP7+BOSS+R11</td>
</tr>
<tr>
<td></td>
<td>0.6971 ± 0.0081</td>
<td>0.693 ± 0.011</td>
<td>CFHTLenS+Others</td>
</tr>
<tr>
<td>$\Omega_b$</td>
<td>0.030 ± 0.029</td>
<td>0.031 ± 0.030</td>
<td>CFHTLenS</td>
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<tr>
<td></td>
<td>0.0471 ± 0.0012</td>
<td>0.0472 ± 0.0016</td>
<td>WMAP7+BOSS+R11</td>
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<tr>
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<td>0.04595 ± 0.00086</td>
<td>0.0470 ± 0.0015</td>
<td>CFHTLenS+Others</td>
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<tr>
<td>$q_0$</td>
<td>−0.57 ± 0.27</td>
<td>−0.29 ± 0.40</td>
<td>CFHTLenS</td>
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<tr>
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<td>−0.568 ± 0.016</td>
<td>−0.574 ± 0.025</td>
<td>WMAP7+BOSS+R11</td>
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<tr>
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<td>−0.585 ± 0.011</td>
<td>−0.594 ± 0.014</td>
<td>CFHTLenS+Others</td>
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<td>$n_s$</td>
<td>0.93 ± 0.17</td>
<td>0.91 ± 0.17</td>
<td>CFHTLenS</td>
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<td>0.965 ± 0.012</td>
<td>0.969 ± 0.014</td>
<td>WMAP7+BOSS+R11</td>
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<td></td>
<td>0.960 ± 0.011</td>
<td>0.972 ± 0.012</td>
<td>CFHTLenS+Others</td>
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<td>$\tau$</td>
<td>0.086 ± 0.014</td>
<td>0.086 ± 0.015</td>
<td>WMAP7+BOSS+R11</td>
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<td>0.081 ± 0.013</td>
<td>0.085 ± 0.015</td>
<td>CFHTLenS+Others</td>
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<td>$\Delta^2_R$</td>
<td>2.465 ± 0.086</td>
<td>2.45 ± 0.13</td>
<td>WMAP7+BOSS+R11</td>
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<tr>
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<td>2.429 ± 0.081</td>
<td>2.361 ± 0.094</td>
<td>CFHTLenS+Others</td>
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<tr>
<td>$A_{SZ}$</td>
<td>0.97 ± 0.62</td>
<td>1.35 ± 0.61</td>
<td>WMAP7+BOSS+R11</td>
</tr>
<tr>
<td></td>
<td>1.33 ± 0.60</td>
<td>1.39 ± 0.57</td>
<td>CFHTLenS+Others</td>
</tr>
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</table>
CFHTLenS: weak lensing and intrinsic alignment

Heymans et al. 2012

6-bin tomography

$\Sigma P(z)$

$\text{n}_{\text{eff}} \times 10^4$

$z$
Cosmology and intrinsic alignment can be Simultaneously fitted.

An intrinsic alignment model is necessary: At least one parameter (A) needed (Bridle et al 2011)

Heymans et al. 2012
Effect of baryonic physics on the mass power spectrum compared to the Dark Matter Only Power spectrum

SN winds, cooling, SF,...
No AGN feedback

Top heavy IMF

All (Booth & Shaye 2009)

Van Daalen et al, 2011
Impact on the weak lensing

\[ \frac{\xi}{\xi_{\text{DMONLY}}}(\cdot) \]

- bin\textsubscript{11} ; \( z = [0, 0.6] \)
- bin\textsubscript{22} ; \( z = [0.6, 1.2] \)
- bin\textsubscript{33} ; \( z = [1.2, 3.4] \)

- REF / DMONLY
- DBLIMFV1618 / DMONLY
- AGN / DMONLY

\[ (\text{arcmin}) \]

\[ 1 \quad 10 \quad 100 \]

\[ 10^{-3} \quad 10^{-4} \quad 10^{-5} \]

\[ 1.1 \quad 10^{-6} \quad 10^{-7} \]

\[ 1.2 \quad 10^{-8} \quad 10^{-9} \]

\[ 2.2 \quad 10^{-10} \quad 10^{-11} \]

\[ (\text{arcmin}) \]
Wiesner et al 2012: SDSS cluster strong lensing suggest some clusters appear over concentrated than predicted for a LCDM model.

Zitrin et al 2012: statistical analysis of 10000 SDSS clusters show more of the large Einstein radii than predicted by LCDM.

The Einstein radius very sensitive to baryonic physics (Killedar et al. 2012)

Mandelbaum et al. 2009: SL selection biases can be substantial
CFHTLenS: mass map and baryon distribution (Van Waerbeke et al 2012)
CFHTLenS: mass map and voids (Van Waerbeke et al 2012)
CFHTLenS proved that lensing can be done at the 1% shape accuracy.

Future surveys (Euclid, LSST) will need a factor 10 improvement in order to measure dark energy and map dark matter and not be limited by systematics.

Stage III surveys are in between (DES, KiDS, HSC(?))

What are the upcoming challenges?
Challenge #1: galaxy shape measurement

The third GRavitational lEnsing Accuracy Testing challenge, or GREAT3, is a blind data challenge held by the world-wide weak lensing community to test weak lensing measurement algorithms.

With several major astronomical surveys beginning to make large-scale cosmological weak lensing measurements in 2013 in order to better understand our cosmological model (including the mysterious dark matter and dark energy), this challenge will play an important role in identifying promising measurement algorithms and quantifying their performance.

The challenge itself will occur in 2013, with preparations actively underway now. For more information about the challenge under development, see the links above.
The Horizon Project

by Legrand François (Sunday 17 February 2008)

Scientific Highlights:

» the Horizon simulation performed at CCRT (CEA)

» the MareNostrum simulation performed at BSC (Spain)

» the GALMER database is now online.

The objective of the HORIZON Project is to federate numerical simulations activities with a program focussed on Galaxy and Large Scale Structure Formation. In a context favorable to HPC (High Performance Computing), the PNC (Programme National Cosmologie), the PNG (Programme National Galaxies) and the PAP (Programme AstroParticule), express their needs to stimulate and coordinate individual efforts in HPC among each domain.

The HORIZON Project was build on several research teams in different institutes. The scientific objective is specifically oriented towards studying galaxy formation in a cosmological framework. Its transverse and federative nature will however allow to develop in a few years high-level expertise in parallel and distributed (GRID) computing, in database management and virtual observations, in...
Challenge #3: photometric redshifts

Photometric redshift Estimation

Photometric redshift estimation is a method to evaluate object distances when spectroscopic estimates become impossible due either to poor signal-to-noise ratio, to instrumental systematics, or to the fact that the objects under study are beyond the spectroscopic limit.

Given the high complexity of the photo-z approach and the multiple factors that influence the results, it is reasonable to test the photo-z codes on real photometric data of objects that have also been observed spectroscopically for precise redshift measurements. The following described experiments have been approached by DAME Team with Machine Learning methods, revealing high quality performance and robustness.

PHAT (PHoto-z Accuracy Testing)

The PHAT (Hildebrandt et al. 2010) consists of a competition engaged by involving several worldwide groups with the aim at evaluate different (theoretical/empirical) methods to extract photo-z from an ensemble of ground-based and space observation catalogues in several bands, composed to
Challenge #4: be imaginative and creative

Challenge #5: work together in peace!
Large synoptic survey telescope

SKA

TMT

Euclid