Cosmology with the Sloan Digital Sky Survey Supernova Search
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Cosmology Background

• The study of the origin and evolution of the Universe.
• First real effort by Einstein in 1916
• Gravity is all the matters at this large scale
• Universe held in “Steady State” by introducing the Cosmologic Constant, $\lambda$, opposing gravity.
The Big Crunch or Chill

- If all you have are galaxies and gravity
- Nothing to oppose mutual attraction.
- Universe either will shrink and end in a singularity or expand forever into a frozen future.
- Einstein posits the cosmological constant, $\lambda$, to prevent this.
De Sitter Disagrees

- De Sitter in 1917 points out that there is no evidence for the cosmological constant.
- Without that the Universe is unstable. It could be expanding or contracting.
- Not taken seriously at first. No evidence for non-clockwork dynamics in the Universe.
Hubble Weighs In

• Most accomplished astronomer of the day. In early 1920’s had discovered galaxies, vastly expanding the size of the known Universe.
• Great advantage as using world’s largest telescope.
Hubble’s Amazing Observation

- In 1929 using 25 nearby galaxies notices that $v = Hd$ (Hubble’s Law).
- Confirmed in 1931
- Implies the Universe is expanding and the Big Bang.
Einstein’s Greatest Blunder?

- No evidence of a cosmological constant. Abandoned.
- Problem switches to measuring $H$ and the mass of the Universe.
- Two together determine ultimate fate the Big Crunch or the Big Chill.
Dark Matter

- Measuring the mass of the universe reveals something amazing.
- Most of it is not glowing.
- Contrast with Solar System.
- Not ordinary matter.
Type Ia Supernova

- Easy to identify
- No H or He, but Si in spectra
- Light curve is unique
Type Ia are Standardizable

- Rate of rise and fall related to brightness
- Thin = dim, Fat = bright
- Related to how much metal there is in the White Dwarf

![Graph showing lightcurves for Low Redshift Type Ia]
• A shocking surprise in 1998.
• Line is not straight.
• Implies that something is accelerating the expansion of the Universe.
• Called Dark Energy
• Combination of Type Ia, Cosmic Microwave Background, and clustering of galaxies imply a very strange Universe.
• Dominated by Dark Energy.
• Headed towards the Big Chill.
Sloan Digital Sky Survey
Supernova Search

- World’s sample of Supernovas is quite small (100’s)
- More would allow tests of Dark Energy (Is it constant in time? Is it constant in space?)
- Sloan Digital Sky Survey ideal for this work (www.sdss.org)
Sloan Digital Sky Survey

- Goal is to map 1/4 of the sky
- 100 Million Objects will have brightness and position
- 1 Million Galaxies will have distances
- 100,000 Quasar distances
- Telescope in New Mexico (Apache Point Observatory)
Sloan Digital Sky Survey

- 15 TB of data
- Supernova search done by repeat viewing of the sky and looking for new bright objects. Today 100’s found by all searches.
- Continuing to take galaxy spectra to get host redshift.
Supernova Candidate

g (srch, tmplt, subtr)
r (srch, tmplt, subtr)
i (srch, tmplt, subtr)
Asteroid
Bright Star
Dipole
Good Candidates

- Good candidates are analyzed further
- Light versus time
- Simple spectrum
- Fit reveals type of supernova (Ia/b/c,II)
- Supernova then have detailed spectrum and photometry from other telescopes
2005-7 Campaigns

• 2005-7 Campaigns went very well
• 500+ Type Ia Supernova found
• Is the worlds largest sample from a single experiment
• Much more work to do. Calibration for brightness and redshift. Correction for metallicity to make standard candle. Etc.
Cosmology Basics

\[ H(z)^2 = H_0^2 \sum_i \Omega_i (1+z)^{3(1+w)} \]

where \( w \) (equation of state parameter) is pressure/density

<table>
<thead>
<tr>
<th>Source of expansion</th>
<th>( W_0(w_a \text{ is } dw/dz) )</th>
<th>Change with ( z )</th>
<th>( \Omega \text{ at } z=0 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Matter (dark, baryon, relic ( \nu ))</td>
<td>( v^2/c^2 \sim 0 )</td>
<td>( \Omega_M(1+z)^3 )</td>
<td>0.3</td>
</tr>
<tr>
<td>Radiation (CMB)</td>
<td>1/3</td>
<td>( \Omega_\gamma(1+z)^4 )</td>
<td>( \sim 10^{-5} )</td>
</tr>
<tr>
<td>Cosmological constant (Best current guess)</td>
<td>-1</td>
<td>( \Omega_\Lambda = \text{constant} )</td>
<td>0.7</td>
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</tbody>
</table>

Sum of \( \Omega_m + \Omega_r + \Omega_\Lambda \) is the geometry of Universe
Systematic uncertainties in matter density parameter $\Omega_M$ for the MLCS2k2 analysis of the $F_{wCDM}$ model, including the BAO+CMB prior. Negative values indicate asymmetric uncertainties.

<table>
<thead>
<tr>
<th>source of uncertainty</th>
<th>uncertainty on $\Omega_M$ for sample:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$a$</td>
</tr>
<tr>
<td>Rest frame $U$-band</td>
<td>$-0.051$</td>
</tr>
<tr>
<td>$z_{\text{min}}$ cut for Nearby sample</td>
<td>$0.000$</td>
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<tr>
<td>MLCS2k2 SN Ia Model Parameters</td>
<td>$0.003$</td>
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<tr>
<td>Galactic Extinction</td>
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<tr>
<td>FORM OF PRIOR</td>
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<tr>
<td>correlated $1\sigma$ changes $R_V$ and $\tau_V$</td>
<td>$0.007$</td>
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<tr>
<td>simulated efficiency for nearby SN Ia</td>
<td>$0.000$</td>
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<tr>
<td>spectroscopic efficiency for SDSS</td>
<td>$0.014$</td>
</tr>
<tr>
<td>spectroscopic efficiency for ESSENCE</td>
<td>$0.000$</td>
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<tr>
<td>spectroscopic efficiency for SNLS</td>
<td>$0.000$</td>
</tr>
<tr>
<td>CALIBRATION</td>
<td></td>
</tr>
<tr>
<td>0.01 mag errors in $U, B, V, R, I$</td>
<td>$0.006$</td>
</tr>
<tr>
<td>shifted Bessell filters</td>
<td>$0.001$</td>
</tr>
<tr>
<td>vary $k_i$ color terms</td>
<td>$0.001$</td>
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<tr>
<td>vary SDSS AB offsets for $g, r, i$</td>
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<tr>
<td>vary ESSENCE $R-I$ color zeropoint</td>
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<tr>
<td>vary SNLS $g, r, i, z$ zeropoints</td>
<td>$0.000$</td>
</tr>
<tr>
<td>vary HST zeropoints</td>
<td>$0.000$</td>
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<tr>
<td>Total</td>
<td>$+0.019$</td>
</tr>
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</table>
Astrophysics Summary

- For more information on the SDSSsn (http://sdssdp47.fnal.gov/sdsssn/sdsssn.html)
- Plenty of work to do.
- Zaven Bush (galaxy vs. CCSN)
- Johanna-Laina Fischer, Levente Dojcsak to FNAL to work with John Marriner on astrophysics (maybe SDSS SN related)
- Brett Sandler to SLAC to work with Rafe Schindler on IR Camera for DES.