Testing Cosmological Models with Large-Scale Galaxy Surveys

Alvise Raccanelli

with M. Kamionkowski, A. Szalay, J. Silk
The expansion of the Universe is accelerating
Why ?
The Dark Side
Dark Energy

\[ G_{\mu\nu} = T_{\mu\nu} + T^{\text{de}}_{\mu\nu} \]
Dark Energy

\[ G_{\mu\nu} = T_{\mu\nu} + T_{\mu\nu}^{\text{de}} \]

The Force
Dark Energy

\[ G_{\mu\nu} = T_{\mu\nu} + T_{\mu\nu}^{\text{de}} \]

Modified Gravity

\[ G_{\mu\nu} + G_{\mu\nu}^{\text{MG}} = T_{\mu\nu} \]
We can look at the clustering of galaxies
Real and Redshift Space in GR

Hubble expansion +
Real and Redshift Space in GR

Hubble expansion +

local density (s)
Real and Redshift Space in GR

Hubble expansion +

local density (s)

time delay (I)
Real and Redshift Space in GR

Hubble expansion +

local density \((s)\)

time delay \((I)\)

convergence \((\kappa)\)
Real and Redshift Space in GR

Hubble expansion +

local density (s)

convergence (κ)

time delay (I)
Real and Redshift Space in GR

Hubble expansion +

local density ($s$)

time delay ($I$)

convergence ($\kappa$)

Alvise Raccanelli

14/12/2015
What if we modify GR?

Effects of deviations from General Relativity on the largest cosmic scales

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(Dated: December 14, 2015)

We investigate how large-scale corrections to galaxy clustering are affected by modifications to General Relativity, for a variety of models and parameterizations.
Braneworlds

5D bulk

\[ e^+ e^- \]

\[ G \]

4D brane

\[ Q \]
Braneworlds

5D bulk

4D brane
Dark Matter

Cold Dark Matter
Dark Matter

Cold Dark Matter

Self-Interacting?
Dark Matter

Cold Dark Matter

Self-Interacting?

“Dark atoms”? 
Did dark matter kill the dinosaurs?

The Solar System's periodic passage through a 'dark disk' on the galactic plane could trigger comet bombardments that would cause mass extinctions.

Elizabeth Gibney

07 March 2014

Mass extinctions such as the one that wiped out the dinosaurs seem to happen with regularity, pointing to possible cosmic causes.
Dark Matter
Dark Matter

Double disk
Dark Matter

Double disk
Dark Matter
Dark Matter

Did Dark Matter Kill the Dinosaurs? Probably Not. But It’s a Fun idea.

By Phil Plait
String Axiverse
Accelerated Cosmic expansion driven by axion-like quintessence field
String Axiverse

Accelerated Cosmic expansion driven by axion-like quintessence field

We can use measurements \((D_A, H)\) to test its parameters
Cosmological constraints to an axiverse-inspired quintessence field

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It has recently been suggested that accelerated cosmic expansion might be driven by an axion-like quintessence field with a sub-Planckian decay constant, an idea inspired by the string axiverse with the potential to address why the cosmic expansion has transitioned from decelerated to accelerated expansion recently. The scenario requires that the axion field be rather near the maximum of its potential, but is less finely tuned than other explanations of cosmic acceleration. The model is parametrized by an axion decay constant \( f = \alpha M_p \) (with \( \alpha \sim 0.1 \) and \( M_p \) the reduced Planck mass), the axion mass \( m \), and an initial misalignment angle \( |\theta_i| \), which is taken to be close to \( \pi \). In order to determine the \( m \) and \( \theta_i \) values consistent with dark energy today, these parameters are mapped onto the observable parameter space of the angular sound horizon at the cosmic microwave background (CMB) surface of last scattering, \( \theta_* \), the Hubble parameter \( H(z) \) at redshift \( z \approx 0.57 \), and the angular diameter distance \( d_A(0.57) \) to the same redshift. Current cosmological data (Planck measurements of CMB temperature anisotropies and measurements of the BAO scale at \( z \approx 0.57 \)) are thus used to constrain the \( \{m, \alpha, \theta_i\} \) parameter space. Parameters of future surveys are then used to assess the extent to which upcoming BAO measurements could push the remaining parameter space into the fine-tuned regime.
String Axiverse

Model A, BOSS

\[
\rho \propto \alpha \cdot \frac{1}{H} \cdot \delta
\]

\[
\alpha = 0.2, 0.4, 0.6, 0.8, 1.0
\]

14/12/2015
Doppler term in the galaxy two-point correlation function: wide-angle, velocity, Doppler lensing and cosmic acceleration effects

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(Dated: December 14, 2015)

We study the parity-odd part (that we shall call Doppler term) of the linear galaxy two-point correlation function that arises from geometry, velocity, doppler lensing and cosmic acceleration effects. As it is important on low redshift and at large galaxy separations, the Doppler term is usually neglected in the current generation of galaxy surveys. For future wide-angle galaxy surveys such as Euclid, SPHEREx and SKA, however, we show that the Doppler term must be included. The effect of these terms is dominated by the magnification due to relativistic aberration effects and it generally mimics the effect from the local type primordial non-Gaussianity with the effective nonlinearity parameter $f_{\text{NL}}^{\text{eff}}$ of a few; we show that this would affect forecasts on measurements of $f_{\text{NL}}$ at low-redshift. Our results show that a survey at low redshift with large number density over a wide area of the sky could detect the Doppler term with a signal-to-noise ratio of $\sim 1 - 20$, depending on survey specifications and the value of magnification bias.
Doppler

wide angle!
\[ \delta^S(\mathbf{r}) = \delta^R(\mathbf{r}) - \left( \frac{\partial v_r}{\partial r} + \frac{\alpha(\mathbf{r})v_r}{r} \right) \]

\[ P^s(k, \mu) = \left[ (1 + \beta \mu^2)^2 + \left( \frac{\alpha \beta \mu}{k \chi} \right)^2 \right] P^r(k) \]
\[ \alpha_1 = 2 - b_e \frac{H(z) \chi(z)}{(1 + z)} \]

\[ \alpha_2 = 2 Q(z) \left[ \frac{H(z) \chi(z)}{(1 + z)} - 1 \right] \]

\[ \alpha_3 = \frac{H(z) \chi(z)}{(1 + z)} \left[ 1 - \frac{3}{2} \Omega_m(z) \right] \]
$P(k) \propto \alpha, f_{\text{NL}} = 0$

$P(k) \propto \text{Kaiser, } f_{\text{NL}} = 0$

$P(k) \propto \text{Kaiser, } f_{\text{NL}} = 0.5$

$P(k_{\perp}, z=0.1)$

\[10^4 \leq P(k) \leq 10^5\]

$10^{-3} \leq k \leq 10^{-1}$
\[ P(k_{\perp}, z=0.9) \]

- \( P(k) \mid \alpha, f_{\text{NL}} = 0 \)
- \( P(k) \mid \text{Kaiser, } f_{\text{NL}} = 0 \)
- \( P(k) \mid \text{Kaiser, } f_{\text{NL}} = 5 \)
Doppler

SNR, z=0.1

SNR, z=1.1

Alvise Raccanelli

JOHNS HOPKINS UNIVERSITY

14/12/2015
Future Surveys
Future Surveys

Deep: PFS, WFIRST
Future Surveys

Deep: PFS, WFIRST

Wide: SPHEREx
Future Surveys

Deep: PFS, WFIRST

Wide: SPHEREx

Deep and Wide: EMU, SKA
SPHEREx: An All-Sky Spectral Survey

Designed to Explore
- The Origin of the Universe
- The Origin and History of Galaxies
- The Origin of Water in Planetary Systems

The First All-Sky Near-IR Spectral Survey
A Rich Legacy Archive for the Astronomy Community with 100s of Millions of Stars and Galaxies

Low-Risk Implementation
- Single Observing Mode
- No Moving Parts
- Large Technical & Scientific Margins
Non-Gaussianity distinguishes between multi- and single-field models.

Projected SPHEREx sensitivity is $\delta f_{NL} < 1$ (2$\sigma$) - Two independent tests via power spectrum and bispectrum.

Competitively tests running of the spectral index.

SPHEREx low-redshift catalog is complementary for dark energy.
## ASKAP - EMU

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<thead>
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<th>Name</th>
<th>Telescope</th>
<th>Area (deg(^2))</th>
<th>Resolution</th>
<th>Sensitivity</th>
<th>No of gals</th>
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<tr>
<td>ATLAS</td>
<td>ATCA</td>
<td>7</td>
<td>10”</td>
<td>15 uJy</td>
<td>6000</td>
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<tr>
<td>ATLAS-SPT</td>
<td>ATCA</td>
<td>100</td>
<td>10”</td>
<td>40 uJy</td>
<td>30,000</td>
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<tr>
<td>EMU (early)</td>
<td>ASKAP</td>
<td>1000</td>
<td>10”</td>
<td>30 uJy</td>
<td>500,000</td>
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<td>ASKAP</td>
<td>31,000</td>
<td>10”</td>
<td>10 uJy</td>
<td>70,000,000</td>
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</table>

- ATLAS is finished
- ATLAS-SPT is underway
- EMU-early will start late 2015/early 2016
- EMU-full will start late 2016?
Thank You