

Cosmology and Cosmic Dawn

Science questions and how RMS astro will address them for the next decade

<http://tinyurl.com/qylyb63>

Primordial cosmology

Is Inflation correct? Did its quantum fluctuations produce primordial gravitational waves at levels corresponding to a simple slow rolling GUT-scale field?

- Inflationary **Gravitational waves**: by 2020, we will know if $r > 0.01$.
 - **CMB B-mode** measurements in the next decade from ground, balloon, and satellites will make the definitive measurements of $r > 0.001$ (key region of parameter space).
- Does the **spectrum** of initial fluctuations give us clues to the physics that drove their production?
 - 21cm measurements of Dark Ages, LSS surveys, mu-type spectral distortions
- Are deviations from **Gaussianity** in the initial fluctuations detectable, revealing physics of the Inflationary action?
 - CMB is now saturated, so future progress will come from **LSS surveys, EOR**

Relativistic/non-relativistic content of the universe:

Neutrinos: mass; number and type of species -

Neutrinos are second most abundant particle in universe (after photons). Their non-zero masses arise from physics outside the standard model; fully understanding their physics is essential to fundamental understanding of matter and processes such as baryogenesis. Transition from relativistic to non-relativistic epoch depends on mass and affects the evolution of structure. Tests physics beyond the standard model.

-- Probes: CMB (uniquely N_{eff}), CMB lensing, LSS

Baryons: density, mass fraction - Comparison of measurements of baryons in astronomical sources, CMB and nucleosynthesis. Probes thermal history of universe.

Dark matter: density, mass - Probes: CMB, LSS, 21 cm, intensity mapping, radio synchrotron, particle physics experiments, galaxy clusters

Cosmic Acceleration: Dark Energy and modified GR

What is the physics driving the present acceleration of the universe? Can we distinguish between Dark Energy and Modified Gravity? Both can fit the expansion history, but can be distinguished by measurements of the growth of structure.

- In coming decade, measures of growth of structure (cross correlation of surveys) and evolution of velocity field (kSZ) will join SNe, BAO, cluster abundance, and lensing as primary probe of DE/acceleration physics.
- Probes: LSS surveys, intensity mapping, SZ cluster counts, CMB

RMS Complementarity: Direct meas. of H_0 , τ

How accurately can direct RMS measurements constrain standard parameters including the **current expansion rate** and **optical depth** to the early universe?

- Independent measurements of H_0 and τ powerfully complement upcoming CMB surveys, enabling accurate cosmology.
- Direct H_0 measurements from strong lensing, megamasers and cosmic sirens may help improve current measurements from $\sim 3\%$ level to 1% in next decade.
- Direct EOR measurements can constrain τ (optical depth to recombination), breaking degeneracies in CMB cosmological parameters determinations.
- These H_0 and τ constraints could improve precision of sum of neutrino mass, N_{eff} , and w by large factors (>2), which could prove decisive.

Dark Ages, Dawn, & Reionization

- Nature of Dark Matter
 - Does Dark Matter annihilate?
 - Does it have a warm component?
- Early Stars
 - Distribution along the Dark Matter Halo mass function
 - Time of collapse
 - Lifetime
 - Spectrum
 - Metals enrichment
 - Contributions to ionization
 - Feedback (e.g., sterilization of haloes)
- Blackhole formation and growth
 - When did first IMBH black holes appear?
 - How did the initial seeds become late time SMBHs?
 - How did BH's contribute to ionization and IGM heating?

Dark Ages, Dawn, & Reionization

- Properties, timing of first galaxies
 - Timing of widespread star formation
 - What contributed to the ionizing background?
 - What was the high-z galaxy luminosity function?
 - What was the radiation f-escape vs halo mass?
 - What was the ionization fraction as a function of redshift?
 - Nature of feedback in galaxy evolution
 - History of chemical enrichment in galaxies & ISM
 - probed with high-z GRBs
 - probed by CO, C+ intensity mapping
 - How do SMBHs and host galaxies coevolve?
- Cosmological Magnetic Fields
 - Are primordial magnetic fields present?
 - How did magnetic fields influence the evolution of large scale structure and early star formation?
- Requirements

OLD MATERIAL

Large Scale Structure: Growth and Evolution

Can we track the growth and development of large scale structure through

- intensity mapping (21cm, CO, C+, H α , OIII, Ly α ,...)
 - Dark Ages (z~15-100): 21cm
 - EOR (z ~ 6 - 15): 21 cm, C+
 - Dark Energy Epoch (z~1-3): 21cm, CO, C+, H α , OIII, Ly α
 - value contingent on departure from vanilla models
- galaxy surveys (optical, IR, mm, 21cm,)
 - concerns of bias, complementarity of bias

CMB lensing

gkSGZ will be a core DE probWith CMB lensing, and SZ cluster counts

Document Map

- Cosmology
 - Initial Conditions
 - Gaussianity
 - IGW
 - Thermal history / Spectral distortions
 - Growth of Structure
 - Cosmic Acceleration / modifications to gravity
 - Nature of Dark Matter
 - Growth of Gravitational potentials
 - Size/Shape of universe
 - direct H_0 measurement
 - large surveys
 - removing degeneracies in current probes (τ)
 - Matter
 - Neutrinos
- Dark Ages + Reionization = Cosmic Dawn
 - What heating sources of IGM?
 - Dark Matter
 - First Stars
 - Black hole formation and growth (stellar mass, quasar)
 - Properties, timing of first galaxies
 - timing of widespread star formation
 - nature of feedback in galaxy evolution
 - Cosmological Magnetic Fields

- Dark Ages, Dawn & Reionization
 - Nature of Dark Matter
 - does Dark Matter annihilate?
 - does it have a warm component?
 - Nature of First Stars: time of collapse, lifetime, spectrum, metal distribution, contributions to ionization, feedback
 - how did early stars cool enough to collapse?
 - when did PopIII stars ignite?
 - how did metals spread through IGM?
 - how long until PopII began?
 - how much did first stars contribute to ionizing budget?
 - efficiency for PopIII and PopII star formation?
 - what feedback on star formation?
 - when did Ly-alpha emission begin?
 - when did Xray emission begin?
 - hardness of Xray emission?
 - Black hole formation and growth:
 - when did first SMBH ($>10^4$ Msun) black holes appear?
 - when seeds for what became SMBH (direct collapse of 10^5 Msun or merging from stellar mass)?
 - contribution to ionization and heating?
 - hardness of xray spectra?

Dark Ages, Dawn, & Reionization

- Properties, timing of first galaxies
 - Timing of widespread star formation
 - What contributed to the ionizing background?
 - What was the high-z galaxy luminosity function?
 - What was escape fraction as a function of halo mass?
 - What was the ionization fraction as a function of redshift?
 - nature of feedback in galaxy evolution
 - History of chemical enrichment in galaxies & ISM
 - probed with high-z GRBs
 - probed by CO, C+ intensity mapping
 - Why did escape fraction evolve? (how did enough photons leak out to ionize?)
 - How do SMBHs and host galaxies coevolve?
- Cosmological Magnetic Fields
 - Are primordial magnetic fields present?
 - How did magnetic fields influence the evolution of large scale structure and early star formation?