First Light And Reionization

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Sovier leaders would love reionization – it is a field where every 5 years something interesting happens.
SDSS Quasars ~ 2005

- SDSS quasars are unambiguous – reionization ended at $z \approx 6$. 
UV luminosity functions are measured all the way to $z \sim 9$. 
Tension between WMAP Thompson optical depth measurement and observed UV LFs is still with us.

Depending on the Planck results, it may or may not remain after ~2015...
Redshifted 21 cm ~ 2015

- Precision Array for Probing the Epoch of Reionization (PAPER)
- Murchison Widefield Array (MWA)
- ...
Overcoming real-world obstacles in 21 cm power spectrum estimation: A method demonstration and results from early Murchison Widefield Array data


New Limits on 21cm EoR From PAPER-32 Consistent with an X-Ray Heated IGM at z=7.7

Redshifted 21 cm ~ 2015

3 orders of magnitude passed.

1 to go…
Redshifted 21 cm ~ 2015

- Progress in measuring the redshifted 21 cm is mind-blowing.
- \( \frac{3}{4} \) of the way already passed with \(~50\%\) reduced funding.
- The actual detection by \(~2015\) is likely.
Theory ~ 2005

- Small boxes
- Hydrodynamics
- Self-consistent RT

- Large boxes
- N-body
- RT in post-processing
Theory ~ 2010

- Small boxes
- Hydrodynamics
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Theory ~ 2015

An Insatiable Need For Computing

Weather Prediction

Genomics Research

Medical Imaging

Forecast

Exascale Problems Cannot Be Solved Using the Computing Power Available Today

Source: www.top500.org
- Sustained peta-scale computing is what needed to jump-start the reionization theory.
- With such computing power, one can run hydro simulations with the fully self-consistent RT in 100 Mpc boxes.
CROC Project

(Tacconi et al 2013)

- Star formation based on the observed molecular Kennicutt-Schmidt relation.
- Standard ("blastwave") feedback model.
- Up to 200,000 dynamic range with AMR.
- Fully self-consistent RT.
CROC Project

- UV luminosity functions
- IGM opacity
Two big guys on the block: JWST and GMT.

By ~2020 we should have:

- Detection of 21 cm signal and the measurement of the 21 cm power spectrum over ~ 1 dex in wavenumber; perhaps, images of a few large HII regions around brightest quasars.
- Detailed numerical simulations that model ~100 Mpc boxes with ~10 pc resolution, resolving galactic disks and the escape of ionizing radiation from star-forming regions.
“21 cm tomography” – matching HII regions to their source galaxies (and yes, hemisphere does matter, MWA & PAPER are in the south):

- relative escape fractions
- with proper modeling – clustering of galaxies and gas
- possibly, in large enough HII regions, constraints on the non-stellar/non-AGN ionizing sources (like DM annihilation)
Let’s Dream! ~ 2020

- Spectroscopy: detailed studies of proximity zones around large quasars:
  - properties of host halos of quasars
  - properties of surrounding IGM (albeit a highly biased part of the universe)

- Spectroscopy: constraining the evolution of the (bright end of the QSO) luminosity function:
  - time-scales for supermassive black hole growth
  - perhaps, constraints on seed masses
Let’s Dream! ~ 2020

- Spectroscopy: metal pollution in the IGM
- Evolution and clustering of Lyman-α emitters:
  - dust abundance in first galaxies (the only place where dust formation/destruction timescales matter)
  - extra clustering of Lyman-α emitters due to foreground absorption (?)
- Other cool stuff someone smart will come with...
Conclusions

- Reionization studies are like Roman legions: steady and unstoppable.
- The rest of this decade will see it becoming multi-wavelength (with multi = 2) – there is little doubt that redshifted 21 cm signal will be detected in the next 2-3 years (barring some major economic crisis).
- GMT and, to a lesser extent, JWST will be instrumental in complimenting radio (gas) with studies of infrared (stars).
The End