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THE EULER CHARACTERISTIC AS A MEASURE OF THE TOPOLOGY OF COSMIC REIONIZATION

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RESUMEN

Presentamos una introducción al uso de la Característica de Euler en simulaciones a gran escala de la época de la reionización cósmica. Para caracterizar la topología del campo de la fracción de ionización, hemos calculado la evolución de su Característica de Euler. Nuestros resultados indican que la evolución de la topología durante la primera mitad de la reionización cósmica, es consistente con la reionización de dentro hacia afuera de un campo de densidad (log) Gaussiano.

ABSTRACT

We present here an introduction to the use of the Euler Characteristic in large-scale simulations of cosmic reionization. To characterize the topology of the ionization fraction field, we calculate the evolution of its Euler Characteristic. We find that the evolution of the topology during the first half of reionization is consistent with inside-out reionization of a (log) Gaussian density field.

Key Words: cosmology: theory — H II regions — methods: numerical

1. INTRODUCTION TO COSMIC REIONIZATION

The epoch of cosmic reionization (EoR) begins with the formation of the first sources of light and ends at the time where most of the intergalactic medium (IGM) is ionized. There are mainly two observations constraining the EoR: The enhanced polarization in the cosmic microwave background (CMB) radiation at large angular scales (resulting from Thompson scattering of the photons off free electrons) and the absence of the Gun-Peterson through in high-redshift quasar spectra (no complete absorption of quasar light bluewards of the Lyα(H) emission line).

If cosmic reionization would be a step function in time, the redshift z of transition can be calculated from the polarization power spectrum of the CMB. The value according to the 5 year WMAP observations is $z \approx 10.9 \pm 1.4$ (Komatsu etal. 2009). The quasar spectra obtained within the Sloan Digital Sky Survey (SDSS) indicate a low, but rapidly rising neutral fraction around $z \sim 6$ (e.g. Willott et al. 2007). The combination of these measurements suggests an extended EoR.

Upcoming 21cm experiments (GMRT[5], LOFAR[6], MWA[7], to name a few), will be able to observe the EoR directly.

1.1. *Simulating Cosmic Reionization*

In a typical EoR simulation, there are five steps:
(1) N-body dark matter (DM) only simulation to get the density field as a function of redshift,
(2) assume gas follows DM → gas-density field,
(3) identify halos,
(4) assign luminosity to halos,
(5) trace ionizing radiation through IGM & ionize.

For step (1), we use the CubeP^{3}M code which was developed from the PMFAST code (Merz, Pen, & Trac 2005), see Iliev et al. (2008). The simulation uses 1024^3 particles and 2048^3 cells, which imply a particle mass of $5.1 \times 10^6\ M_\odot$. The minimum resolved halo mass is $10^8\ M_\odot$ which is approximately the minimum mass of halos able to cool by atomic hydrogen cooling. The cosmological parameters used were for a flat ΛCDM universe with $(\Omega_m, \Omega_b, h, n, \sigma_8) = (0.27, 0.044, 0.7, 0.96, 0.8)$.

Step (5) is performed using the C^2-Ray method (Mellema et al. 2006) on a uniform rectilinear grid

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[5]Giant Metrewave Telescope, `http://gmrt.ncra.tifr.res.in`.

[6]Low Frequency Array, `www.lofar.org`.

[7]Murchison Widefield Array, `www.mwatelescope.org`.