RESEARCH PROPOSAL

Title :

Could Dark Energy Cause a Big Rip? Observational Constraints, Theoretical Models and End- 0f – Universe Scenarios

Objective of the Proposal :

We propose a combined theoretical, computational and observational investigation into the viability of the " Big Rip" scenario, in which phantom dark energy (equation of state Parameter ($\omega < -1$) causes the cosmic scale factor to diverge in finite proper time, destroying bound structures from galaxy clusters down to atoms. The project will

derive robust analytic conditions for a finite time singularity under general dark energy parametrizations ,

perform cosmological simulations to track structure disruption under phantom expansion histories and

constrain the relevant parameter space with present and near-term observations (Type Ia supernovae, BAO,CMB, redshift space distortions and standard siren gravitational wave measurements).

The work will produce updated limits on www and its time dependence, simulated timelines for disaaembly of bound systems as a function of dark – energy parameters and observational strategies to decisively rule in /out parameter regions leading to a Big Rip within astrophysically relavent timescales.

Back ground and Motivation:

Dark energy drives the accelerated expansion of the universe. The simplest model ΔCDM uses a cosmological constant with $\omega = -1$.

If dark energy is " phantom " with constant $\omega < -1$, the energy density increases with time and the scale factor can diverge at a finite future time ,the so called Big Rip.

Determing whether a Big Rip is possible requires both (i) precise constraints on www and its evolution and (ii) physical modelling of how accelerated expansion disrupts bound systems. This Project unites both.

Key Research Questions :

What is the time line (relative to today) for disruption of structures : galaxy clusers $\rightarrow$ $galaxies \longrightarrow solar\ systems \longrightarrow planets \longrightarrow molecules \longrightarrow atoms$?

What current or near term observations can decisively rule out parameter regions that produce astrophysically relavent Big rip timescales

How robust are these results when including in homogeneities, back reaction, and non trivial dark energy dynamics?

Expected Outcomes :

Analytic Paper : Conditions for finite-time cosmic singularities under general dark- energy parameterizations.

Observational constraints Paper : updated credible regions on dark – energy parameters and explicit probability that a Big Rip occurs before specified times (eg ., 1 Gyr, 10 Gyr, 100 Gyr)

Simulation study : sequence of N body / hydro experiments showing structural disruption stages; timelines for gravitational un binding of typical clusters, galaxies,and planetary systems for benchmark phantom models.

Policy/forecast brief: which near term surveys will most strongly constrain the Big – Rip parameter region.

Public dataset and code repository with simulation snapshots, analytic scripts and posterior samples.

Reference:

1.Riess, A. G. et al. (1998). *Observational Evidence from Supernovae for an Accelerating Universe and a Cosmological Constant.*
Astronomical Journal, 116, 1009.

2.Perlmutter, S. et al. (1999). *Measurements of Ω and Λ from 42 High-Redshift Supernovae.*
Astrophysical Journal, 517, 565.
[DOI: 10.1086/307221]

3. Caldwell, R. R. (2002). *A Phantom Menace? Cosmological consequences of a dark energy component with super-negative equation of state.*
Physics Letters B, 545, 23–29.