News from (/in/about) the dark

Episode 4:

WANTED: Dark matter clustering properties from subgalactic to cosmological scales

Montpellier – May 20-22 2019

Summary

Special thanks to:

Secretary (travel/stay): Lydie Le Clainche
Secretary (logistic): Amel Chennouf

Local dynamics, Galactic dynamics, Gaia (Benoit, Giacomo, James, Simon, Thomas, Mihal, Chervin, Jean-Baptiste)

* Gaia: a new era in precision astrometry
  - total halo mass
  - core vs cusp
  - phase-space distribution
  - test different dark matter properties: clustering on small scales, local density, global density, etc.
  - many new things: local features, minor mergers around the Galactic center, etc.

* Data: look messy at first sight, not so easy to analyze (efficiencies, calibration, systematics, etc.) …

* … But: controlled analytical methods (deriving from CBE) actually powerful to make sense of data!
  - action-angle methods a good way to interpret the stellar population behavior
  - local structure in velocity space understood from perturbed CBE: impact of the (distant) bar can be probed locally!

* … And complemented by numerical experiments
  - Sagittarius stream may also impact on the local velocity fields of stars

* … Streams! Constraints on global halo shape/potential + subhalos to come

* Back to f_0 (unperturbed DF)
  - minimal (spherical symmetry + isotropy) self-consistent analytical methods (improved Eddington) in ~10% agreement wrt zoom-in simulations for DM velocity moments
  - can be improved to account for axisymmetry, or rotating halos

* Theoretical improvement in dynamical stability studies (analytical methods)
  - rotating halos → new instabilities found
  - cusps/cores

* Statistical theory
  - well suited to test extra-DM scenarios (small-scale perturbers)
  → Fuzzy DM fluctuations can be treated as effective massive particles: only statistical properties of grav. field matter
  → Scattering off stars induce diffusion => constraints in the ballpark!

LCDM cosmology, small-scale structures, small-scale issues (Annalisa, Arturo, Martin, Gaétan, Raphaël, Kim)

* Cosmological simulations
  - → go bigger 500 Mpc
  - ← go more resolved
  - Baryonic physics based on semi-empirical recipes (gas cooling/heating, stellar evolution, metal enrichment from tables)
  - Absent: radiative transfer, radiation pressure, chemistry
  - Baryonic physics somewhat calibrated on observations
  - Still predictive for non-calibrated observables
  - TNG: core/cusp +diversity issues not yet assessed (when?)

* Stellar formation recipes
  - go from simple to more sophisticated recipes
  - strong differences
  - issue of calibration vs theory / how to rescale subgrid models

* Subhalos: analytical studies (LCDM – can be adapted to any shape of initial power spectrum)
  - analytical models reproduce qualitative features observed in simulations (spatial distribution + properties of subhalos)
  - can go down to free-streaming mass scale!
  - detailed study of tidal shocks induced by baryons: disk shocking, star encounters
  - preliminary: smallest masses ($< 1M_{sun}$) strongly depleted
  - can be fully connected to effective particle physics models

* Subhalos / satellite galaxies: numerical studies (idealized simulations)
  - understand evolution of infalling subhalos
  - very resilient to tides
  - internal structure evolves: some modeling available
  - make sense of some observations: anticorrelation between inner density of dwarves and pericenter

* Small-scale issues: SIDM
  - no longer the core-cusp pb → core-cup problem ;-) (a new prediction: SIDM turns cusps into cups!)
  - solve the diversity problem
  - Interesting new feature pointed out: core collapse + phase diagram

Dark ages, first stars, Ly-alpha, 21 cm (Riccardo, Laura, Yuxiang)

* Ly-alpha
    - improved analysis extending capability to capture different shapes in the power spectrum
    - very strong constraints on models that truncate the power spectrum (WDM, fuzzy DM)

* 21 cm and dark matter
    - WIMPs are more complex than a cross section (mediators, mass degeneracies in exotic particle spectrum)
    - use of 21cmfast
    - impact of DM on reionization
    - important role of DM clustering on small scales

* 21 cm and first stars
    - a very complex problem (treat mean free path of photons of different energies in cosmological volumes with forming galaxies)
    - a lot of recent improvements to include the impact of small halos
    - future improvement will rely on balance between inputs from cosmological simulations and semi-analytical models
    - 21 cm as a future constraint on structure formation (luminosity functions, etc.)

Scalar field cosmology: primordial black holes and time-dependent (Sébastien, Tristan)

* PBHs
    - we are all coming from PBH ejecta!
    - a new scenario for baryogenesis: relies on spectator scalar field (e.g. the axion field)
    - anthropic selection in the field parameter space:
    - should be careful with observational constraints (e.g. impact of clustering)

* Scalar fields in cosmology
    - often considered as artificial patches, but actually very constrained, and cannot lead to arbitrary predictions
    - a new theory for understanding swings ;-) … and cosmological features (e.g. Hubble tension)

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Mille mercis pour votre participation et vos contributions !

News from the Dark – Next
2020: Strasbourg (TBC)
2021: Annecy (TBC)
2022: Montpellier
stay tuned...