Galaxy and cluster clustering

ongoing activities and general numerical issues

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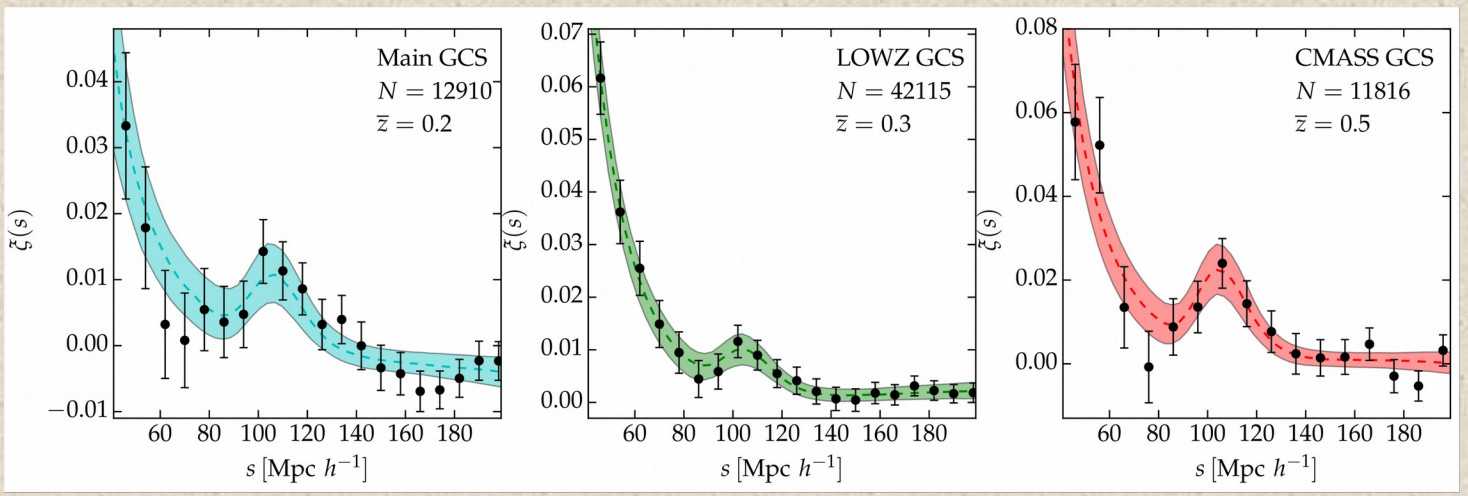
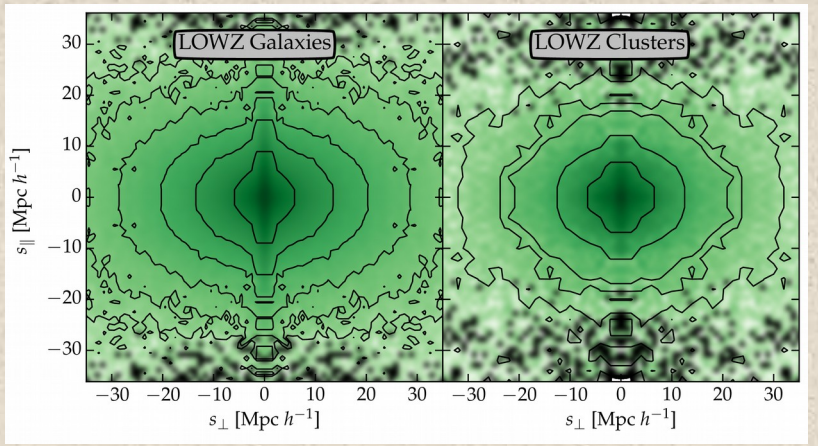
Clustering in Italy

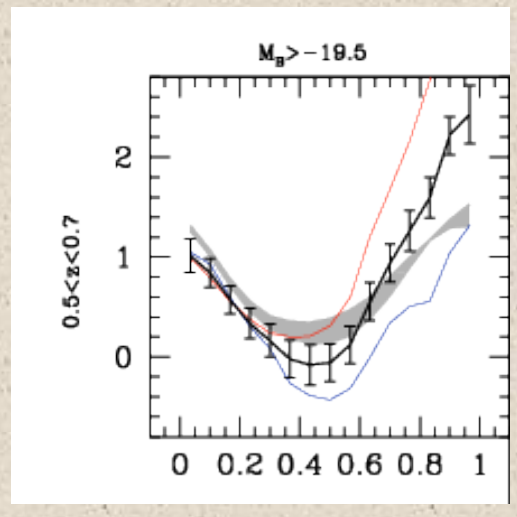
- An increasingly large community in Italy is working on clustering
- This interest has been triggered mainly by the large galaxy surveys in which Italian researchers are involved, such as VIPERS (PI Guzzo), and planned future missions, such as Euclid
- Cosmology with clustering: clustering shape, baryon acoustic oscillations, redshift-space distortions, Alcock-Paczynski test, higher-order statistics, etc.
- Galaxy evolution with clustering: constraints on semi-analytic models, bias, clustering as a function of tracer properties, AGN hosts and lifetime, etc.

2-point and 3-point correlation functions

Veropalumbo, Marulli et al. 2014-2016 ; Moresco, Marulli et al. 2016

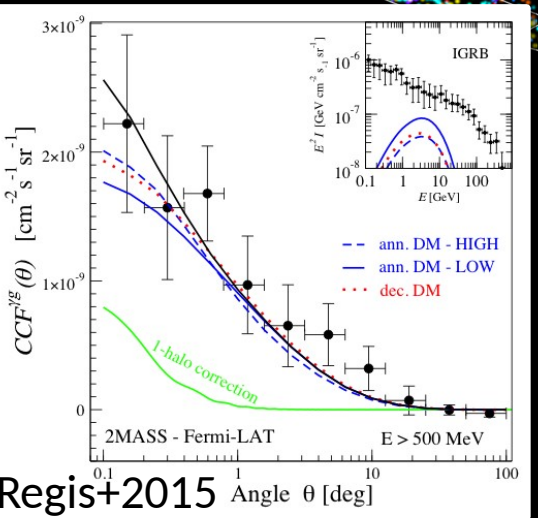






X-correlation with LSS: e.g. Fermi γ-ray background vs. 2MASS

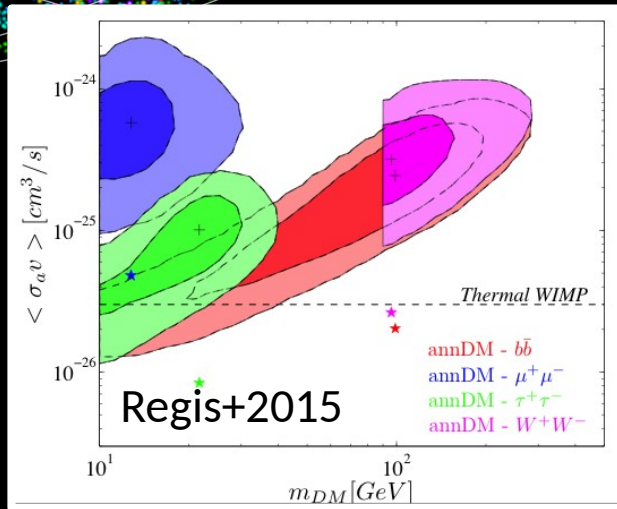
$$CCF(\vartheta) = \langle \delta I(\alpha)\delta N(\alpha+\vartheta) \rangle$$



Regis+2015

Measured x-correlation
vs. DM-annihilation model

Constraints on DM particle
Mass and x-section



Activities for the next future

- The aim is to extend these works to analyse the huge datasets that will be provided by the next-generation missions, like Euclid

- This represents a big challenge, both in terms of the implementation of statistical methods to analyse these large datasets, and for what concerns the modelling, with sufficient accuracy, of the measured quantities as a function of the cosmological model to be tested

Clustering in Euclid

Science Working Group

- Luigi Guzzo
- Will Percival
- Yun Wang

Organisation Unit - LE3

- Jean-Luc Starck
- Enzo Branchini
- Filipe Abdalla

Implementation and validation of numerical codes to measure the clustering of galaxies and clusters of galaxies

- two-point correlation function

  galaxy: de la Torre
  clusters: de la Torre, Marulli
- power spectrum

  galaxy: Balaguera-Antolinez
  clusters: Balaguera-Antolinez, Marulli
- three-point correlation function

  galaxy: Moresco
  clusters: Moresco, Marulli
- bispectrum

  galaxy: Porciani
  clusters: Porciani, Marulli
- covariance matrices of two-point correlation function and power spectrum

  galaxy: Monaco
  clusters: Hoyle

Numerical issues

In the recent past:

- one single code developer, or few (often developer = user) → no need for any specific code language, numerical libraries, operating systems, etc.
- software: few lines of code → simple linear structure, no need for object-oriented languages (e.g. Fortran was ok)
- hardware: 1 CPU → scalar codes ; no need to parallelize or aggressively optimize the algorithms
- no big issues on validation and documentation → a Readme file was enough
- one or few specific tasks for a single code → one code language was ok, no need for code integrations (no wrapper needed to convert from one language to another)

Numerical issues

Now and in the next future:

- many code developers working together → need of collaborative environments (e.g. CODEEN for Euclid) and common repositories to organise the activities (e.g. SVN, GitHub)
- software: huge number of code lines → object-oriented languages are now highly recommended (e.g. C++, Python)
- hardware: thousands of CPUs → codes have to be parallelized and optimized to run on large clusters in order to analyse increasingly large datasets
- significant efforts on validation and documentation (e.g. doxygen)
- many tasks to be accomplished → wrapper needed to connect codes written in different languages (e.g. SWIG)

What is required

→ astronomers have to develop complex numerical codes, that cannot be implemented by software engineers (scientific knowledges are required)

→ high-level computing skills are required : object-oriented languages, collaborative environments, parallelization, optimization, documentation, etc.

→ many work hours are needed for code implementation and validation

→ huge computing resources are mandatory to optimize, parallelize and validate the algorithms, and generate large mock catalogues