UNIVERSITÀ
DEGLI STUDI DI MILANO-BICOCCA

COURSE SYLLABUS

Physics of Galaxy Clusters

86R-XXXV-PGC

Obiettivi

Corso introduttivo alla fisica degli ammassi di galassie.
L'obiettivo principale è quello di fornire una panoramica delle proprietà generali degli ammassi di galassie e dare una base di partenza per eventuali studi più approfonditi sui singoli argomenti.

Contenuti sintetici

Vedi programma esteso

Programma esteso

Title: PHYSICS OF GALAXY CLUSTERS

SETTING THE CONTEXT

- The observed Universe:
- Redshift definition and Hubble-Lemaitre law
- Redshift surveys
- Local Large Scale Structure (LSS): from the Milky-Way to Laniakea
- Definition of Group of Galaxies, Cluster of Galaxies, Supercluster, Void
- The primordial Universe and brief Universe's history
- The simulated Universe: simulations of the LSS
- Motivation for the study of galaxy clusters

A MULTI-WAVELENGTH VIEW

- Hubble Diagram and the galactic content in clusters
- Morphology - density relation of galaxies
- Optical Cluster Catalogues and morphological classification from galactic content
- Total mass of clusters from the dynamics of the galaxies (virial theorem)
- Mass-to-light ratio
- Rotation curves in Sp galaxies
- Gravitational lenses: strong and weak lensing effect
- Introduction to the X-Ray Astronomy for galaxy clusters
- Properties of the Intra-Cluster Medium (ICM; cooling, heating)
- X-ray spectra of clusters
- Total mass from the ICM temperature and density profiles
- Matter composition of galaxy clusters
- Baryonic mass fraction
- Clusters mass function
- ICM entropy
- Metal content in the ICM and enrichment mechanisms

COOL-CORE CLUSTERS

- The core properties of dynamically relaxed clusters:
- Cooling time, density, temperature profiles
- Brightest Clusters Galaxies (BCG)
- Cooling flow and gas flow suppression (AGN feedback)
- Spitzer thermal conduction and turbulence
- Fate of the cooling gas

MERGERS IN CLUSTERS

- Properties of the dynamically un-relaxed clusters
- Mergers shocks: the Bullet cluster
- Shock kinematic, Rankine-Hugoniot jump conditions
- Energetic of clusters mergers
- Cold Fronts in un-relaxed clusters: merger cold fronts
- Cold fronts in relaxed clusters: gas sloshing
- Diffuse radio emission in clusters: halos, relics, mini-halos
- Group scale accretion in clusters outskirts
- Missing baryon problem and cluster outskirts

Prerequisiti

Modalità didattica

Video lezioni pre-registrate

Materiale didattico

BIBLIOGRAFIA UTILE PER APPROFONDIMENTI

Una panoramica generale sugli ammassi

Schneider P. 2016, "Extragalactic Astronomy and Cosmology - an Introduction", http://www.bruzual.org/~gbruzual/direccion/libro.pdf

Review generale (un po' datata per la parte osservativa, ma ottima per la parte fisica)

Sarazin C. 1988, "X-ray emission from clusters of galaxies", http://ned.ipac.caltech.edu/level5/March02/Sarazin/frames.html

Gli ammassi nei raggi X

Boehringer & Werner 2009 "X-ray Spectroscopy of Galaxy Clusters" https://arxiv.org/pdf/0907.4277.pdf

Review storica sugli ammassi

Biviano. A. 2000, "From Messier to Abell: 200 years of science with Galaxy Clusters", https://arxiv.org/abs/astro-ph/0010409

Simulazioni cosmologiche e formazione degli ammassi

Borgani & Kravtsov 2009, "Cosmological simulations of galaxy clusters", http://arxiv.org/abs/0906.4370

Kravtsov & Borgani 2012, "Formation of galaxy clusters", https://www.annualreviews.org/doi/pdf/10.1146/annurev-astro-081811-125502

Misura di massa da lenti gravitazionali

Hoekstra et al. 2013, “Masses of galaxy clusters from gravitational lensing”, https://arxiv.org/pdf/1303.3274.pdf

La metallicità del gas X

Mernier et al. 2018, "Enrichment of the hot intracluster medium: observations", https://arxiv.org/pdf/1811.01967.pdf

Fisica dei cool-cores

Peterson & Fabian 2006, "Xray spectroscopy of Cooling Clusters", https://arxiv.org/pdf/astro-ph/0512549.pdf

AGN feedback nei cool-cores

McNamara & Nulsen 2012, “Mechanical feedback from active galactic nuclei in galaxies, groups and clusters”, https://arxiv.org/pdf/1204.0006.pdf, https://iopscience.iop.org/article/10.1088/1367-2630/14/5/055023/pdf

Voit & Donahue 2005, "Cooling time, freefall time and precipitation in the cores of ACCEPT galaxy clusters", https://iopscience.iop.org/article/10.1088/2041-8205/799/1/L1/pdf

Gaspari, Tombesi & Cappi 2020, "Linking macro-, meso- and microscales in multiphase AGN feeding

and feedback" (utili anche le referenze nel paper), https://arxiv.org/pdf/2001.04985.pdf

Cluster mergers

Sarazin 2001, "The Physics of Cluster Mergers", https://cds.cern.ch/record/501265/files/0105418.pdf

Shock e cold front negli ammassi

Markevitch & Vikhlinin 2007, "Shocks and cold fronts in Galaxy Clusters", https://arxiv.org/abs/astro-ph/0701821

Il primo articolo sull'ammasso Pallottola

Markevitch et al. 2002, "A Textbook Example of a Bow Shock in the Merging Galaxy Cluster 1E 0657–56", https://iopscience.iop.org/article/10.1086/339619

La prima misura di massa del Bullet dalle lenti gravitazionali

Clowe et al. 2006, "A Direct Empirical Proof of the Existence of Dark Matter", https://iopscience.iop.org/article/10.1086/508162

Cold front (observations and simulations)

ZuHone & Roediger 2016, "Cold fronts: probes of plasma astrophysics in galaxy clusters" https://www.cambridge.org/core/services/aop-cambridge-core/content/view/S0022377816000544

Diffuse radio emission in clusters

Feretti et al. 2012, "Clusters of galaxies: observational properties of the diffuse radio emission", http://www.ira.inaf.it/~ggiovann/mio/review.pdf

van Weeren et al. 2019, "Diffuse Radio Emission from Galaxy Clusters", https://arxiv.org/pdf/1901.04496.pdf, https://link.springer.com/content/pdf/10.1007/s11214-019-0584-z.pdf

Periodo di erogazione dell'insegnamento

Marzo-Aprile 2020

Modalità di verifica del profitto e valutazione

Esame orale

Orario di ricevimento

Per ogni informazione o domanda relativa al corso e/o agli argomenti svolti, contattare la docente direttamente all'indirizzo e-mail sabrina.degrandi@inaf.it