FISHING FOR JELLYFISH GALAXIES

■ Jellyfish galaxies are extremely fast-moving galaxies which blast through the centres of galaxy clusters, causing material to be dislodged and removed,sometimes producing spectacular tails of material which trail behind the galaxy.

■ This stripped gas trailing behind the disc of a galaxy can give the appearance of a jellyfish, hence the name "Jellyfish Galaxy".

■ These galaxies are fairly rare,but with large surveys of astronomical data available, many of them could already be observed, and are just waiting to be identified.

CLASSIFYING JELLYFISH GALAXIES

■ A jellyfish galaxy is a type of galaxy found in galaxy clusters. They are characterised by ram pressure stripping of gas from the affected galaxy by the intracluster medium.

■ They are assymetric in appearance.

■ They have important features like Tales, Spiral arms, Unwinding spiral arms, Merging.

IMPORTANT FEATURES

■When a fast-moving galaxy enters a galaxy cluster, the gas within the cluster can exert a "drag" force on the galaxy, known as Ram-Pressure.

■ If this drag is strong enough, the galaxy’s own gas can be pushed and ultimately removed, potentially trailing behind as a tail.

■ During extreme interactions, the disturbance to the gas can ignite a short burst of star formation

FEATURES OF TAILS

■ Tails of material are strong indicators that a galaxy is experiencing stripping.

■ Ram-pressure strips the gas and dust from a galaxy disc shows signs of a tail, which looks like material being “blown” out of the galaxy.

- In some cases, the unwinding spiral arms might form a tail behind the galaxy
- Some galaxies might be disturbed, or unwinding, but not far enough to resemble a tail (NO Tile).

FAETURES OF SPIRAL ARMS

- A common feature in star forming galaxies is the presence of spiral arms in the disc of the galaxy
- Which appear as bright lanes of material spiralling like pinwheel arms from the centre.

Asymmetry

- Asymmetric appearances are strong indicators that a galaxy is experiencing stripping.
- When a galaxy experiences ram-pressure, the force of the impact pushes a lot of its gas into a trail behind the galaxy. Asymmetry might be evidenced by more material on one side of the galaxy than another, or a brighter appearance to one side of the galaxy.

FEATURES OF UNWINDING SPIRAL ARMS

- The spiral arms of a galaxy can be stripped, causing them to appear to be unwinding Under certain conditions, ram-pressure can effectively "unwind" the arms of a spiral galaxy.
- If they appear looser at the edges, are opening more on one side of the disk than the other, or if some of the spiral arms differ in length or shape from the others, this could be a sign of ram-pressure.

FEATURES OF MERGING GALAXIES

- Galaxies can collide, or approach each other closely enough to gravitationally perturb each other. These disturbances can appear similar to the effects of ram-pressure stripping
- Gravitationally disturbance is usually easy to spot, as there will be a nearby galaxy – often a similar size and usually also showing signs of disturbance.

GALAXY CLUSTERS

■ Galaxy Clusters are the largest gravitationally bound structures in the universe. They are the “cosmic cities” in which the highest concentrations of galaxies in the universe are located.

■ Within a galaxy cluster, the galaxies themselves reside in a large cloud of very hot gas, known as the Intergalactic medium.

REFERENCE

https://www.zooniverse.org/projects/cbellhouse/fishing-for-jellyfish-galaxies/classify

The Astronomy and Astrophysics Review volume 30, Article number: 3 (2022)

Ram pressure stripping in high-density environments

INDRODUCTION

Jellyfish galaxies are extremely fast-moving galaxies which blast through the centres of galaxy clusters, causing material to be dislodged and removed, sometimes producing spectacular tails of material which trail behind the galaxy. These galaxies are fairly rare, but with large surveys of astronomical data available, many of them could already be observed, and are just waiting to be identified.

Galaxies living in rich environments are suffering different perturbations able to drastically affect their evolution. Among these, ram pressurestripping, i.e. the pressure exerted by the hot and dense intracluster medium (ICM) on galaxies moving at high velocity within the cluster gravitational potential well, is a key process able to remove their interstellar medium (ISM)and quench their activity of star formation.

The physical process

High density regions are generally characterised by a hot ($T \sim 10^7 - 10^8$ K)and dense ($nICM \sim 10^{-4} - 10^{-2}$ cm^{-3}) ICM trapped within their gravitationalpotential well (e.g. Sarazin 1986).

The ICM emits X-ray emission with a distribution roughly corresponding to the density squareprojected along the line of sight, extending up to the virial shock. A gas cloud(e.g., a galaxy with the ISM remained) moving with a velocity V relative to theICM suffers a drag force. The drag force (by the ions in the ICM) exerts theram pressure on the cloud that can be written as (when the relative velocityis normal to the cloud surface).

$$\mathbf{P = \rho ICMV^2}$$

which is able to remove the gaseous component of its ISM whenever it overcomes the gravitational forces keeping the gas anchored to the stellar disc of the galaxy.
According to Kuzmin (1956) the gravitational potential Φ of an
infinitely thin stellar disc of radius R at a distance z perpendicular to the discis:

$$\Phi(R, z) =- GMstar/\sqrt{R2(a+z)^2}$$

The condition for stripping the gas at
a given radius R are satisfied whenever

$$\underline{P \geq \Sigma gas|\partial\Phi(R, z)/\partial z| = G\Sigma gasMstar|(a + z)}$$
$$\underline{(R2 + (a + z)^2)^{3/2}|}$$

which occurs at a height zmax from the disc given by $\partial^2\Phi/\partial z^2=0$.
Defining the maximum restoring force above the disc (at given R) as a threshold gives the traditional criterion for instantaneous stripping:

$$\rho ICMV^2\perp >$$
$$2\pi G\Sigma star\Sigma gas=v^2rot\Sigma gas/Rgal$$

The RPS depends on both the properties of the high density region (ρicm), on the motion of the galaxy within it (v , where$V\perp$ indicate the component perpendicular to the galaxy disc plane), and onthe physical properties of the galaxies themselves(σstar, σgas, vrot, and rgal).It is important to underline that ram pressure is an hydrodynamic interactionbetween two different gas phases, the (mainly cold) ism of the perturbedgalaxy with the (mainly hot)ICM. for this reason stars, which have a verysmall cross section to the gas flow and much higher internal pressure than the external ram pressure, are unperturbed during the interaction. second ordereffects, due to the heating of the stellar disc after the stripping of the gaseousdisc, can be present.They can induce a mild change of the orbitsof the stars which produces ultra diffuse discs.These effects on the structure of the stellar disc are expected to bemore important in dwarf systems, where the gravitational potential well of the galaxy is the shallower.

RPS is a general process in astronomy whenever there is a relative bulk motion between a moving object and its surroundings, e.g., mergers of galaxy clusters and groups (elongation and trails on the X-ray morphology), bent radio jets and the stripped ISM at the scale of galaxies, pulsar wind nebulae,stellar wind (including the heliosphere) at the scale of stars and compact objects. RPS can also work on individual stars, especially on those with strong winds. One of the best examples at the scale of stars is the Mira star with a 4 pc tail that is believed to be mainly composed of H2 gas^2.

Properties of high-density regions

The external pressure acting on the disc of spiral galaxies inhabiting clusters depends on two main parameters, the ICM density ρICM that is tied to the ICM gas fraction of the cluster and the velocity of the galaxy with respect to the ICM V that is tied to the cluster mass.Two fundamental properties of clusters are mass and size, which are often connected. While new characteristic sizes of clusters like the mean matter density radius and splashback radius have been proposed (e.g. Kravtsov & Borgani 2012), we still use the virial radius in this work. Particularly, the virial radius adopted in this work is r200 (rΔ as the radius enclosing an overdensity of Δ times the critical density of the Universe at that redshift).

we use several systems with different mass as examples(given below)The dominant mass component in clusters is dark matter (~ 85% of the total mass).

Cluster	Luminosity distance (Mpc).	r200 (Mpc)	M200 (1014 M)	Ref
Virgo	16.5	0.974	1.06	1, 2
Norma	69.6	1.80	6.75	3, 4
Coma	100	1.97	8.90	5, 6
A1367	92.2	1.41	3.26	7, 4

Group	-	0.70	0.39	8

Most baryons in clusters are in the hot ICM emitting X-rays. The classical model on the ICM density profile is the β-model ,with the ICM density proportional to $r^{-3\beta}$ asymptotically beyond the central core. However, a single β-model (or even a double β-model) has been shown to be too simple to describe the ICM density profile, with β typically increasing with radius at the cluster outskirts.

The self-similar relations for properties of galaxy clusters, originally proposed by Kaiser (1986),treat galaxy groups and clusters of different masses as identical objects after scaled by their mass. The useful self-similar relations for this work are summarized here (at a fixed over-density Δ).

Total mass and the ICM mass:

$$M_\Delta \text{ (or } M_{ICM,\Delta}) \propto E(z)^{-1}$$

The ICM properties typically depend on both mass and redshift.

Radius: $r_\Delta \propto M_\Delta^{1/3} E(z)^{-2/3}$

ICM density: $n_e \propto E(z)^2$

ICM temperature: $T \propto M_\Delta^{2/3} E(z)^{2/3}$

ICM pressure: $P \propto n_e T \propto M_\Delta^{2/3} E(z)^{8/3}$

Note that the ICM density is independent of mass with the self-similar assuption. Assuming dark matter particles, ICM and cluster galaxies are all virialized in the same potential,

Galaxy velocity dispersion:

$\sigma_V \propto T^{1/2} \propto M_\Delta^{1/3} E(z)^{1/3}$

The galaxy velocity dispersion is a robust measure of the cluster mass,with the expected self-similar relation. On the other hand, the observed $\sigma_V - T$ correlation is typically steeper than the self-similar relation with an average slope of 0.6 - 0.7.

Using σ_V as the typical velocity of cluster galaxies, ram pressure should follow the same relation as the ICM pressure. The above relation would also suggest the crossing time in the cluster, $2R_\Delta/\sigma_V \propto E(z)^{-1}$,and is independent of the mass. However, the $E(z)^{-1}$ factor simply comes from the definition of the cluster size (r_Δ), also as the free-fall time of the cluster has the same $E(z)^{-1}$ dependency.

The above self-similar relations serve as the simplest model for the ICM mass scaling and evolution, while the actual ICM scaling and evolution can be different from scale-dependent physical processes (e.g:baryonic processes like radiative cooling, AGN feedback and galactic wind) and the fact that some assumptions for the self-similar model are not accurate.Observations have shown the importance of baryon physics,most significant in low-mass systems, e.g:elevated hot gas entropy in low-mass systems, a significant mass dependency on the hot gas fraction from massive galaxies, to galaxy groups and clusters and an observed $L_X - M$ relation steeper than the self-similar relation.

The relations of global properties of the ICM, the efficiency of the micro transport processes in the ICM is also important in the studies of RPS and the associated tails. Giving the low ICM density, the mean free path of particles in the ICM is large

$$\lambda = 23\ (kT_{ICM}/10^8\ K)^2 (n_e/10^{-3}\ cm^{-3})^{-1} kpc$$

This is comparable to the sizes of galaxies. However, magnetic field in the ICM significantly affects the micro transport processes in the ICM.While studies with the Chandra and XMM data on the ICM suggest suppression of heat conductivity and viscosity in the ICM, the most definite constraints require high energy resolution X-ray spectroscopy at arcsec scales, coupled with the high-angular resolution X-ray morphological studies. On the other hand, potentially kinematic and morphological studies of RPS tails can also put constraints on the efficiency of the micro transport processes in the ICM.

Galaxies physical parameters