Exploring the Evolution of Nugget Galaxies Using Neighbors in the RESOLVE Survey

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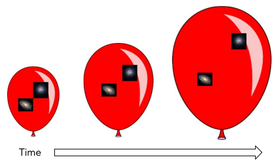
Background [I]

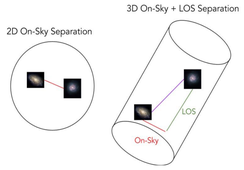
What are galaxies? Galaxies are massive collections of gas, dust, and stars. They are also gravitationally bound by dark matter.

What are galaxy environments? Galaxies are not isolated in space nor do they stay still. Galaxies are often gravitationally bound to each other in different ways (ex: **galaxy groups**) and this causes them to move towards, around, and away from each other, which drives their evolution.

Did you know the universe is expanding?

- Galaxies recede from each other in proportion to distance at recessional velocities
- Light from galaxies becomes redshifted
- Recessional velocities can be measured for individual galaxies or galaxy groups
- Use to calculate line of sight (LOS) distances





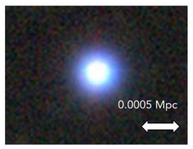
Galaxy Separations and Neighbors

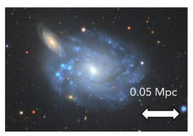
- Metric for studying galaxy environments
- 2D vs 3D – different purposes
- Galaxies in galaxy groups have a lot of different motion, which can mess up recessional velocity measurements

Nugget Galaxies

- Very compact galaxies (small radii given their masses compared to normal galaxies)
- Categorized into **newborn** (highly star-forming), **aging,** and **dead** (no star formation) nuggets
- Newborn nuggets formed through events of intense gas inflow

Exploring the environments of nuggets can help us learn about galaxy evolution.





Methods [II]

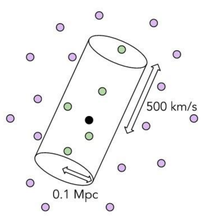
Neighbor Search Methods

Cylinder Search (Neighbor Counts)

- Locates neighbors within cylindrical volume
- Limits face of cylinder to radius of **0.1 Mpc**
- Limits height of cylinder to **500 km/s** redshift of central galaxy (limits LOS distance)
- Computes **2D projected distances**

KD-Tree Search (Nearest Neighbors)

- K-Dimensional Search (in 3 dimensions for us)
- Computes **2D projected distances** for galaxies in the same group and **3D distances** for galaxies in different groups



: Galaxies outside of the cylindrical search
: Galaxies inside of the cylindrical search
: Galaxy we are trying to find neighbors of (at center of cylinder)

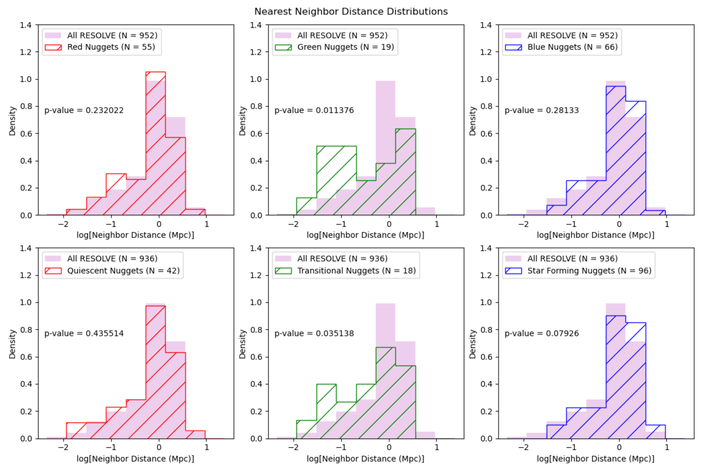
Results [III]

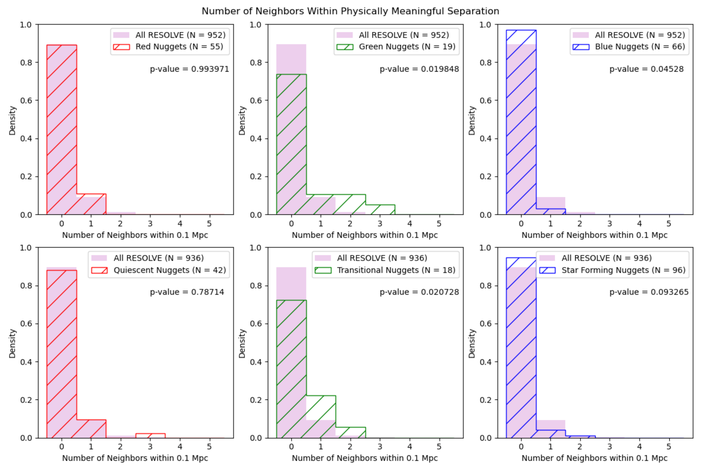
We use galaxies from the REsolved Spectroscopy Of a Local VolumE (RESOLVE) survey, with two samples of nuggets in the local universe classified by color and star-formation rate (SFR) corrected for dust extinction.

	Color	SFR
Newborn	Blue	Star Forming
Aging	Green	Transitional
Dead	Red	Quiescent

Two sets of histograms comparing each nugget type and classification to control samples of non-nuggets with similar selection criteria

- Nearest neighbor distance distributions – Found by KD-Tree Search
- Number of neighbors within physically meaningful distance for interactions – Found from Cylinder Search





Discussion [IV]

We use the Mann-Whitney-U statistical test to determine whether the distributions between nuggets and the RESOLVE control samples are the same or not. Our criteria for two samples being statistically the same are p-values corresponding to confidence above 3σ, or p-values above ~0.002. The p-values in the table below correspond to the probability of the null hypothesis (that two samples are the same) being true.

- P-values corresponding to confidence above 1σ: $p > \sim 0.32$
- P-values corresponding to confidence above 2σ: $p > \sim 0.05$

Nugget Classification	Neighbor Distance Distribution	Number of Neighbors within 0.1 Mpc
Red Nugget	$p = 0.232$	$p = 0.994$
Quiescent Nugget	$p = 0.436$	$p = 0.787$
Green Nugget	$p = 0.011$	$p = 0.020$
Transitional Nugget	$p = 0.035$	$p = 0.021$
Blue Nugget	$p = 0.281$	$p = 0.045$
Star Forming Nugget	$p = 0.079$	$p = 0.093$

Observations from Histograms and p-values:

- **Red/Quiescent Nuggets:** High p-values (majority of which are above 1σ confidence level) indicate the most similarity to the control samples.
- **Green/Transitional Nuggets:** Low p-values (all of which are below 2σ confidence level) indicate the least similarity to the control samples.
- **Blue/Star-Forming Nuggets:** Range of p-values comparing these nuggets to the control samples (all are below 2σ confidence level but one is below 1σ confidence level).

What does this tell us about galaxy evolution with nuggets?

- A theory for nugget formation (especially in the nearby universe) is galaxy mergers, however there is no clear indirect evidence of this because blue/star-forming nuggets do not appear to show greater isolation compared to non-nuggets.

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