Hydro ART simulations sample
Stellar Merger Trees

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CANDELS Theory Workshop - UCSC -
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Collaborators, Daniel Ceverino, Nir Mandelker, Adi Zolotov, Marcello Cacciato, Loren Hoffman, Avishai Dekel, Joel Primack.

AMR simulation hydro ART, (Kratsov, Klypin), 30 zoom-in simulations of high redshift galaxies, spatial resolution 35-70 kpc.

Main focus, VDI, disc evolution, bulge formation.
Sample

http://www.wikihost.org/w/art_hydrocosmosims

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</table>
Stellar Merger trees

Introduction
Galaxy and clump detection
Group finder
Decomposition of the density field into a tree structure
Merger history
Clump tracking

Analysis
Co-rotating clumps?
Origin of the stellar population

Conclusion

How can I help

Gas mosaics
Stellar Merger trees

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Overview

1. Introduction
2. Galaxy and clump detection
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   - Decomposition of the density field into a tree structure
   - Merger history
   - Clump tracking
3. Analysis
   - Co-rotating clumps?
   - Origin of the stellar population
4. Conclusion
5. How can I help
Pipeline

1. Group finding on stellar component: Galaxies, clumps.
2. Merger trees.
3. Analysis: Galaxy evolution, In-situ clump, Ex-situ clump (mergers/interactions)
AdaptaHOP: group-finder algorithm, inspired from SUBFIND and HOP

Written in 2003 by Stéphane Colombi.

 Incorporated to SAM GalICS (Galaxies In Cosmological Simulations) from 2005 as part of the Horizon Project (http://www.projet-horizon.fr/, PI: Romain Teyssier)

Also used to detect clumps in AMR zoom-in simulations Ramses (Devriendt) ART (Tweed).
Basic idea

- Gets a SPH density for each particle $n$ closest neighbors Oct-tree scheme.
- Groups particles around local density maxima.
- Maps those maxima in a structure tree.
- Defines galaxies and clumps from the hierarchy of density peaks.
- Note: Galaxies and clumps are not stripped of unbound particles.
Selection of clumps candidates

- Number of particles: “mass” thresholding.
- Shape selection $\rho_{\text{max}} \alpha > \langle \rho_{\text{node}} \rangle$, size $r > r_\epsilon$.
- Removing Poisson noise,
  $\langle \rho_{\text{node}} \rangle > \rho_t \ast [1 + \text{fudge}/\sqrt{N}]$
- Only topological, no unbinding.
Symbols: filled: local maxima, open: local saddle point
Density distribution = groups of particles around maxima connected by saddle points.
Symbols: filled: local maxima, open: local saddle point
First density thresholding, cut haloes from the background.
\( \rho_t = 80 < \rho_{DM} \) analog to FOF \( b=0.2 \).
Mapping the halo internal structure

Symbols: filled: local maxima, open: local saddle point
Separating local maxima into nodes by increasing density of saddle points
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Separating local maxima into nodes by increasing density of saddle points

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Mapping the halo internal structure

Symbols: filled: local maxima, open: local saddle point
Some density peak might not be isolated as node (low number of particles, Poisson noise)
Merger trees

- Star particles used as tracer.
- One descendent per galaxy/clump
- In-situ clump: no progenitor detected as the separate galaxy.
- Ex-situ clump: at least one progenitor detected as a separate galaxy.
- Merger fraction.
Clump finding, clump tracking.
Stellar Merger trees

Clump finding, clump tracking.

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8/8/2012
Clump finding, clump tracking.

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Clump finding, clump tracking.
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Clump finding, clump tracking.
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Clump finding, clump tracking.
Clump finding, clump tracking.
Clumps co-rotating with the disc.

Visualization in the rotation frame of the galaxy

\[ j_z = L_{\text{star}} \cdot L_{\text{gal}} \quad \text{and} \quad j_{\text{max}} = |r_{\text{star}}| \cdot |v_{\text{star}}| \]
Clumps co-rotating with the disc.

Visualization in the rotation frame of the galaxy

Smooth component + In-situ clumps

\[ j_z = L_{\text{star}} \cdot L_{\text{gal}} \quad \text{and} \quad j_{\text{max}} = |r_{\text{star}}| \cdot |v_{\text{star}}| \]
Clumps co-rotating with the disc.

Visualization in the rotation frame of the galaxy

\[ j_z = L_{\text{star}} \cdot L_{\text{gal}} \quad \text{and} \quad j_{\text{max}} = |r_{\text{star}}| \cdot |v_{\text{star}}| \]
3 criteria classification

1. structural decomposition: (Clump finder), smooth, In-situ clumps, Ex-situ clumps
2. kinematic decomposition: stellar halo, stellar bulge, stellar disc.
3. Stellar origin: (merger trees), star is born in the halo, bulge or disc component, born in a In-situ clump, born ex-situ (merger fraction)
### 3 criteria classification

#### Classification scheme

<table>
<thead>
<tr>
<th></th>
<th>Smooth</th>
<th>In-situ clumps</th>
<th>Ex-situ clumps</th>
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<tbody>
<tr>
<td></td>
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<td>H B D</td>
<td>H B D</td>
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<td>000 010 020</td>
<td>001 011 021</td>
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<td>1:3&lt;f</td>
<td>700 710 720</td>
<td>701 711 721</td>
<td>702 712 722</td>
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</table>
3 criteria classification

Useful fraction for Bulge (j=1) Disc (j=2)

- \( \mu_{\text{IsDisc}}(j) = \sum_{k=0}^{2} m(2jk) / \left( \sum_{i=0}^{7} \sum_{k=0}^{2} m(ijk) \right) \)
- \( \mu_{\text{IsClump}}(j) = \sum_{k=0}^{2} m(3jk) / \left( \sum_{i=0}^{7} \sum_{k=0}^{2} m(ijk) \right) \)
- \( \mu_{\text{Ex-situ}}(j) = \left( \sum_{i=4}^{7} \sum_{k=0}^{2} m(ijk) \right) / \left( \sum_{i=0}^{7} \sum_{k=0}^{2} m(ijk) \right) \)
- \( \mu_{f>10}(j) = \left( \sum_{i=6}^{7} \sum_{k=0}^{2} m(ijk) \right) / \left( \sum_{i=0}^{7} \sum_{k=0}^{2} m(ijk) \right) \)
- \( \mu_{3}(j) = \left( \sum_{k=0}^{2} m(7jk) \right) / \left( \sum_{i=0}^{7} \sum_{k=0}^{2} m(ijk) \right) \)
- \( \mu_{\text{IS}}(j) = \sum_{i=0}^{7} m(ij1) / \left( \sum_{i=0}^{5} \sum_{k=0}^{2} m(ijk) \right) \)
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Stellar fractions

Bulges + Discs 3 < z < 4

- $f_{Es} < 1:10$
- $1:10 < f_{Es} < 1:3$
- $1:3 < f_{Es}$

MW1  MW2  MW3  MW4  MW5  MW6  MW7  MW8  MW9  MW10  MW11  MW12  SFG1  SFG4  SFG5  SFG9  VLO1  VLO2  VLO3  VLO4  VLO5  VLO6  VLO7  VLO8  VLO9  VLO10  VLO11  VLO12

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Stellar fractions

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**Bulges+Discs**

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<th>ls halo</th>
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<th>ls clump</th>
<th>$f_{E_0} &lt; 1:10$</th>
<th>$1:10 &lt; f_{E_0} &lt; 1:3$</th>
<th>$1:3 &lt; f_{E_0}$</th>
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</table>

**Stacked evolution**
Conclusion

A sample of 30 high redshift galaxies. (Same cosmology, resolution)
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Same Postprocessing pipeline
- Group-finding on stars
- Merger-trees.
- In-situ, Ex-situ discrimination from merger tree
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A sample of 30 high redshift galaxies. (Same cosmology, resolution)

2 Same Postprocessing pipeline
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3 Further analysis
   - Extra kinematic decomposition.
   - Detailed stellar tracking according to both structural decomposition and kinematic decomposition.
   - Define global measure and properties.
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- Define global measure and properties.

What’s to be done.
- DM merger trees
- Gas inflow (wet mergers disc instabilities)
All the simulations, post analysis are on the Jerusalem cluster. The wiki is a guide to find the data there.

Upgrade and advertise the wiki with mosaics.

Share and enjoy

- Make the stellar merger trees available.
- (standard format, what would you need?)
- Provide DM merger trees as well.