Hydro ART simulations sample

Stellar Merger Trees

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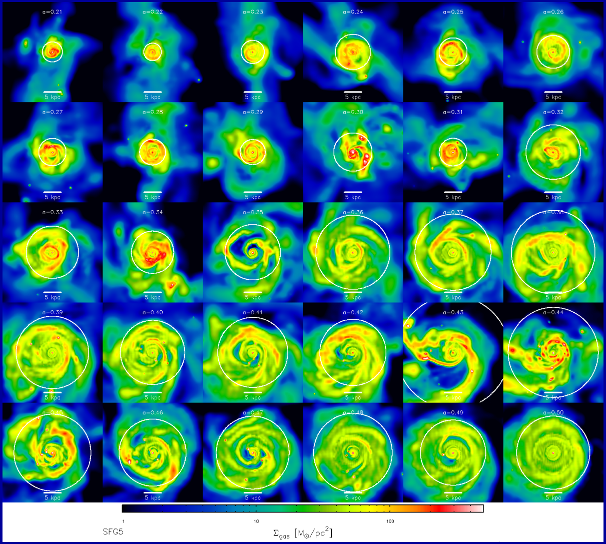
Analysis of ART simulations.

- Collaborators, Daniel Ceverino, Nir Mandelker, Adi Zolotov, Marcello Cacciatto, 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

Galaxy	Target M_v 10^{12} $M_\odot$	R_v kpc	M_v 10^{12} $M_\odot$	M_{star} 10^{11} $M_\odot$	M_g 10^{11} $M_\odot$	a_{fin}
MW01	1.53	102	0.81	0.72	0.57	0.42
MW02	1.21	105	0.89	2.56	1.12	0.34
MW03	1.93	099	0.73	0.60	0.51	0.42
MW04	4.01	123	1.42	1.41	0.89	0.42
MW06	40.9	106	0.92	1.06	0.49	0.50
MW07	1.70	073	0.30	0.30	0.22	0.50
MW08	1.41	071	0.28	0.28	0.15	0.50
MW09	1.10	059	0.16	0.19	0.08	0.50
MW10	1.53	102	0.82	0.72	0.44	0.50
MW11	1.42	088	0.53	0.51	0.28	0.40
MW12	1.69	130	1.70	2.06	1.01	0.48
VL01	2.00	117	1.23	1.54	0.75	0.37
VL02	2.00	101	0.81	0.89	0.46	0.50
VL03	2.04	117	1.22	1.44	0.76	0.33
VL04	2.06	109	1.01	1.33	0.51	0.50
VL05	2.00	118	1.28	1.29	0.75	0.41
VL06	2.01	099	0.75	0.94	0.32	0.50
VL07	2.61	129	1.66	2.15	0.82	0.35
VL08	2.66	112	1.09	1.35	0.46	0.50
VL09	2.59	086	0.49	0.61	0.24	0.34
VL10	2.59	102	0.81	0.95	0.44	0.50
VL11	2.64	130	1.73	2.02	0.81	0.50
VL12	2.61	105	0.90	0.96	0.51	0.50
SFG1	3.30	129	1.66	2.10	0.87	0.46
SFG4	3.29	112	1.09	1.16	0.66	0.42
SFG5	3.33	123	1.38	1.52	0.78	0.50
SFG8	6.59	121	1.38	1.70	0.72	0.35
SFG9	5.17	135	1.89	2.44	1.22	0.49

Gas mosaics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5 kpc
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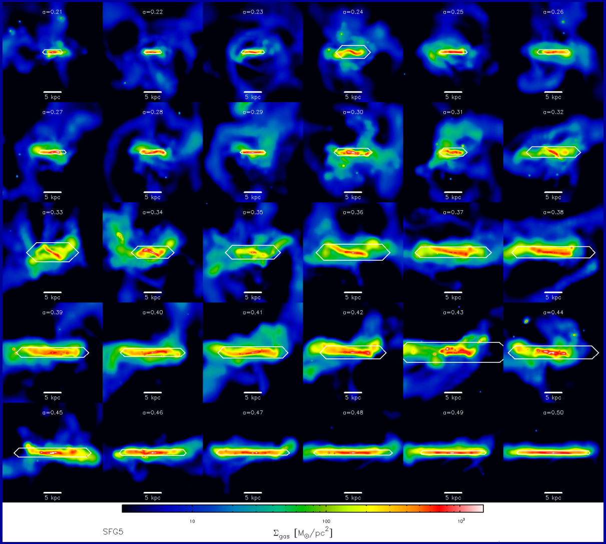
10
100
SFG5
Σ_{gas} [$M_\odot/pc^2$]

Gas mosaics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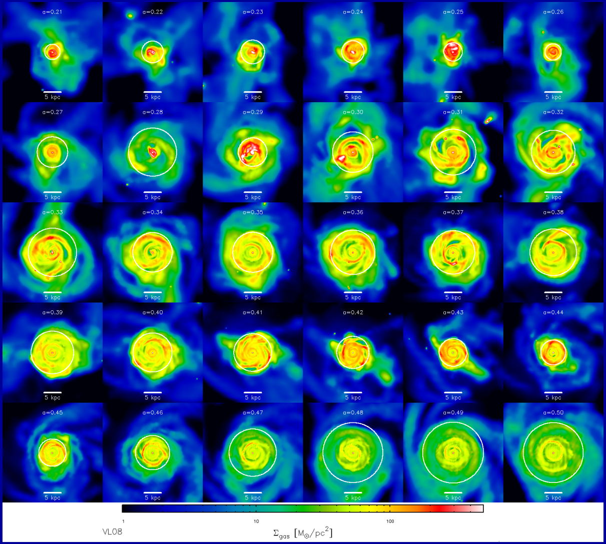
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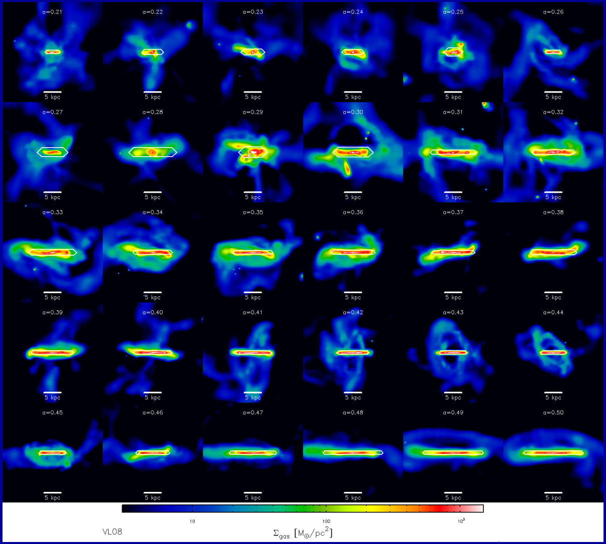
VL08
Σ_{gas} [$M_\odot/pc^2$]

Gas mosaics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Overview

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

- 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).

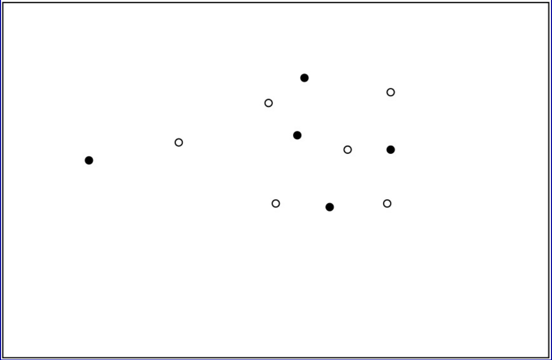
Basic idea

- 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

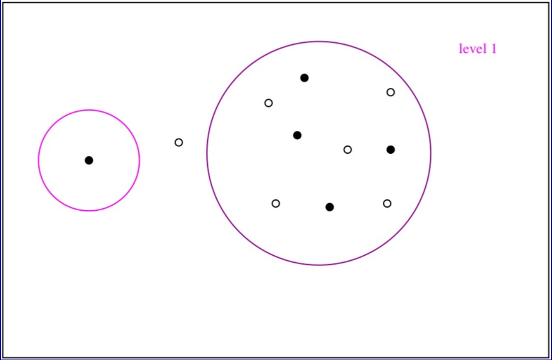
- Number of particles: “mass” thresholding.
- shape selection $\rho_{\mathrm{max}}\alpha \;>\; <\rho_{\mathrm{node}}>$, size $r > r_\epsilon$.
- Removing Poisson noise,
  $<\rho_{node}> \;>\; \rho_t * [1 + \mathrm{fudge}/\sqrt{N}]$
- Only topological, no unbinding.

Mapping the halo internal structure



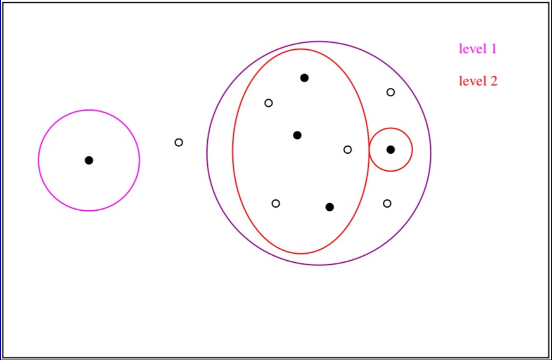
Symbols: filled: local maxima, open: local saddle point
Density distribution= groups of particles around maxima connected by saddle points.

Mapping the halo internal structure



Symbols: filled: local maxima, open: local saddle point
First density thresholding, cut haloes from the background.
$\rho_t = 80 < \rho_{\mathrm{DM}} >$ 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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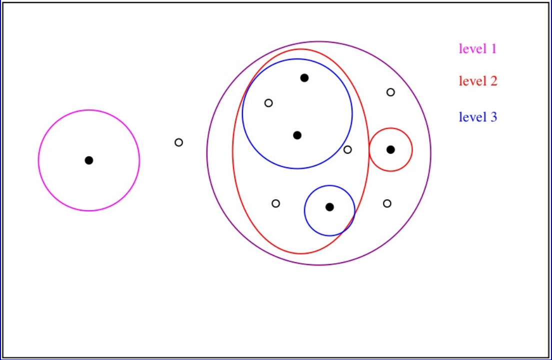

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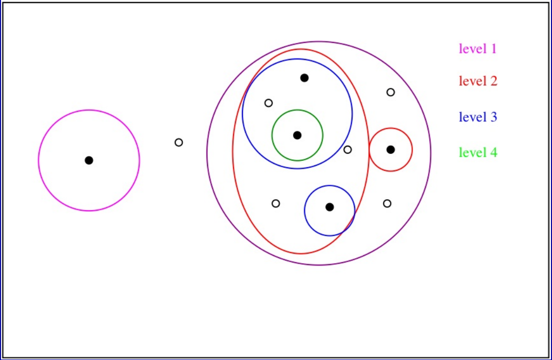
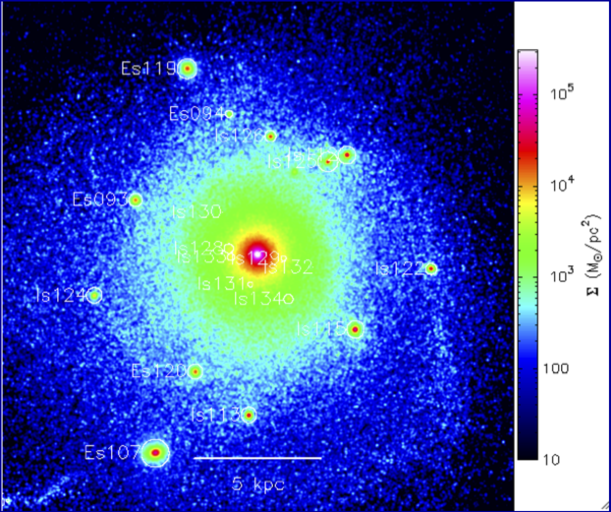


Symbols: filled: local maxima, open: local saddle point
Some density peak might not be isolated as node (low number of particles, Poisson noise)

Merger trees

1. Star particles used as tracer.
2. One descendent per galaxy/clump
3. In-situ clump: no progenitor detected as the separate galaxy.
4. Ex-situ clump: at least one progenitor detected as a separate galaxy.
5. merger fraction.

Clump finding, clump tracking.



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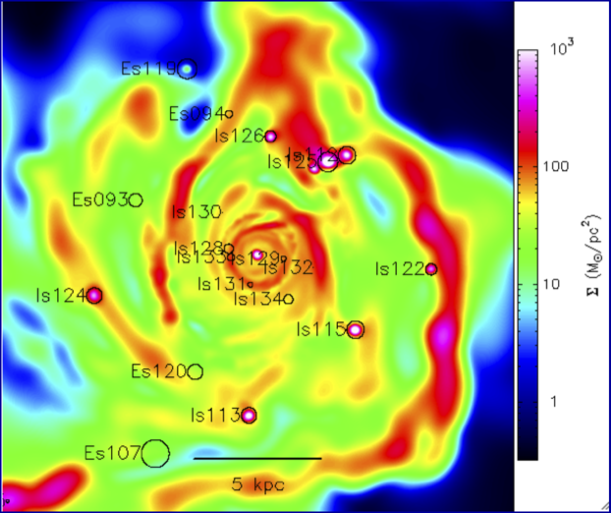

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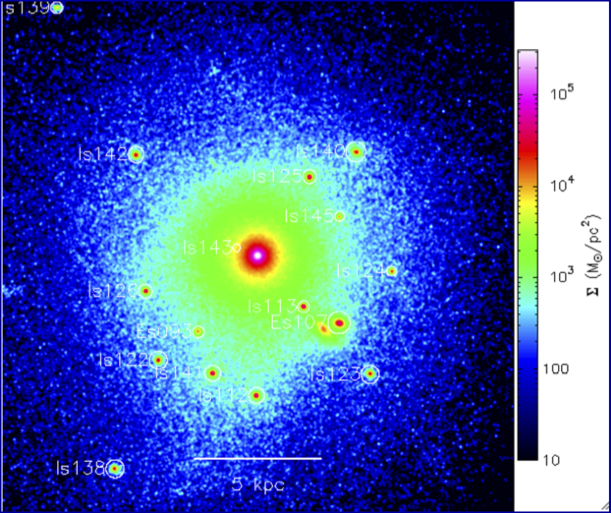

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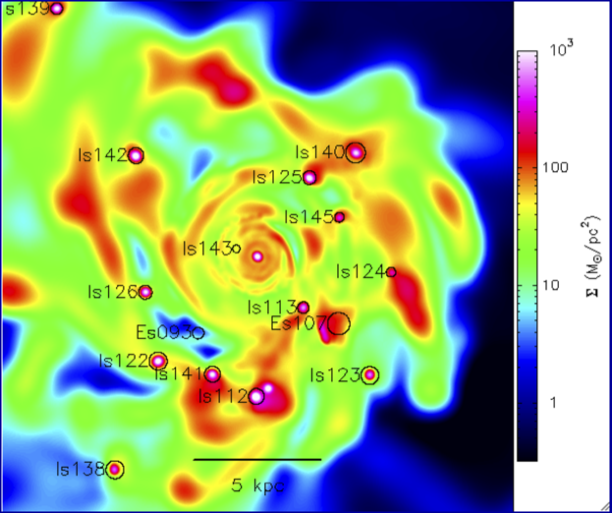
Clump finding, clump tracking.



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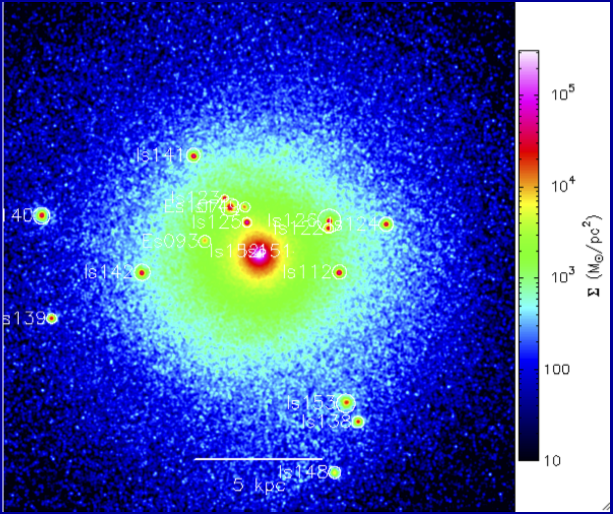

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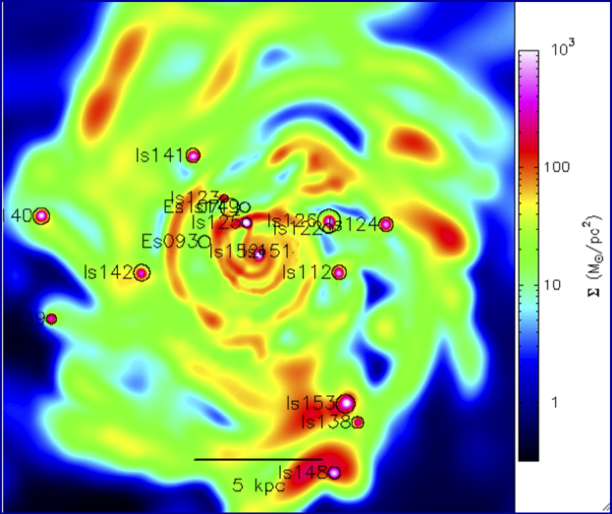
Clump finding, clump tracking.



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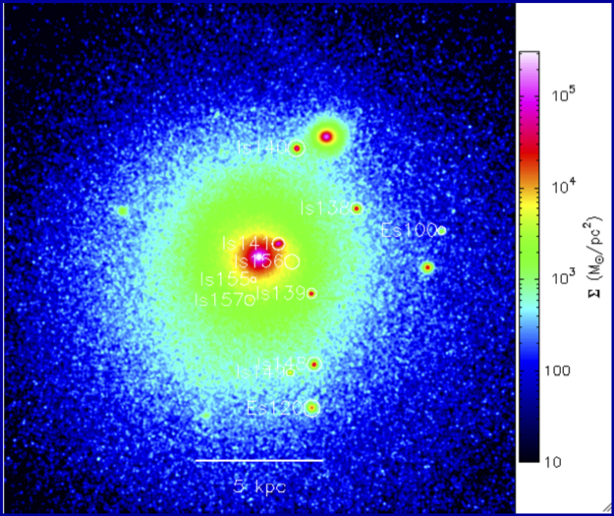

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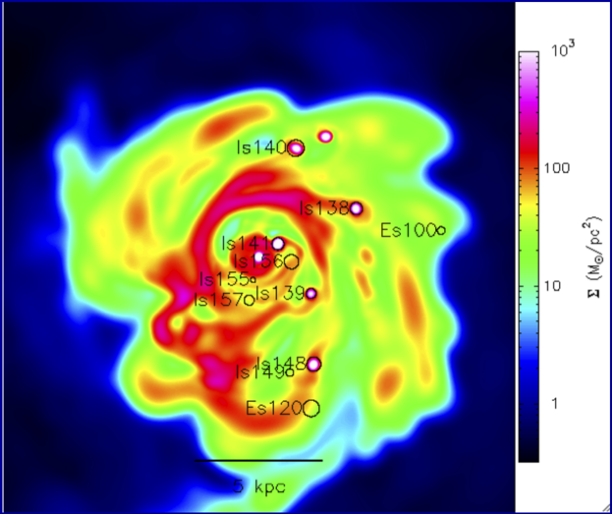
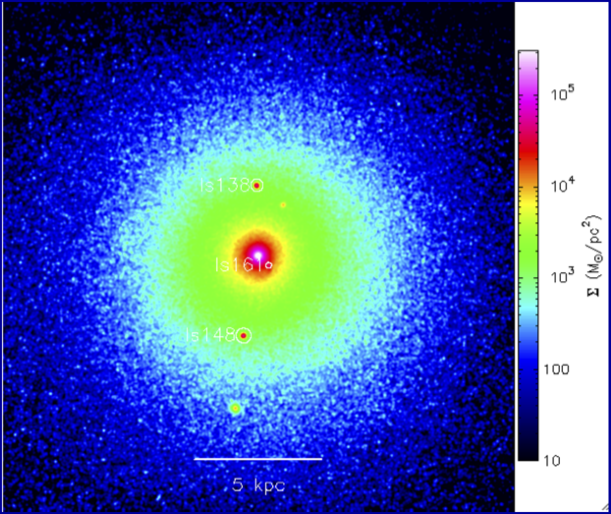
Clump finding, clump tracking.



a=0.40

Clump finding, clump tracking.



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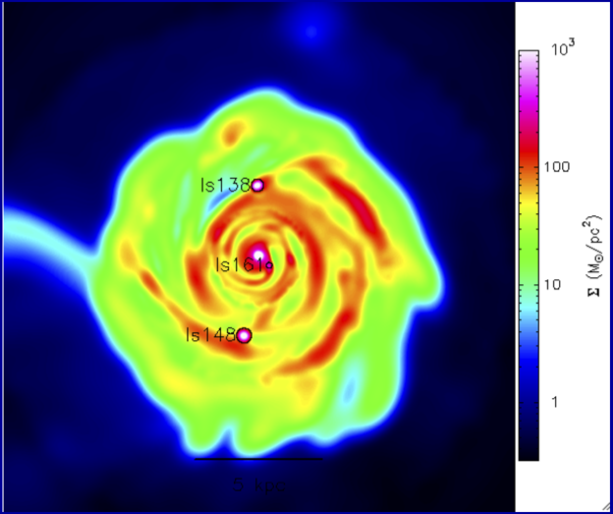
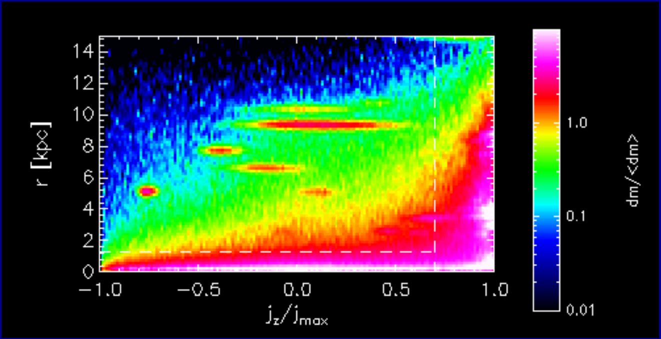
Clump finding, clump tracking.



a=0.41

Clumps co-rotating with the disc.

Visualization in the rotation frame of the galaxy[1]



Smooth component + In-situ clumps + Ex-situ clumps

[1] $j_z = \mathbf{L}_{\rm star}.\mathbf{L}_{\rm gal}$ and $j_{\rm max} = |r_{\rm star}| * |v_{\rm star}|$

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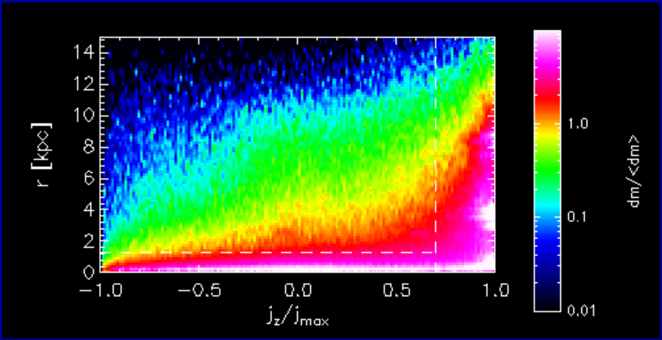

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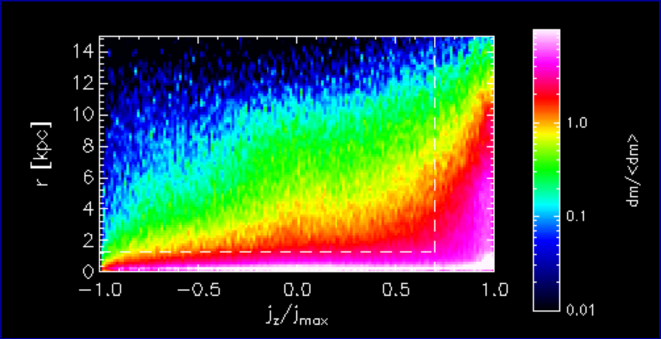


Smooth component

[1] $j_z = \mathbf{L}_{\rm star}.\mathbf{L}_{\rm gal}$ and $j_{\max} = |r_{\rm star}| * |v_{\rm star}|$

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

	Smooth			In-situ clumps			Ex-situ clumps		
	H	B	D	H	B	D	H	B	D
born in halo	000	010	020	001	011	021	002	012	022
born in bulge	100	110	120	101	111	121	102	112	122
born in disc	200	210	220	201	211	221	202	212	222
born in clump	300	310	320	301	311	321	302	312	322
$1{:}\infty<f<1{:}30$	400	410	420	401	411	421	402	412	422
$1{:}30<f<1{:}10$	500	510	520	501	511	521	502	512	522
$1{:}10<f<1{:}3$	600	610	620	601	611	621	602	612	622
$1{:}3<f$	700	710	720	701	711	721	702	712	722

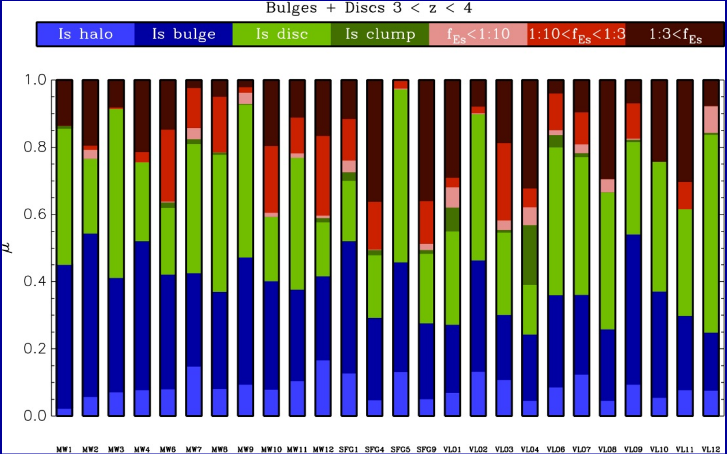
3 criteria classification

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

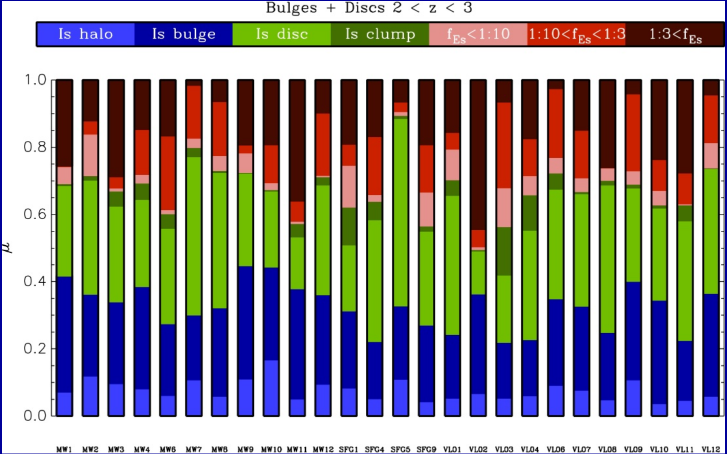
- $\mu_{\mathrm{IsDisc}}(j) = \sum_{k=0}^{2} m(2jk) / \left(\sum_{i=0}^{7} \sum_{k=0}^{2} m(ijk)\right)$
- $\mu_{\mathrm{IsClump}}(j) = \sum_{k=0}^{2} m(3jk) / \left(\sum_{i=0}^{7} \sum_{k=0}^{2} m(ijk)\right)$
- $\mu_{\mathrm{Ex-situ}}(j) = \left(\sum_{i=4}^{7} \sum_{k=0}^{2} m(ijk)\right) / \left(\sum_{i=0}^{7}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

Stellar fractions

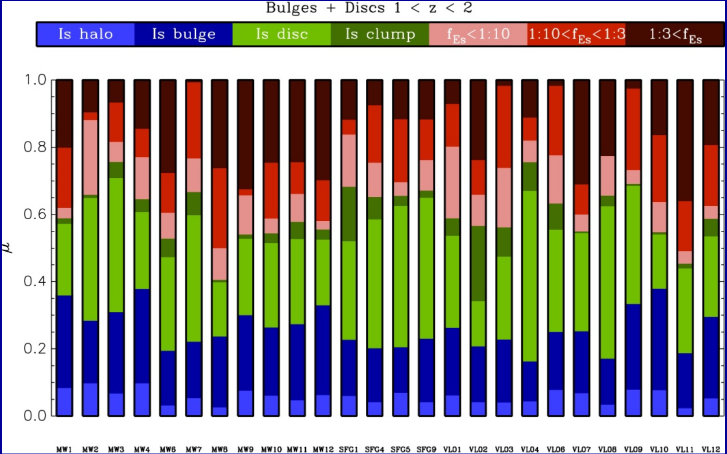
Stellar Merger trees



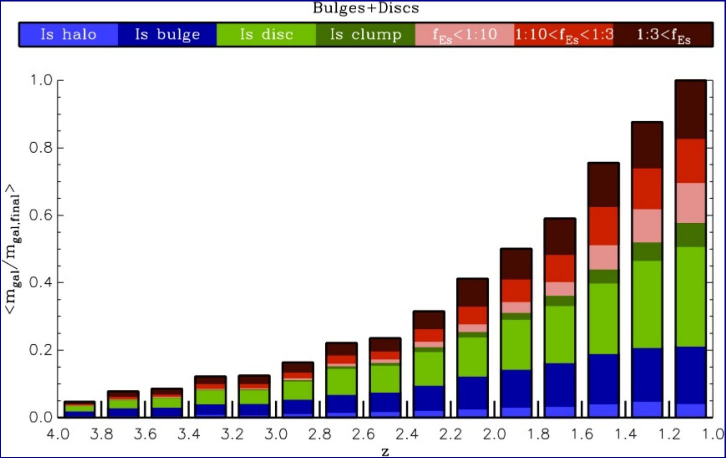
Stellar fractions



Stellar fractions



Stacked evolution



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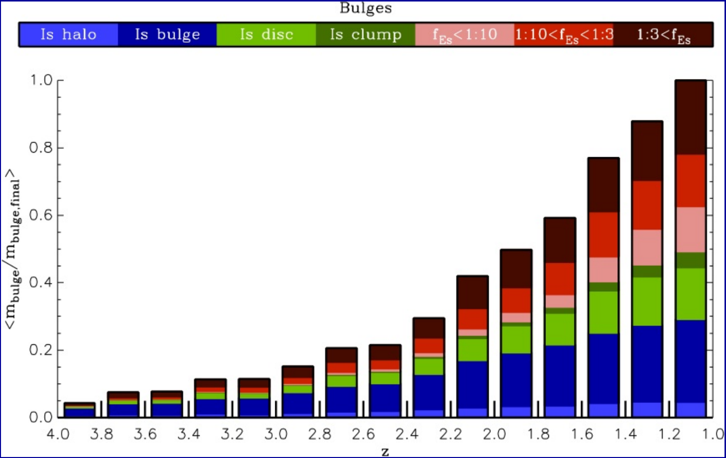

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   - Extra kinematic decomposition.
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   - Define global measure and properties.
4. What's to be done.
   - DM merger trees
   - Gas inflow (wet mergers disc instabilities)

1. All the simulations, post analysis are on the Jerusalem cluster. The wiki is a guide to find the data there.
2. Upgrade and advertise the wiki with mosaics.
3. Share and enjoy
   - Make the stellar merger trees available. (standard format, what would you need?)
   - Provide DM merger trees as well.