Constrain the satellite fraction in HSC

Modelling RSD in DESI

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Overview

Goal

Constrain the high mass ($\log(M_*/M_\odot) \gtrsim 11.5$) satellite fraction ($f_{\mathrm{sat}}$) in Hyper Suprime-Cam (HSC) observations. Why HSC? Large volume – more massive galaxies, deep images – better M_*.

How

- In an N-body simulation, map some halo property (*e.g.* M_{peak}, V_{max}@M_{peak}) to M_*, with some scatter.
- Optimize this mapping in to fit some HSC observations (*e.g.* SMF, clustering).
- Measure f_{sat} in the best fitting mock.

See also

Reddick 2013 did this for SDSS

Observations + Simulation data

Hyper Suprime Cam

- Eventually – 1400 deg^2, 5σ detection to $r \approx 26$ (point sources).
- Data here – 230 deg^2, $0.25 < z < 0.45$.
- $\sim$ 4500, 30 $\log(M_*/M_\odot) > 11.5,\ 12$
- $\sim$ 95% spec-z.

MDPL2

- $1\ \mathrm{Gpc\,h^{-1}}$ per side
- Volume 40x current HSC
- Snapshot at $z \sim 0.37$
- $m_p = 1.5 \times 10^9 M_\odot \mathrm{h}^{-1}$

Fitting choices

Halo Parameter

$M_* = f(\mathrm{halo\,property})$. We build models with V_{max}@M_{peak} and M_{peak}.

Functional form

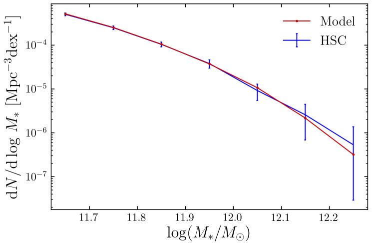
We use the 5 parameter form from Behroozi 2010 (though only 3 are needed), and a linear scatter – $\sigma(\mathrm{halo\,property})$.

Fitting Data

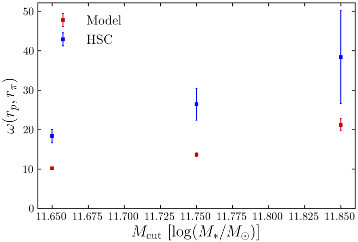
- The SMF
- Counts in cylinders: $\xi(r_p, r_\pi)$ in a single $r_p < 1\,\mathrm{Mpc}$ and $r_\pi < 10\,\mathrm{Mpc}$ bin. HSC doesn't have enough data for a more detailed measurement of clustering. This is a cross correlation between galaxies $\log(M_*/M_\odot) > M_{cut}$ and $M_{cut} - 0.1 < \log(M_*/M_\odot) < M_{cut}$.

Fits with M_{halo}

SMF

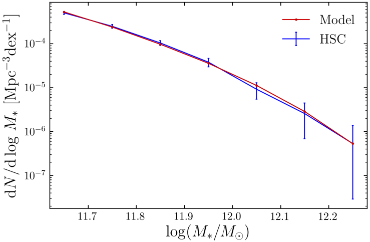


Clustering

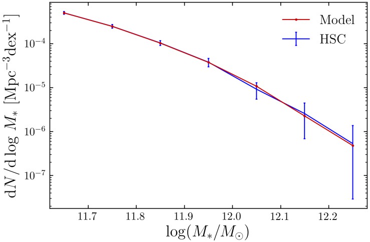


Bestfit Models 1: SMF

$V_{\max}@M_{\mathrm{peak}}$

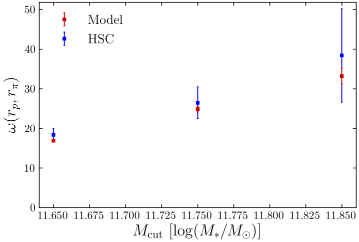


M_{peak}

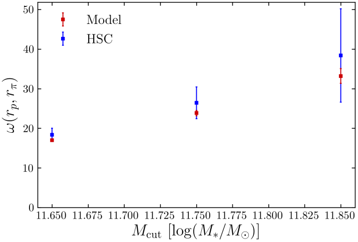


Bestfit Models 2: Clustering

V_{max}@M_{peak}



M_{peak}



Results 1: $f_{\rm sat}$

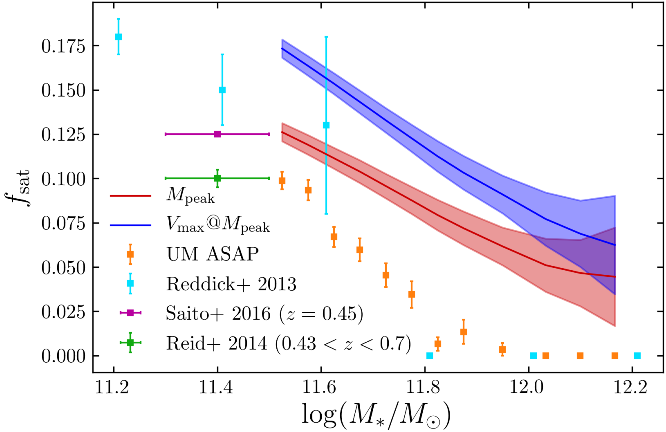


Figure: Errors on the UM are statistical from the bestfit. Errors on our mocks include the uncertainty of the parameters.

Questions

- Can we use X-ray observations to measure $f_{\rm sat}$ in observations?
- Are there other ways in which centrals can be distinguished from satellites? Shape, orientation, something else?

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Modelling RSD in DESI

Modelling RSD in DESI with the Universe Machine?

The Universe Machine (UM)

- Semi-empirical model that computes $SFR(V_{\max}, z, \dot{V}_{\max})$
- Fits many observations: SMF, clustering, CSFR, etc

Table 2. Table of parameters.

Symbol	Description	Equation	Parameters	Section
$\sigma_{SF}(z)$	Scatter in SFR for star-forming galaxies	3	2	3.2
$V(z)$	Characteristic $v_{\max}$ in SFR – $v_{\max}$ relation	6	4	3.2
$\epsilon(z)$	Characteristic SFR in SFR – $v_{\max}$ relation	7	4	3.2
$\alpha(z)$	Faint-end slope of SFR – $v_{\max}$ relation	8	4	3.2
$\beta(z)$	Massive-end slope of SFR – $v_{\max}$ relation	9	3	3.2
$\gamma(z)$	Strength of Gaussian efficiency boost in SFR – $v_{\max}$ relation	10	3	3.2
δ	Width of Gaussian efficiency boost in SFR – $v_{\max}$ relation	11	1	3.2
$Q_{\min}(z)$	Minimum quenched fraction	13	2	3.2
$V_Q(z)$	Characteristic $v_{\max}$ for quenching	14	3	3.2
$\sigma_{VQ}(z)$	Characteristic $v_{\max}$ width over which quenching happens	15	3	3.2
$r_c(z)$	Rank correlation between halo assembly history ($\Delta v_{\max}$) and SFR	16	4	3.2
τ_R	Correlation time for long-timescale random contributions to SFR rank	–	1	3.2
f_{short}	Fraction of short-timescale random contributions to SFR rank	19	1	3.2
T_{orphan}	Threshold for $v_{\max}/v_{\text{Mpeak}}$ at which disrupted haloes are no longer tracked	–	1	3.3
f_{merge}	Fraction of host halo's radius below which disrupted satellites merge into the central galaxy	–	1	3.3
α_{dust}	Characteristic rate at which dust increases with UV luminosity	22	1	3.4
$M_{\text{dust}}(z)$	Characteristic UV luminosity for dust to become important	23	2	3.4
$\mu(z)$	Systematic offset in both observed stellar masses and SFRs	24	2	3.5
$\kappa(z)$	Additional systematic offset in observed SFRs	25	1	3.5
$\sigma_{\text{SM,obs}}(z)$	Random error in recovering stellar masses	26	1	3.5
$\sigma_{\text{SFR,obs}}(z)$	Random error in recovering SFRs	27	0	3.5

Notes. $\Delta v_{\max}$ is described by Eq. 1 in §3.1. Symbols followed by "(z)" depend on redshift and are described by multiple parameters (see equation references above). τ_R is expressed in units of the halo dynamical time ($(\sqrt{\frac{4}{3}\pi G\rho_{\text{vir}}})^{-1}$) and so has an implicit redshift dependence. The total number of model parameters is 44.

Parameter Reduction?

Currently there is huge amount of flexibility in the UM model that we might not need, particularly in SFR at high z and in quenching physics.

Peter estimates that $10 - 15$ params could be removed in those areas.

Resolution Requirements

We need to resolve the satellites that build up the large centrals. Rodriguez-Gomez estimates that the bulk of $\log(M_*/M_\odot) > 11.4$ galaxies comes from $\log(M_*/M_\odot) > 10.4$ (that mostly grow from in-situ star formation).
90% of these galaxies are in halos with $\log(M_{\rm halo}/M_\odot) > 11.5$ at $z = 0$. However these need to be tracked at higher redshifts. Peter estimates that the UM needs to resolve $\log(M_{\rm halo}/M_\odot) > 10.5$.
What m_p can we use?

Questions

- N-body resolution requirements for the UM to do RSD?
- How many UM params can be cut?
- Baryonic effects?