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IMPRINTS OF RADIAL MIGRATION ON THE MILKY WAY'S METALLICITY DISTRIBUTION FUNCTIONS

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ABSTRACT

Recent analysis of the SDSS-III/APOGEE Data Release 12 stellar catalogue has revealed that the Milky Way's metallicity distribution function (MDF) changes shape as a function of radius, transitioning from being negatively skewed at small Galactocentric radii to positively skewed at large Galactocentric radii. Using a high resolution, N–body+SPH simulation, we show that the changing skewness arises from radial migration – metal-rich stars form in the inner disk and subsequently migrate to the metal-poorer outer disk. These migrated stars represent a large fraction ($> 50\%$) of the stars in the outer disk; they populate the high metallicity tail of the MDFs and are, in general, more metal-rich than the surrounding outer disk gas. The simulation also reproduces another surprising APOGEE result: the spatially invariant high-[α/Fe] MDFs. This arises in the simulation from the migration of a population formed within a narrow range of radii (3.2 ± 1.2 kpc) and time (8.8 ± 0.6 Gyr ago), rather than from spatially extended star formation in a homogeneous medium at early times. These results point toward the crucial role radial migration has played in shaping our Milky Way.

Миграция в тонком диске – асимметрия распределений по металличности

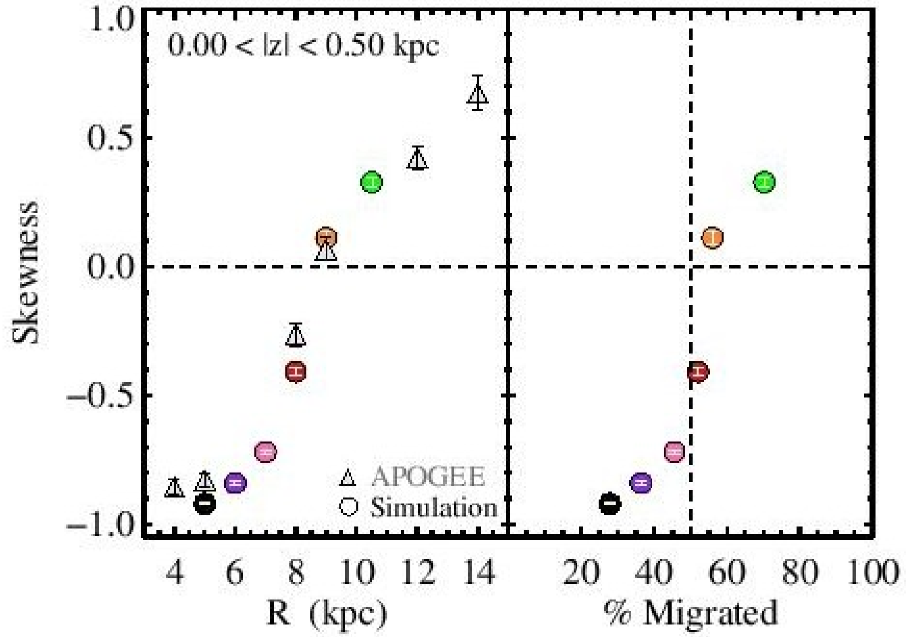

Figure 3. Left: the skewness of simulation (circles) and APOGEE (triangles) MDFs as a function of present day radius within the mid-plane ($0 \leq |z|/\text{kpc} < 0.5$). Right: the trend in the simulation between skewness and the fraction of migrated stars; note, the color of the circles between the two panels are the same.

А в толстом диске асимметрий нет!

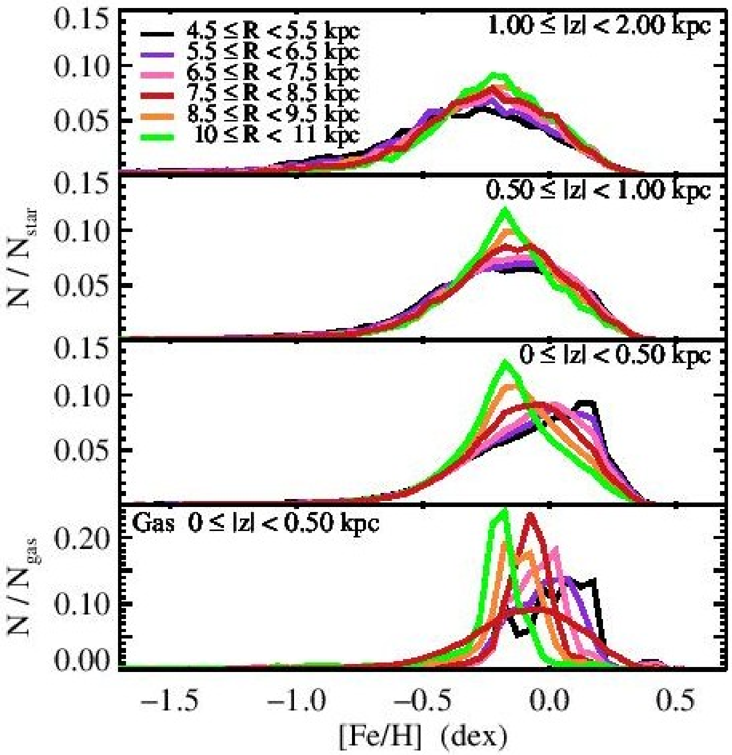

Figure 2. MDF as a function of present day radius for all stars in the simulation. Varying distances from the mid-plane are considered: (top panel) $1.0 \leq |z|/\text{kpc} < 2.0$, (top middle panel) $0.5 \leq |z|/\text{kpc} < 1.0$, and (bottom middle panel) $0 \leq |z|/\text{kpc} < 0.5$. The gas MDF is also shown for comparison (bottom panel); the gas MDF is peaked at lower metallicities than the star MDF at the same height.

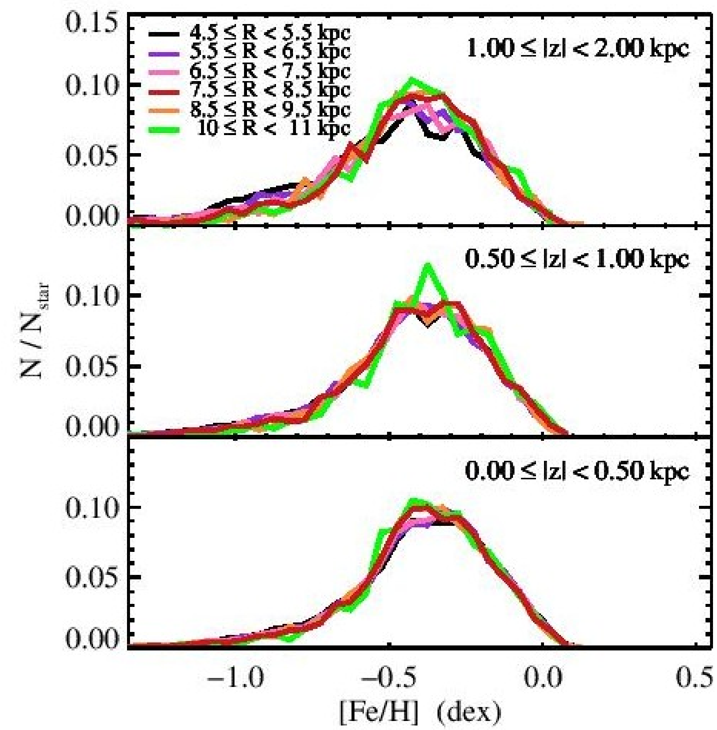

Figure 5. Identical to Figure 2 for the high-$[\alpha/\text{Fe}]$ stars.

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Molecular Gas and Star Formation in the Cartwheel

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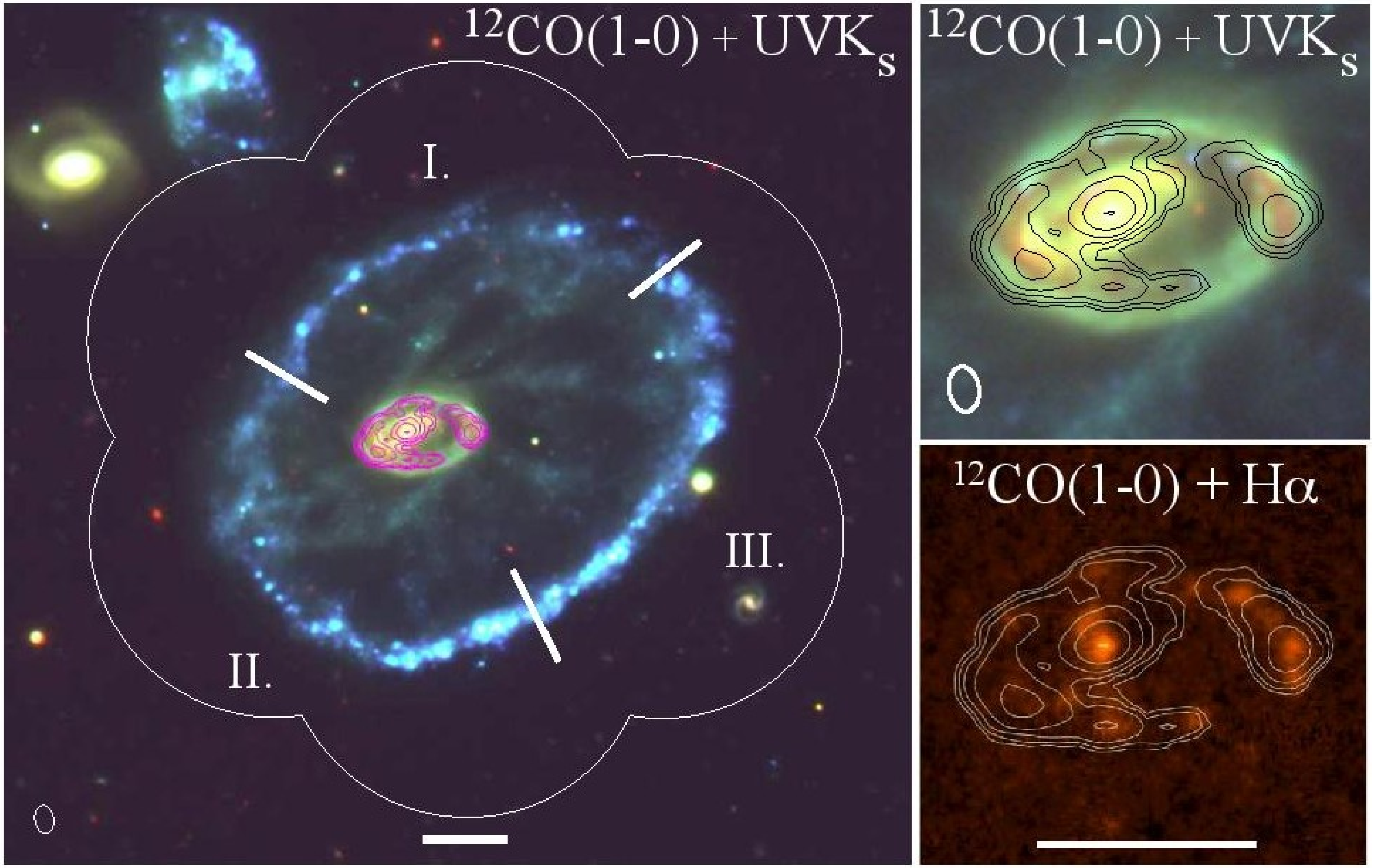
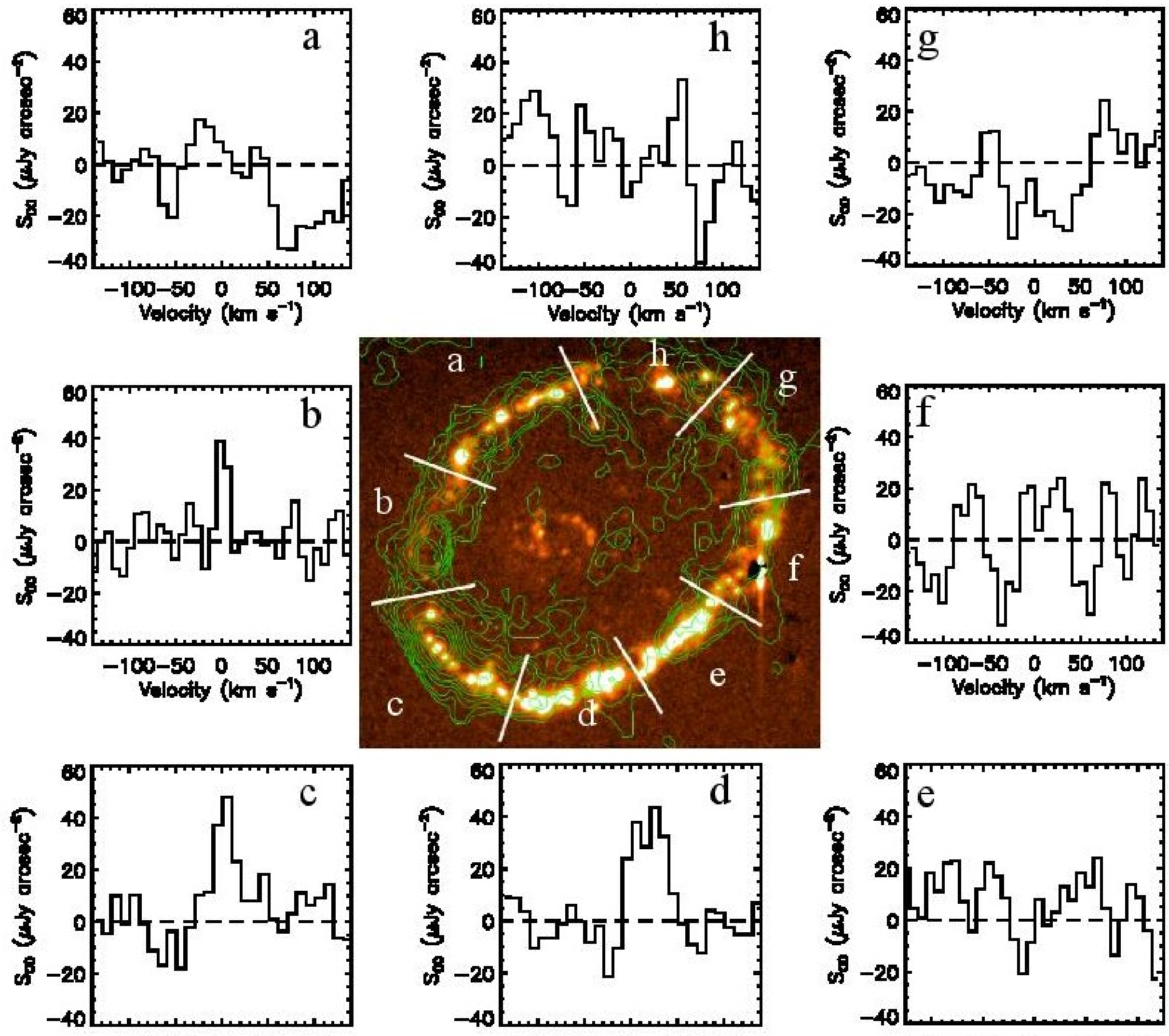
ABSTRACT

Atacama Large Millimeter/submillimeter Array (ALMA) ^{12}CO(J=1-0) observations are used to study the cold molecular ISM of the Cartwheel ring galaxy and its relation to HI and massive star formation (SF). CO moment maps find $(2.69 \pm 0.05) \times 10^9$ $M_\odot$ of H_2 associated with the inner ring (72%) and nucleus (28%) for a Galactic I_{CO}-to-N_{H_2} conversion factor (α_{CO}). The spokes and disk are not detected. Analysis of the inner ring's CO kinematics show it to be expanding ($V_{exp} = 68.9 \pm 4.9$ km s^{-1}) implying an ≈ 70 Myr age. Stack averaging



$^{12}CO(1\text{-}0) + UVK_s$
I.
II.
III.
$^{12}CO(1\text{-}0) + UVK_s$
$^{12}CO(1\text{-}0) + H\alpha$



a
b
c
d
e
f
g
h
S_{CO} (μJy arcsec^{-2})
Velocity (km s^{-1})
−100 −50 0 50 100
60
40
20
0
−20
−40

Звездообразование во внешнем кольце – не по Кенникату

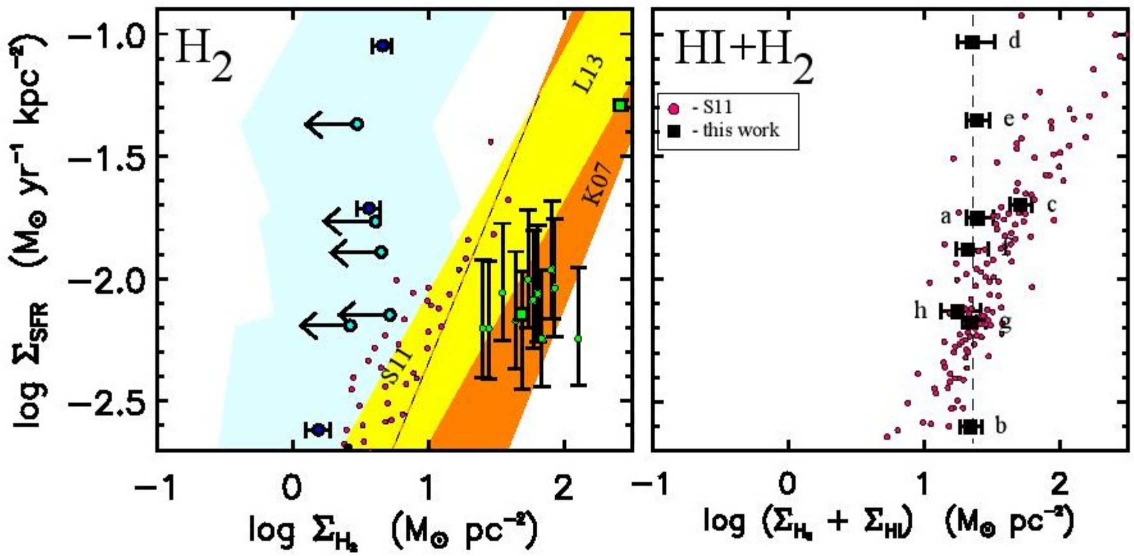


Fig. 5.— The Cartwheel's SF law. (top-left) Derived H_2 SF law for the outer and inner rings. The nucleus and averaged inner ring are represented by squares. The shaded area indicates the allowed Σ_{H_2} given α_{CO}'s dispersion in Magdis et al. (2011). (bottom-left) The

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Evidence for a change in the dominant satellite galaxy quenching mechanism at $z = 1$

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Кардинальные различия в quenching на z=1 и z=0!

ABSTRACT

We present an analysis of galaxies in groups and clusters at $0.8 < z < 1.2$, from the GCLASS and GEEC2 spectroscopic surveys. We compute a "conversion fraction" $f_{\rm convert}$ that represents the fraction of galaxies that were prematurely quenched by their environment. For massive galaxies, $M_{\rm star} > 10^{10.3} M_{\odot}$, we find $f_{\rm convert} \sim 0.4$ in the groups and ~ 0.6 in the clusters, similar to comparable measurements at $z = 0$. This means the time between first accretion into a more massive halo and final star formation quenching is $t_p \sim 2$ Gyr. This is substantially longer than the estimated time required for a galaxy's star formation rate to become zero once it starts to decline, suggesting there is a long delay time during which little differential evolution occurs. In contrast with local observations we find evidence that this delay timescale may depend on stellar mass, with t_p approaching $t_{\rm Hubble}$ for $M_{\rm star} \sim 10^{9.5} M_{\odot}$. The result suggests that the delay time must not only be much shorter than it is today, but may also depend on stellar mass in a way that is not consistent with a simple evolution in proportion to the dynamical time. Instead, we find the data are well-matched by a model in which the decline in star formation is due to "overconsumption", the exhaustion of a gas reservoir through star formation and expulsion via modest outflows in the absence of cosmological accretion. Dynamical gas removal processes, which are likely dominant in quenching newly accreted satellites today, may play only a secondary role at $z = 1$.

Скопления на z=1 – как на z=0

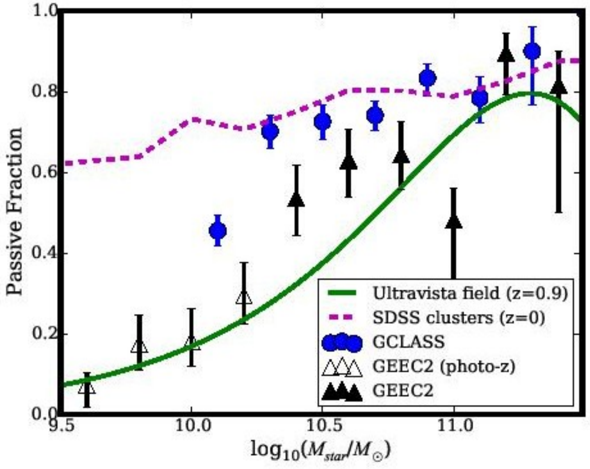

Figure 3. The fraction of passive galaxies as a function of stellar mass is shown for the GEEC2, GCLASS samples, compared with a sample of SDSS clusters (Omand et al. 2014) and the Ultravista (Muzzin et al. 2013) field at $z = 0.9$. The GCLASS (cluster) sample shows high passive fractions, consistent with observations at $z = 0$. The group sample shows a more modest enhancement of passive fraction, with no significant enhancement at masses below $M_{\rm star} = 10^{10.3} M_{\odot}$.

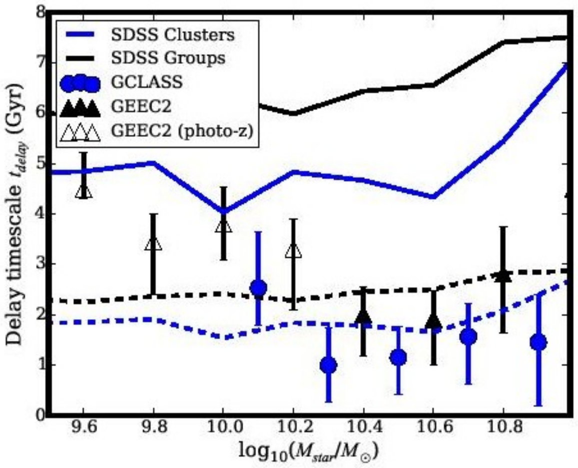

Figure 7. Derived from the values of t_p presented in Figure 6, and assuming a constant $t_{\rm fade} = 0.5 \pm 0.2$ Gyr, we show the delay time $t_{\rm delay}$ as a function of redshift and halo mass. Again the solid lines show the $z = 0$ results from SDSS, and the dashed lines show the same curves rescaled by $(1 + 0.9)^{-1.5}$, corresponding to dynamical time evolution.

А механизмы quenching – разные!

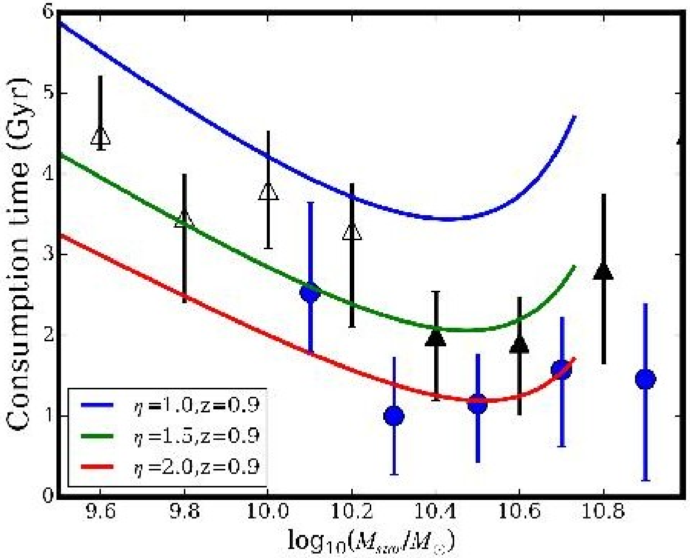

Figure 8. Lines show the maximum time over which a satellite galaxy of a given stellar mass, at redshift $z = 0.9$, could maintain its SFR unchanged once cosmological accretion of matter has stopped. The time is measured assuming that any depletion of the reservoir does not reduce the SFR, following McGee et al. (2014). These models make the simple assumption that star formation is accompanied by outflows that permanently carry away mass at a rate ηSFR from the galaxy, with η independent of mass and redshift. We compare with our GCLASS (blue circles) and GEEC2 (triangles) data over the relevant stellar mass range, and find the observed stellar mass dependence is in remarkably good agreement with the $1.5 < \eta < 2.0$ model predictions. The small halo-mass dependence might indicate that dynamical effects still play a secondary role in the more massive clusters.