ySAM

Yonsei University
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Yonsei or 'Yi' Semi-Analytic Model

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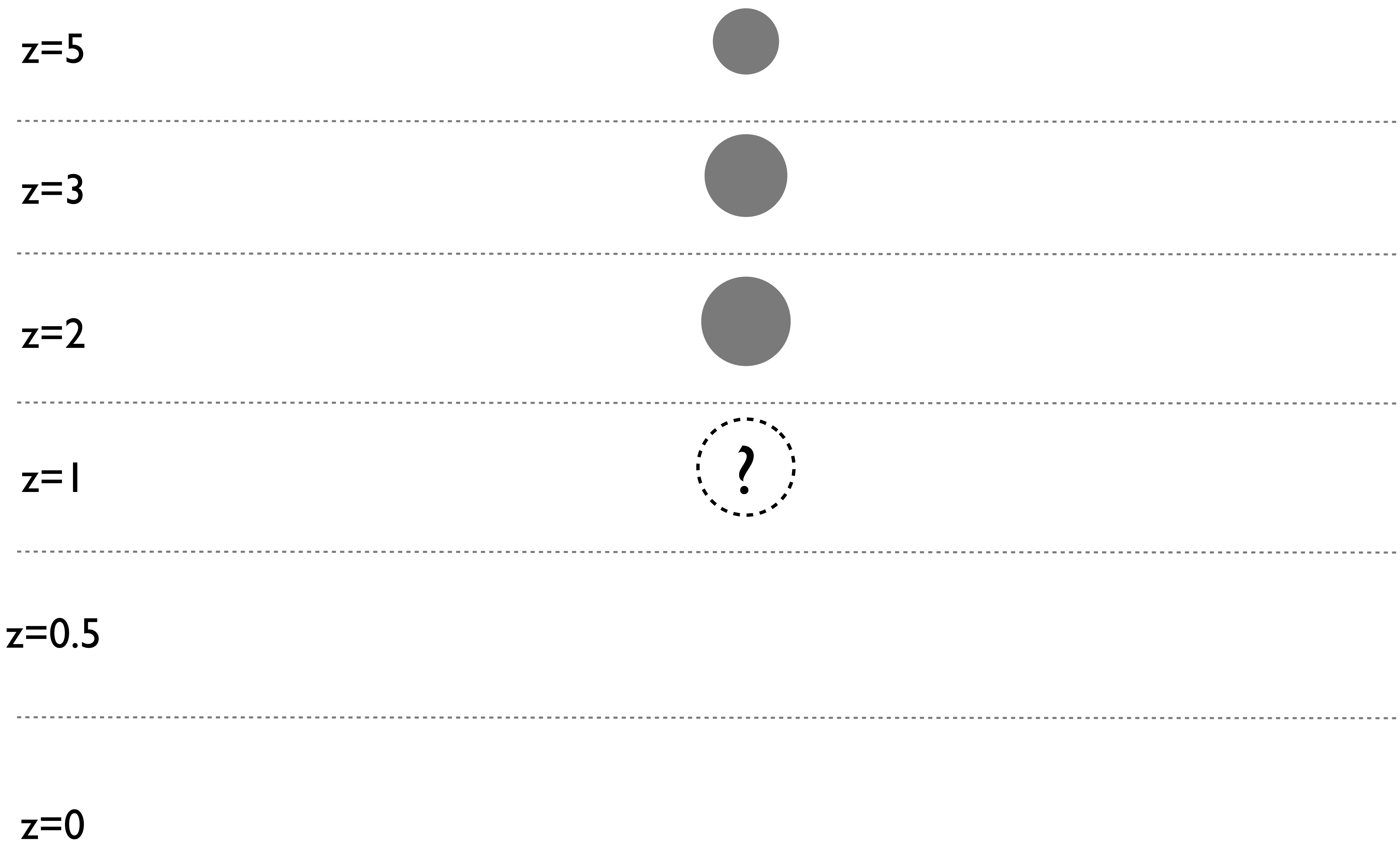
- ySAM has been developed by Sukyoung Yi and Jaehyun Lee since 2010 using IDL
- The code is mainly motivated by Sadegh Khochfar, Julien Devriendt, Rachel Somerville, and Darren Croton's models
- Unique prescriptions of ySAM
  - Rigorous stellar evolution and mass loss
  - Additional processes for tracing subhalo properties

- Treatments for halo merger trees in ySAM
  - Cases Not allowed

1) Disappear without any descendant before merger



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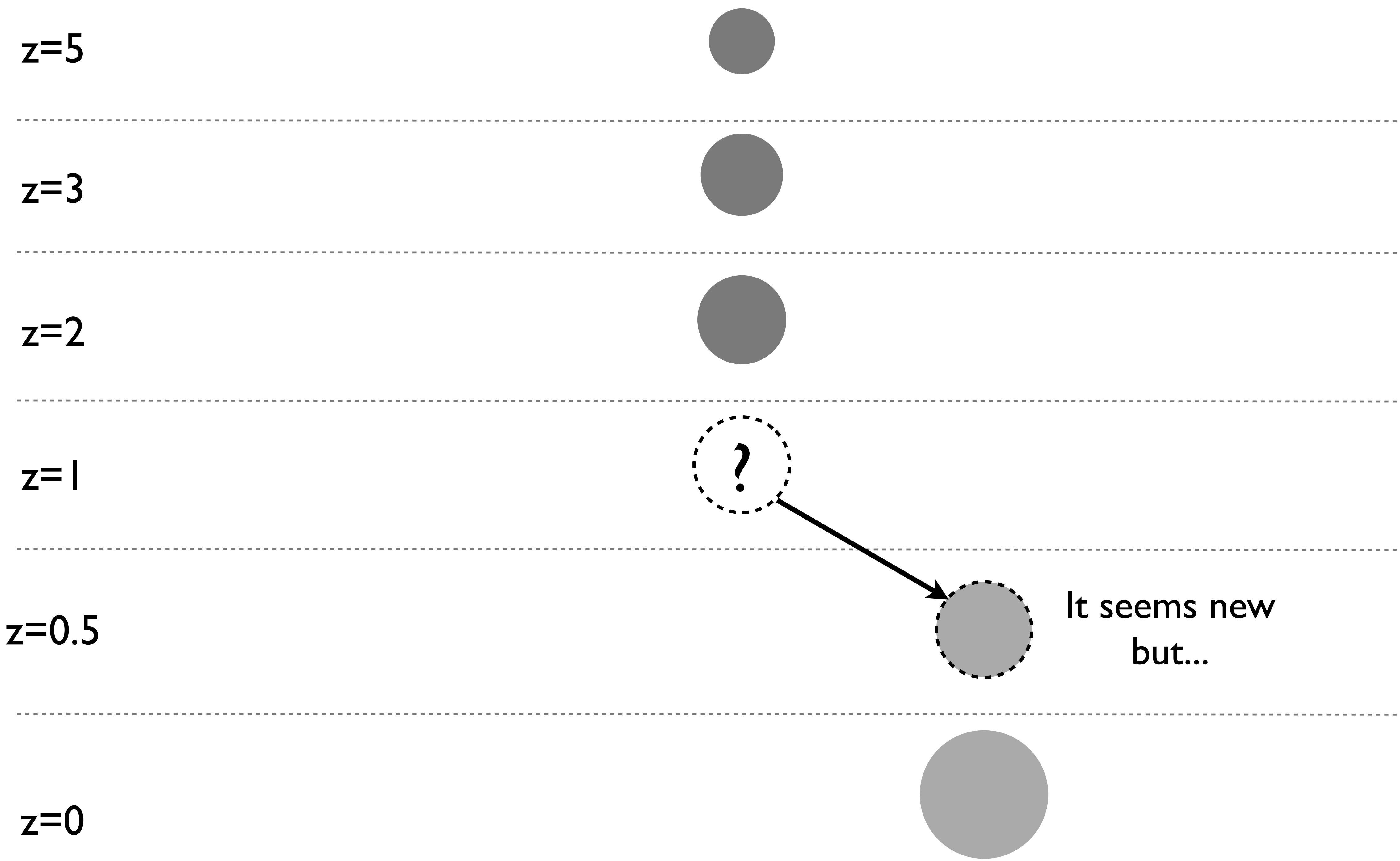

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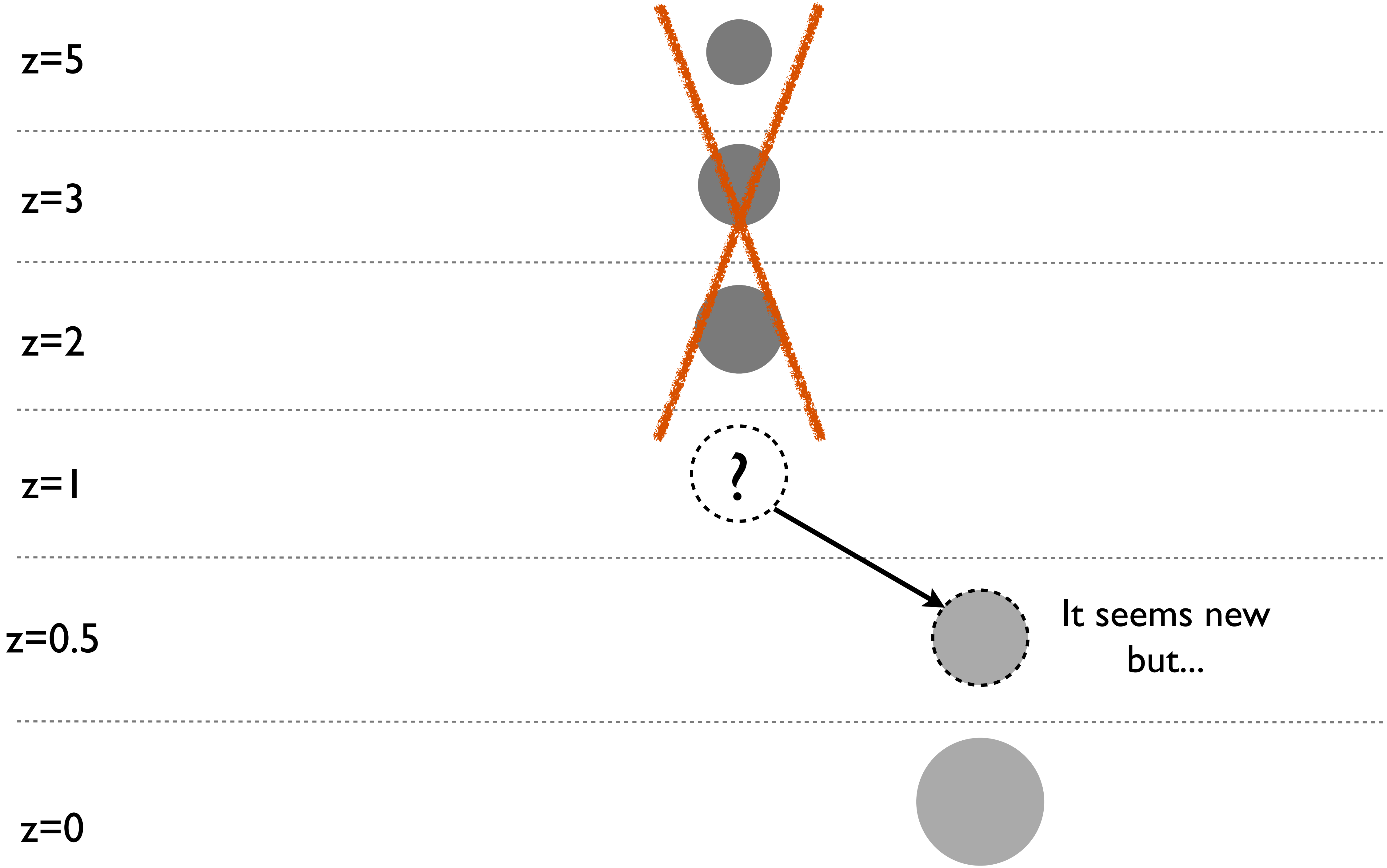

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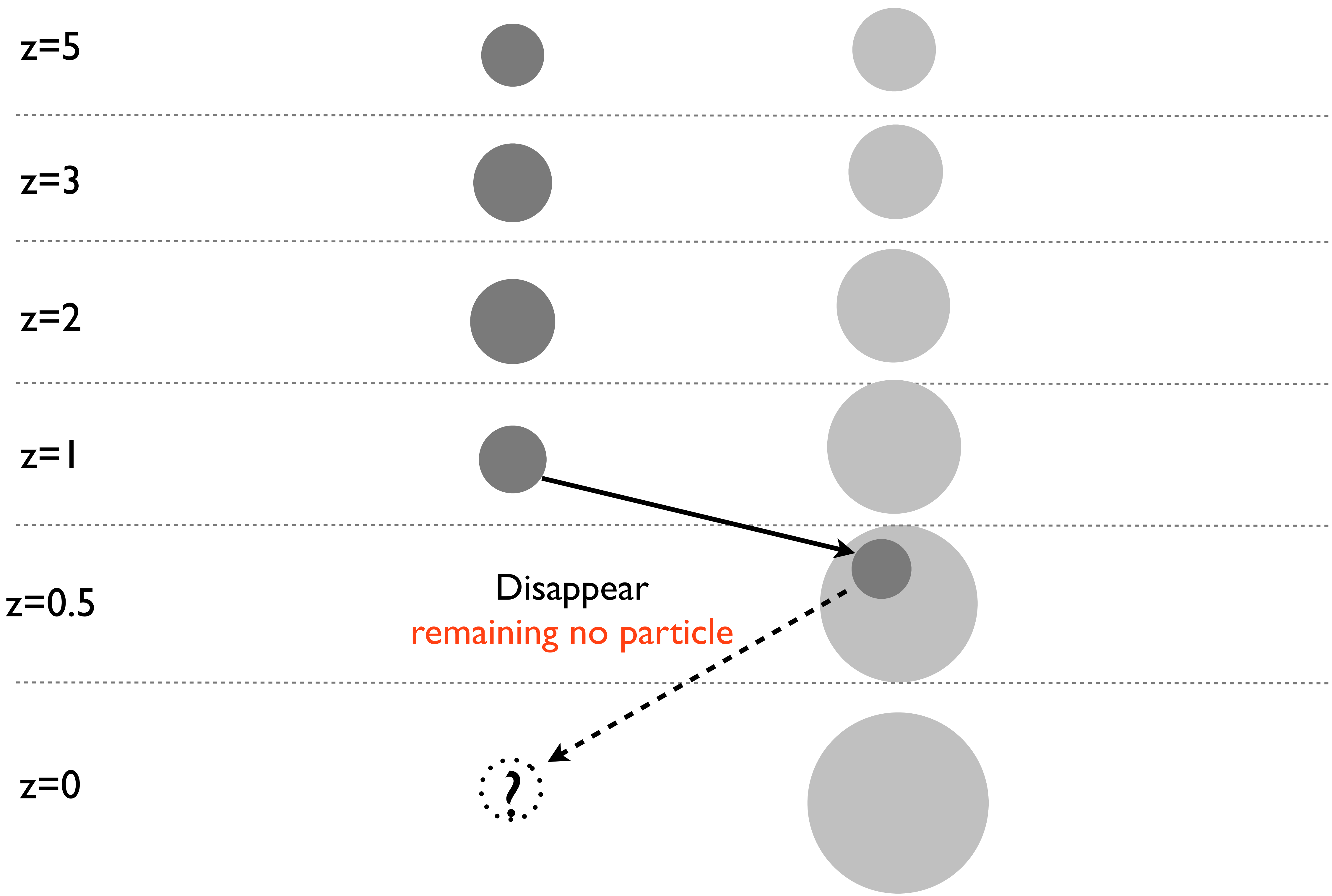
2) Disappear as subhaloes leaving no descendent



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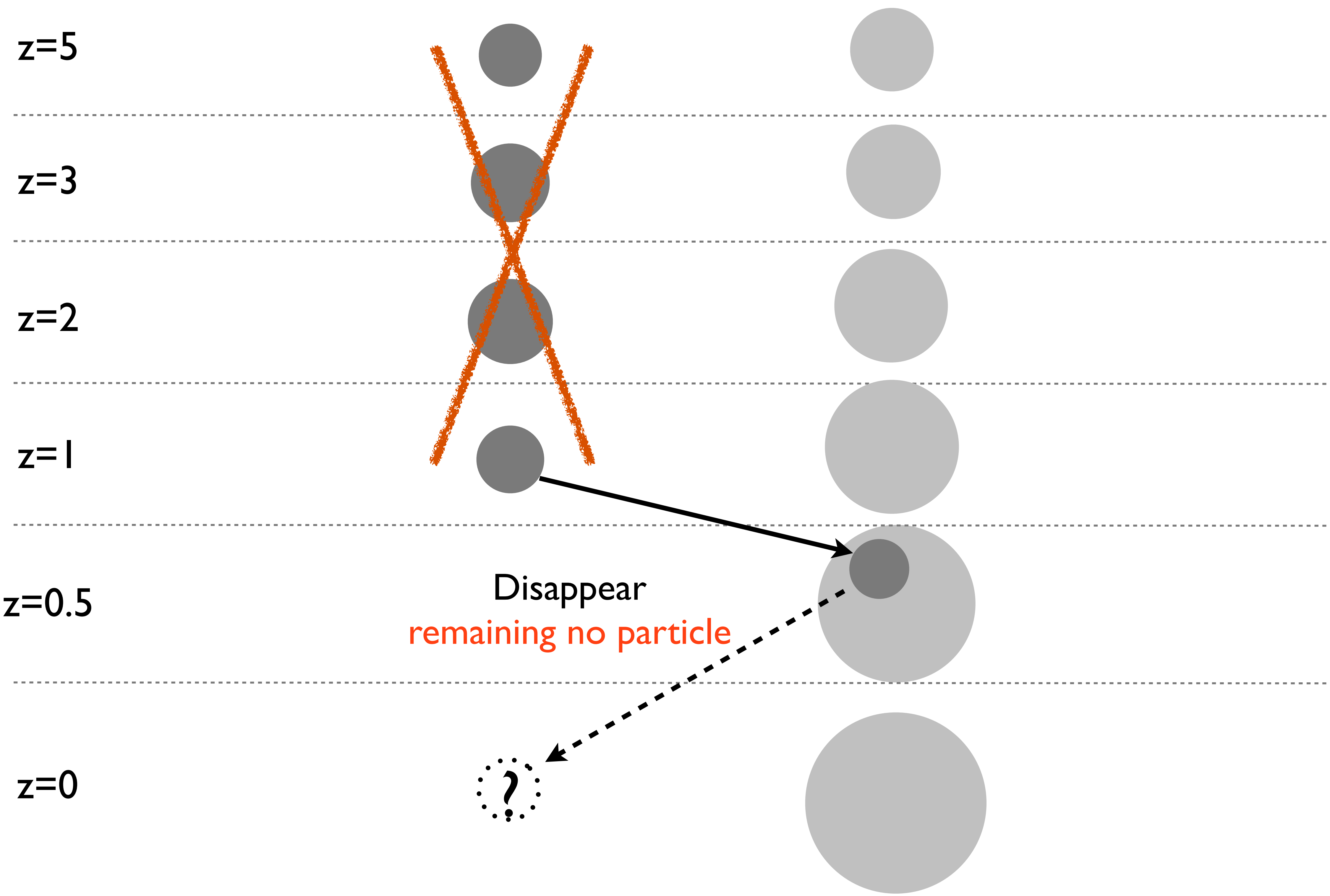

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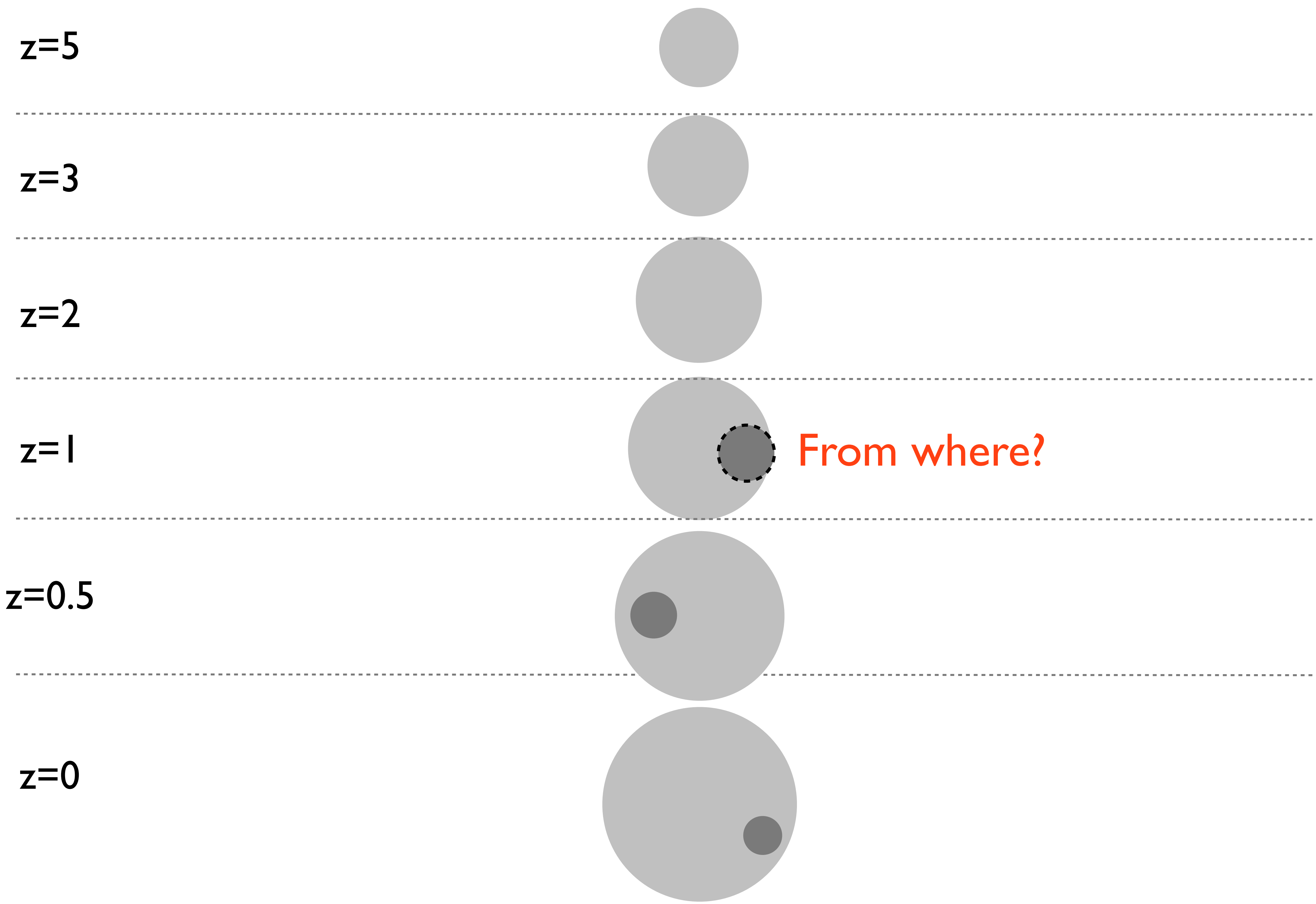
3) Identified as subhaloes with no progenitor



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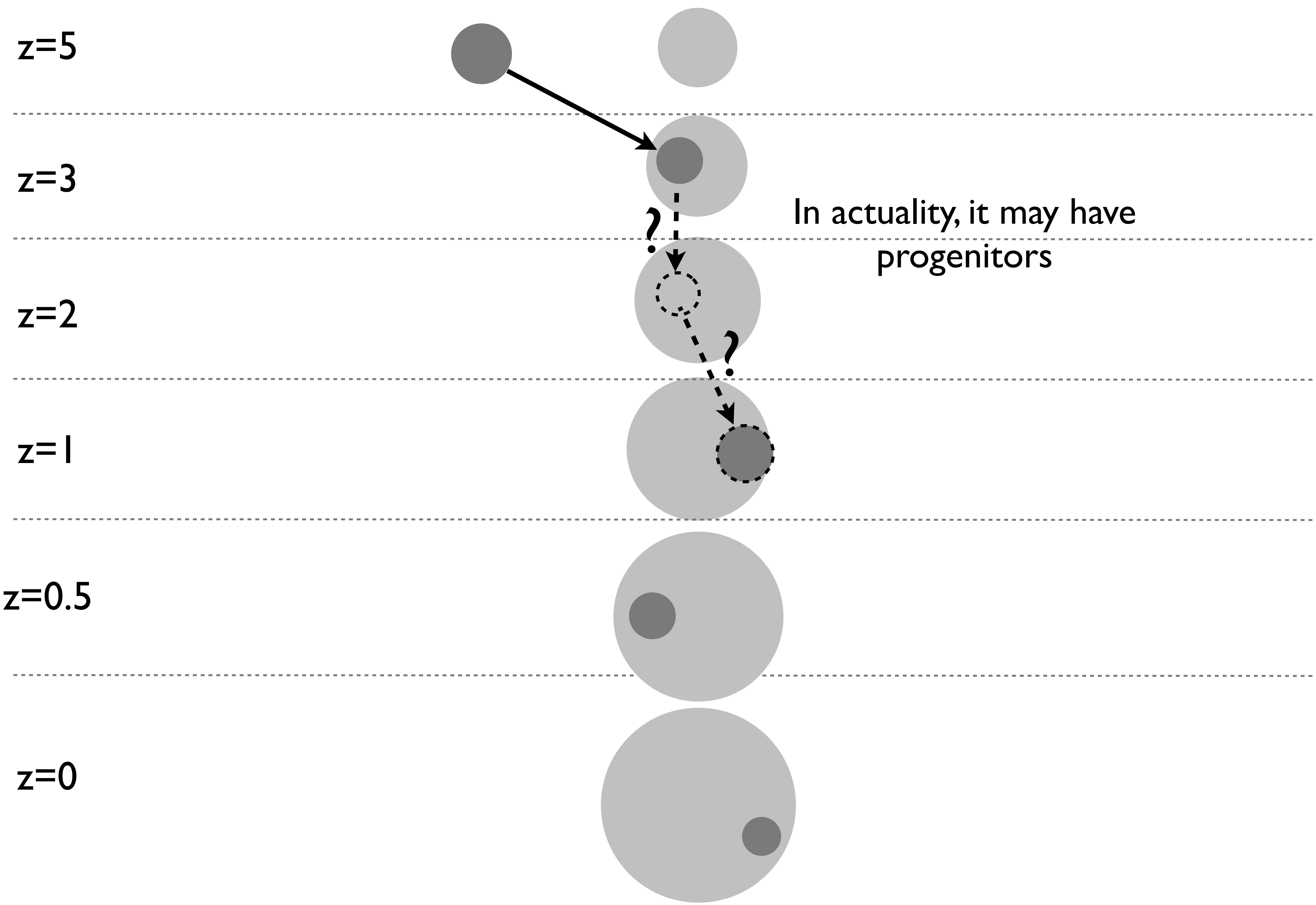


- Additional processes for orphan subhaloes
  - If subhaloes disappear before reaching very central regions ($<0.1R_{vir}$), ySAM additionally calculates their merging timescales, orbits and mass.
    - Merging timescale

$$t_{\rm merge}({\rm Gyr}) = \frac{0.94\epsilon^{0.60}+0.60}{2C}\frac{M_{\rm host}}{M_{\rm sat}}\frac{1}{\ln[1+(M_{\rm host}/M_{\rm sat})]}\frac{R_{\rm vir}}{V_c}$$

Jiang+08

    - Dynamical friction

$$\frac{{\rm d}\vec{v}}{{\rm d}t}_{\rm dynf} = -\frac{GM_{\rm sat}(t)}{r^2}\ln\Lambda\left(\frac{V_c}{v}\right)^2\left\{{\rm erf}\left(\frac{v}{V_c}\right)-\frac{\sqrt{\pi}}{2}\left(\frac{v}{V_c}\right)\exp\left[-\left(\frac{v}{V_c}\right)^2\right]\right\}\vec{e_v},$$

Binney+08

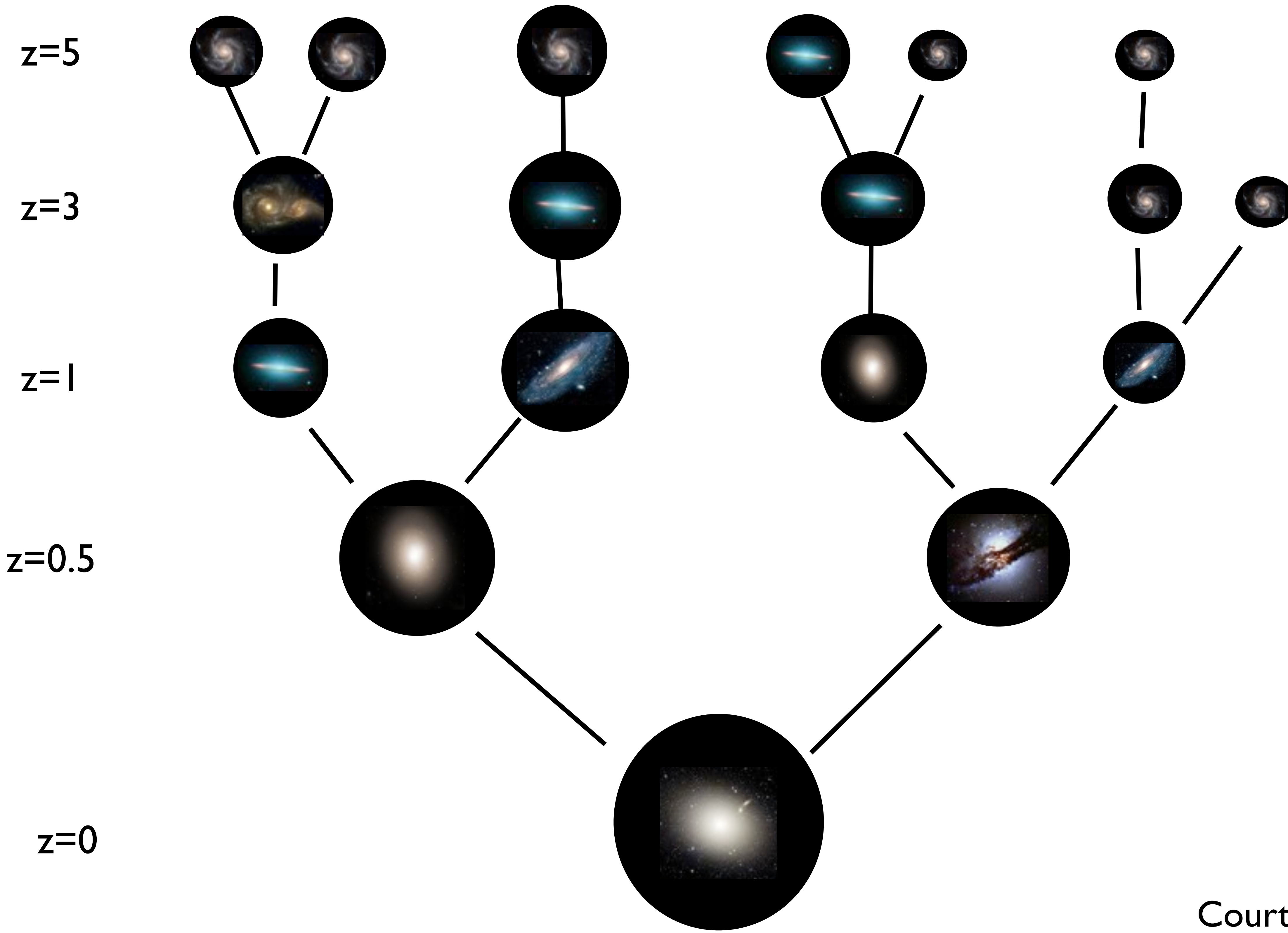
    - Sphere of Influence - Subhaloes hold particles within the radii

$$r_{\rm soi}\sim r\left[\left(\frac{M_{\rm sat,tot}}{M_{\rm host}(<r)}\right)^{-0.4}(1+3\cos^2\theta)^{0.1}+0.4\cos\theta\left(\frac{1+6\cos^2\theta}{1+3\cos^2\theta}\right)\right]^{-1}$$

Battin 87

- Prescriptions governing baryonic physics
  - Gas cooling - White & Frenk (1991), Sutherland & Dopita (1993)
  - Star formation - Kauffmann et al. (1993)
  - Merger-induced starburst - Somerville et al. (2008), Cox et al. (2008)
  - Tidal stripping of hot gas - Kimm et al. (2011)
  - Ram pressure stripping of hot gas - Font et al. (2008), McCarthy et al. (2008)
  - AGN feedback
    - QSO mode - Kauffmann & Haehnelt (2000)
    - Radio mode - Croton et al. (2006)
  - Supernova feedback - Somerville et al. (2008)
  - Chemical evolution - gradual mass loss of stellar populations, Lee & Yi (2013)

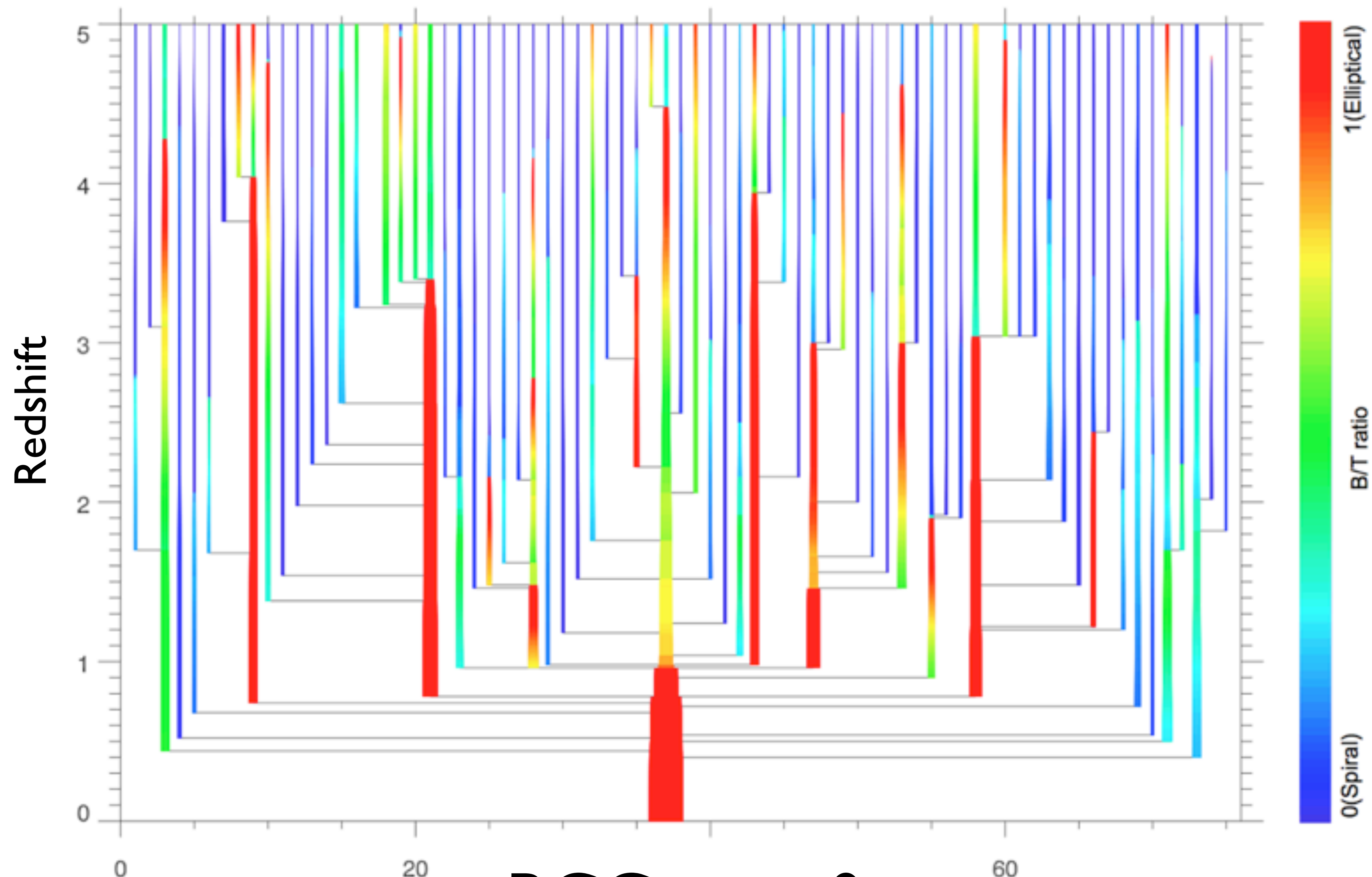
- Stellar mass growth and mass loss history in galaxies
  - Massive galaxies have more than several thousands of stellar populations



Courtesy - S.K.Yi

- Stellar mass growth and mass loss history in galaxies
  - In SAM, $N_{population} \leq N_{progenitor} \times N_{timestep}$

~10^4 for BCGs
~10^3 for large satellites
~10^2 for isolated galaxies



BCG at z=0

- Stellar mass growth and mass loss history of galaxies
  - ySAM rigorously calculates evolution of each stellar population in galaxies.

	Pop1 ($Z=0.01Z_\odot$)		Pop2 ($Z=0.05Z_\odot$)		Pop3 ($Z=0.1Z_\odot$)		Pop4 ($Z=0.3Z_\odot$)		Pop5 ($Z=0.5Z_\odot$)		Pop6 ($Z=Z_\odot$)		Galaxy	
	M_*	M_{loss}	M_*	M_{loss}	M_*	M_{loss}	M_*	M_{loss}	M_*	M_{loss}	M_*	M_{loss}	M_*	M_{loss}
z=5	5	0											5	0
z=4	4.5	0.5	8	0									12.5	0.5
z=3	4.1	0.4	7.2	0.8	4	0							15.3	1.2
z=2	3.8	0.3	6.6	0.6	3.6	0.4	3	0					17	1.3
z=1	3.6	0.2	6.1	0.5	3.3	0.3	2.7	0.3	1	0			16.7	1.3
z=0	3.5	0.1	5.8	0.3	3.0	0.3	2.5	0.2	0.9	0.1	0.5	0	16.3	1.0

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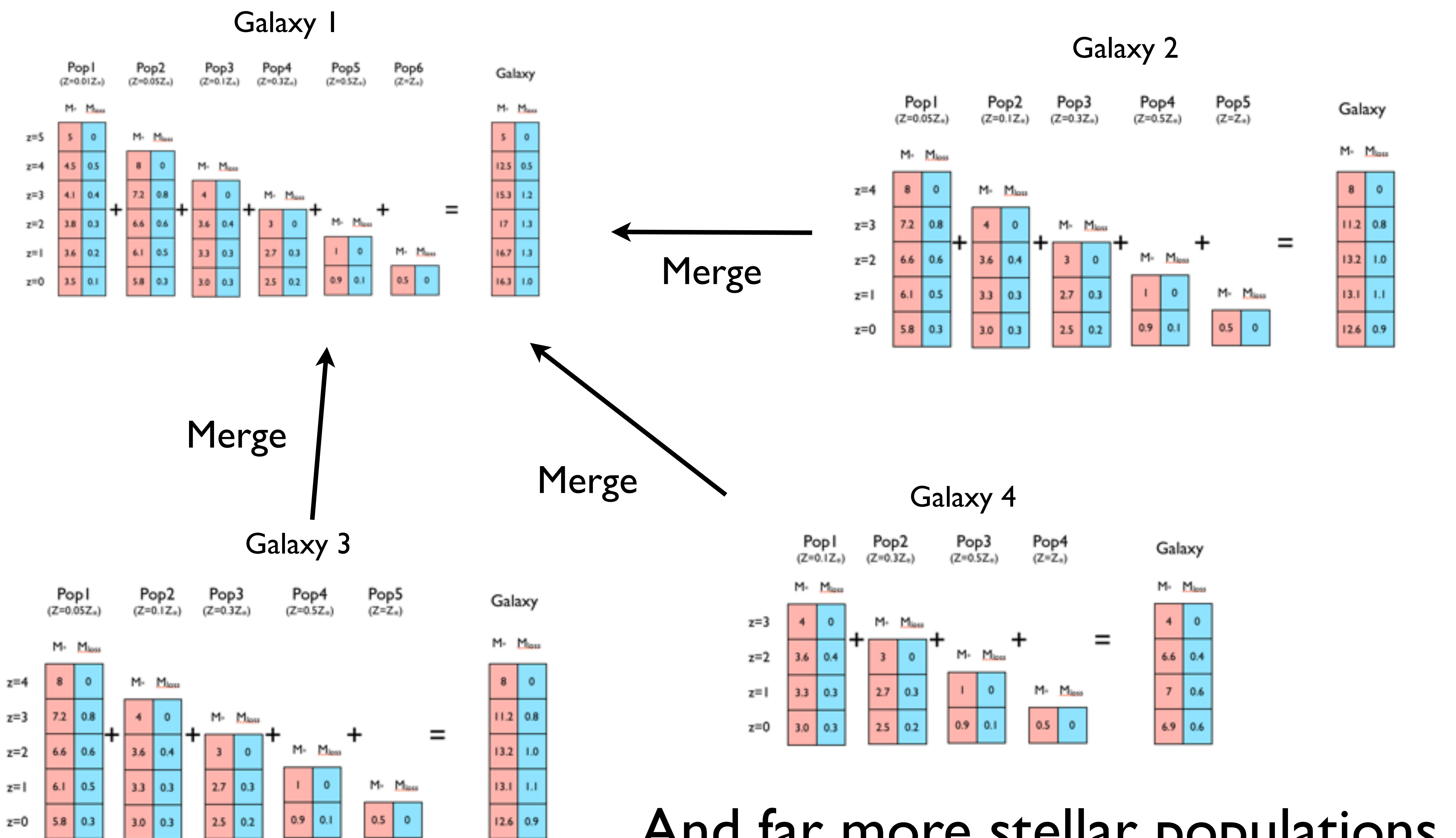

And far more stellar populations and galaxies ....

- Free parameters tuned for calibration in ySAM
    - Star formation efficiency - ϵ_{sf} (~0.02)
    - Stellar mass fraction scattered by mergers - $f_{scatter}$ (0.2-0.5)
    - QSO mode AGN feedback efficiency - f_{BH} (0.005-0.04)
    - Radio mode AGN feedback efficiency - κ_{AGN} (0.00001-0.0004)
    - Supernova feedback efficiency - ϵ_{SN} (1.0-3.0), α_{rh} (2.0-3.5)

- What can ySAM provide?
    - Stellar mass (bulge, disk, and components born outside, in-situ, merger-induced starburst, and scattered by mergers)
    - Cold and hot gas mass
    - Metallicity (bulge, disk, cold and hot gas)
    - Host-satellite relations between galaxies
    - SMBH mass
    - M_{200}, R_{200}, velocity, and position of orphan subhaloes
    - Star formation rates in bulge and disk
    - Luminosity in $L_\odot$
    - Galaxy merger histories