The diverse evolutionary pathways of Milky Way-like galaxies with TNG50

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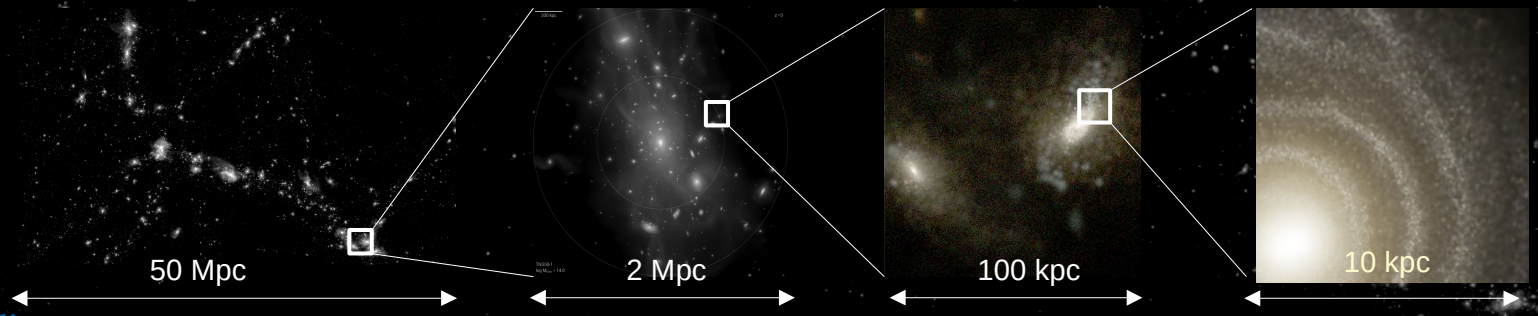
Project goals:
We identify MW-like analogs in the cosmological simulation TNG50 to answer the question of how many pathways can lead to the formation of a MW-like galaxy at z=0.

Open scientific questions

- Assembly history: *how many pathways can lead to a MW-like galaxy at z=0?*
- Effect of mergers: *do they destroy discs? Insitu/exsitu stellar fraction?*
- (Bulge and) disc formation: *inside-out growth or simultaneous?*

Our tool

- Cosmological simulation TNG50
  - Highest resolution run of the IllustrisTNG project
  - Cubic volume: ~50 comoving Mpc side length
    Particles: 2160^3 gas - and DM-particles
  - Particle masses: 8×10^4 M_{sun} (gas), 4×10^5 M_{sun} (DM)
  - Large volume and high resolution: from Virgo-sized galaxy clusters to resolve galactic structure: spiral arms, bulge or disk length and height



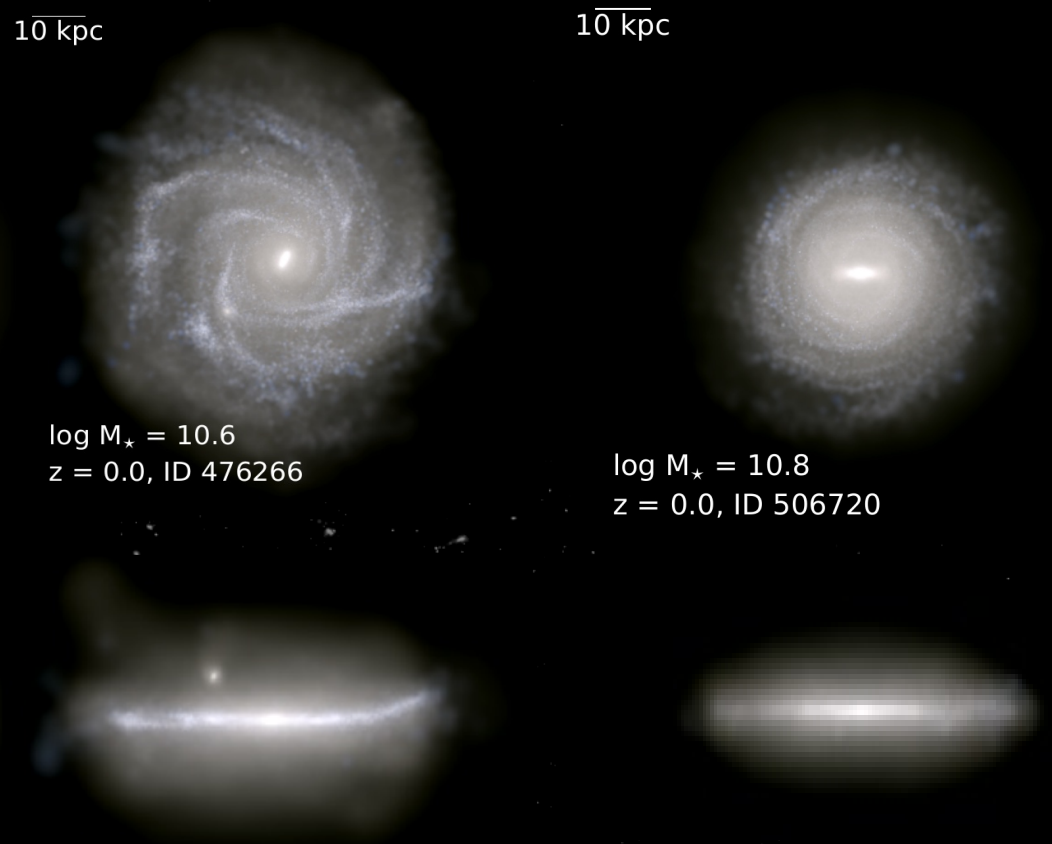
Selection of the Milky Way-like galaxies in TNG50

- Conditions to be selected as “Milky Way-like”
  - (A) M200,c of the halo in mass range (0.6 - 2) x 1012 Msun
  - (B) Subhalo is central of a halo in the mass range M200,c = (0.6 - 2) x 1012 Msun
  - (C) Shape: triaxiality factor T < 0.33
  - (D) Circularity: fractional mass of stars with ε > 0.7 is > 0.4

The galaxy is considered MW-like if (at redshift 0):

A and B and (C or D)

→ **160 MW-like galaxies in TNG50**
matching this criterion



Results: integrated and structural stellar properties

- **Stellar mass**

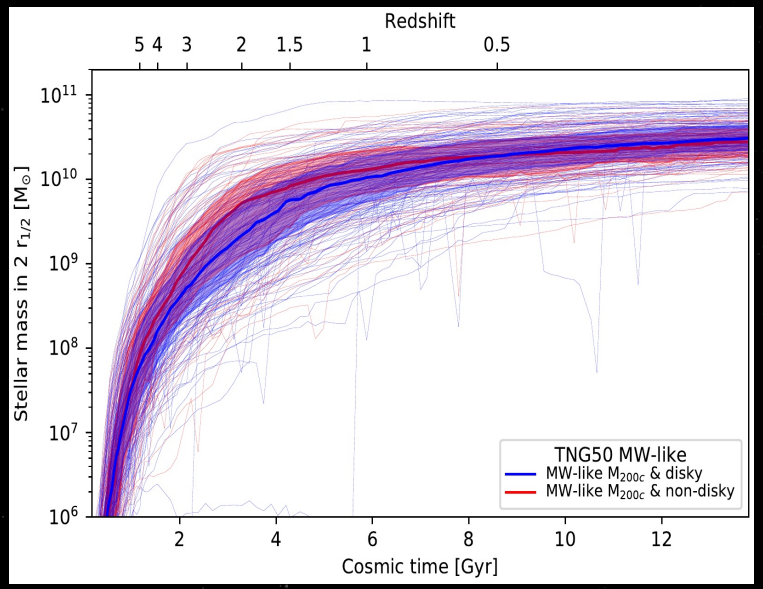
Large scatter: 2×10^{10} - 9×10^{10} M_{sun} at z=0 corresponds to 10^{8} - 3×10^{10} M_{sun} at z=2

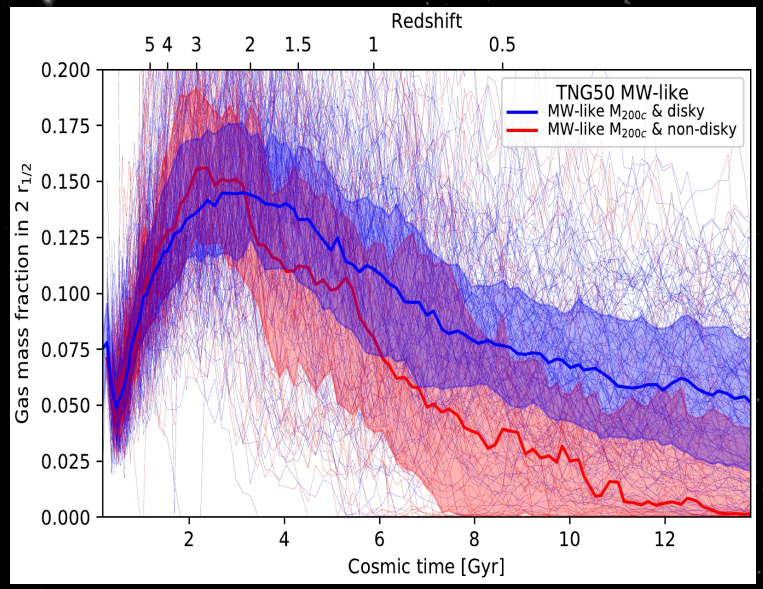
- **Gas mass fraction**

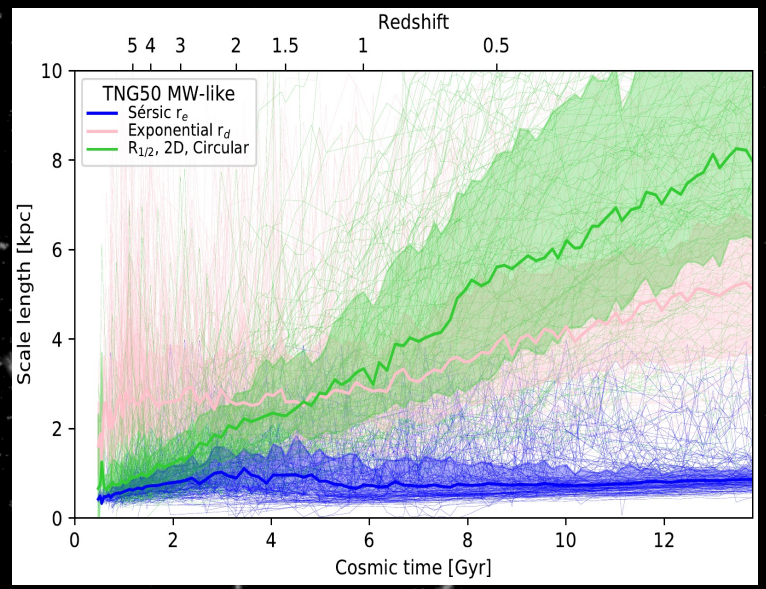
Disky galaxies have on average higher gas mass fractions since z=2

- **Disk length**

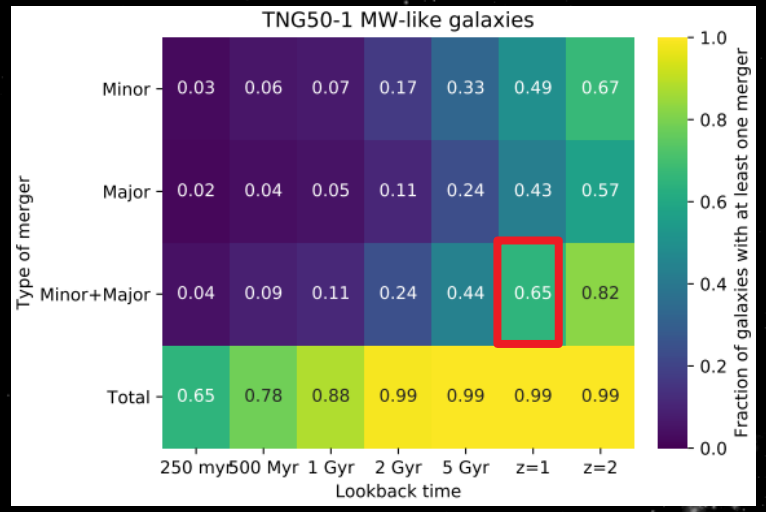
On average, the disk length grows by a factor of ~2 since z=1 and linearly with time



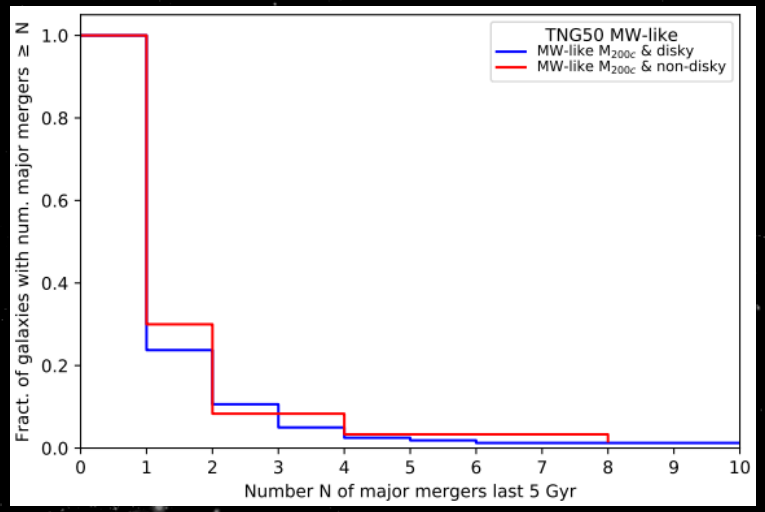




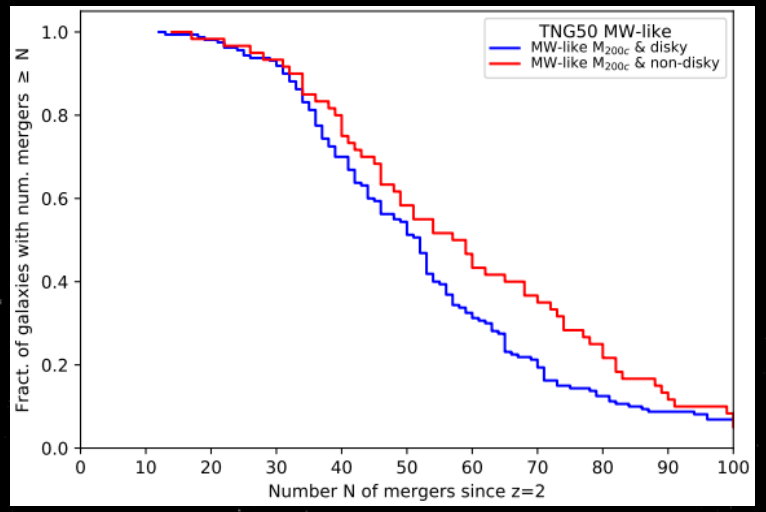
Results: the role of mergers in the assembly histories



MW-like galaxies undergo, on average, a similar number of major and minor mergers. >50% had at least 1 major or minor merger since z=1



~25% of the MW-like, disky galaxies had at least one major merger in the last 5Gyr: it is possible to have a recent major merger and still be disky at z=0



The difference between disky and non-disky MW-like galaxies is more evident when all kinds of mergers are counted

Conclusions

- Many different paths lead to MW-like galaxies:
  - Large scatter in stellar mass: a range of 2×10^{10} - 9×10^{10} M_{sun} at z=0 corresponds to 10^{8} - 3×10^{10} M_{sun} at z=2
- Some general trends can be recognized:
  - Stellar mass content: ~50% assembled by z=1
  - Disk size: increasing ~linearly with time (factor of 2 since z=1)
- Compared with the non-disky isolated galaxies in the same mass range, MW-like disky galaxies have:
  - Higher gas content since z~2
  - Less massive black holes
  - Slightly more quiet assembly history, but not by much