High resolution cosmological simulations of z~2 disks

Shy Genel

With:
Reinhard Genzel, Thorsten Naab, Amiel Sternberg, Nicolas Bouché
• The observations: context and open questions
• The cosmological simulations: model & setup
• Clumps survival
• Comparisons to observations
The SINS survey

- High-z disks, unlike local spiral galaxies, are:
  - Clumpy
  - Gas rich
  - Thick
  - “turbulent”
Things we’d like to know

• What drives the high velocity dispersion in $z \sim 2$ disks? Is it ‘real’ turbulence?

• How long do the clumps survive? Do they migrate inwards to form a bulge?
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The simulation setup

• Cosmological zoom-in simulations in a 100 Mpc box

• Resolution levels: $M_{\text{gas}}=6 \times 10^6 M_{\odot}$ (200 pc @ $z=2$);
  $M_{\text{gas}}=7 \times 10^5 M_{\odot}$ (100 pc);
  $M_{\text{gas}}=1 \times 10^5 M_{\odot}$ (50 pc)

• Halos of $\sim 10^{12} M_{\odot}$ @ $z=2$, selected by halo formation history:
  • (1) no $>1:3$ merger @ $2<z<3$
  • (2) halo growth rate $> 500 M_{\odot}/\text{yr}$
  • These criteria represent $\sim 15\%$ of the halos of $\sim 10^{12} M_{\odot}$
The model

• Gadget-2 (Springel+ 2005) version from Davé, Oppenheimer, Finlator (2006..2010):
  • Primordial + metal cooling
  • Haardt & Madau (2001) UV background
  • Momentum-driven super-wind (kinetic FB) model (following Murray, Quataert & Thompson 2005)
  • Metal and mass (gas recycling) feedback from: SNII, SNIa and AGB stars
The model – modifications

• Effective EOS for star-forming gas:
  • Isothermal with a polytropic ($\gamma_{\text{eff}}=4/3$) pressure floor $\Rightarrow$ Jeans mass resolved

• Schmidt law for star-formation
  • $\text{sSFR} \sim \rho^n \Rightarrow$ Kennicutt 1998 star-formation law

• Explicit threshold on $\Sigma_g$ for star-formation
The role of the wind

- Reduced $M_\ast/M_h$ (‘galaxy formation efficiency’)
- Increased gas fractions
- Increased sSFR
The role of the wind

- Flat rotation curves, TFR

[Graphs showing the effect of winds on circular velocity curves and the TFR with/without winds.]
Disk stability

stiff EOS
(Springel & Hernquist 2003)

$\gamma=4/3$ EOS
Clump survival and the SF law

- Interplay between $T_{\text{SF}}/\eta$ and dynamical time:

- Kennicutt 1998 law $\Rightarrow$ Transient clumps

- Constant $T_{\text{SF}} = 1\text{Gyr}$ (Genzel+ 2010, Daddi+ 2010) $\Rightarrow$ Enough time to virialize
Mock images and dust

Observed optical

Observed J-band

Observed H-band
Mock images and dust

Observed optical  Observed J-band  Observed H-band
Clump kinematics

• Clumps are minima in vertical velocity dispersion, $\sigma \sim 20$ km/s

• Clumps have circular velocities $(GM/R)^{0.5}$, $\sim 50$-100 km/s

• But these are hard to observe, because...
Clump kinematics

- Clumps are not virialized, i.e. they are collapsing until they are dispersed
- ‘beam smearing’

⇒ Best observed resolution may be able to dynamically detect the clumps only marginally
Conclusions and prospect

- Momentum-driven winds and resolution of \(~100\) pc make gas-rich star-forming disks at \(z\sim 2\)

- A model where clumps disrupt before they virialize seems consistent (or to say the least, as consistent as other models) with observations

- What next:
  - More (and more representative) halos
  - Investigate the origin of large velocity dispersions
  - Quantitative/statistical comparison with observations