High resolution cosmological simulations of z~2 disks

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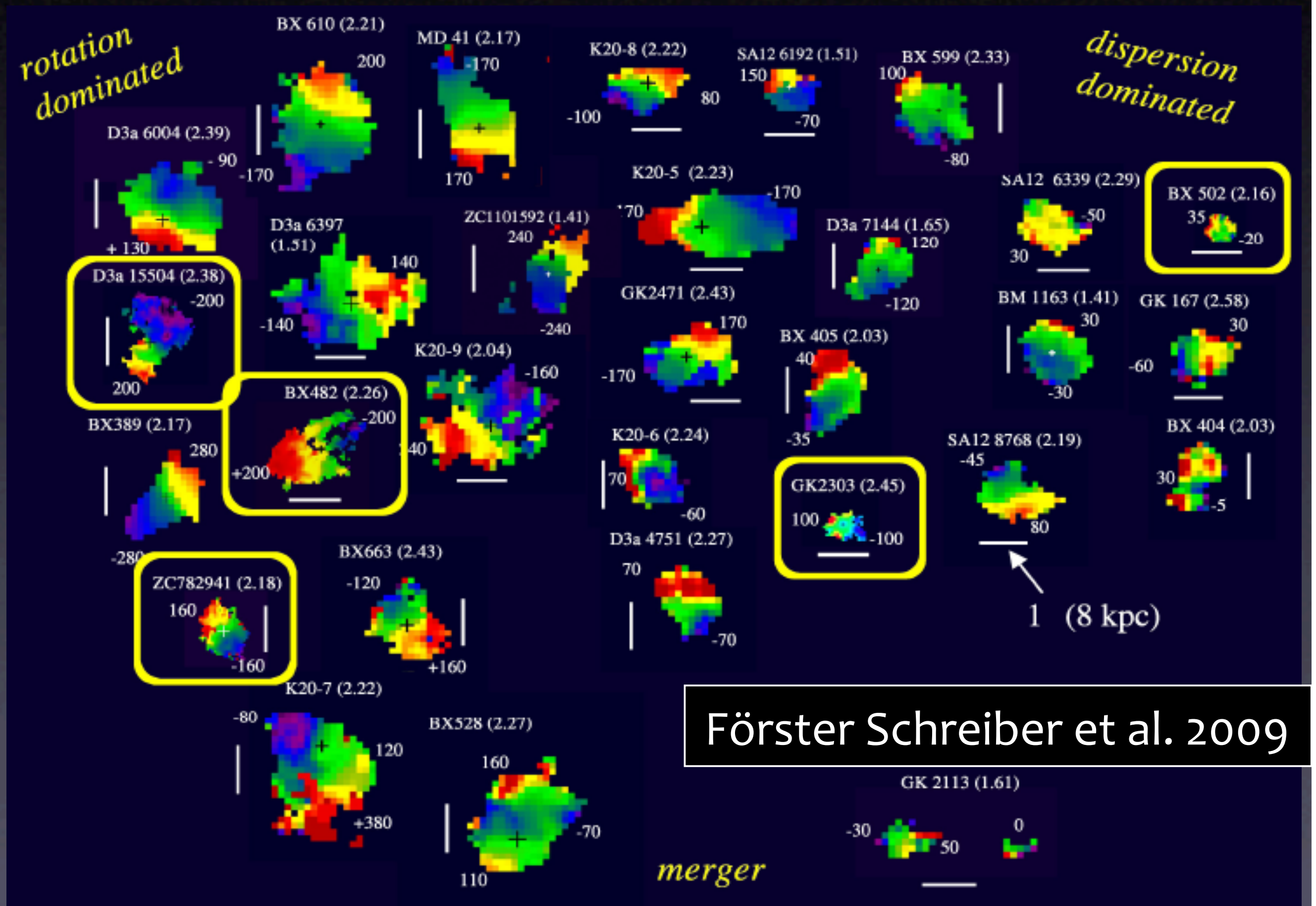
Outline

- The observations: context and open questions
- The cosmological simulations: model & setup
- Clumps survival
- Comparisons to observations

The SINS survey

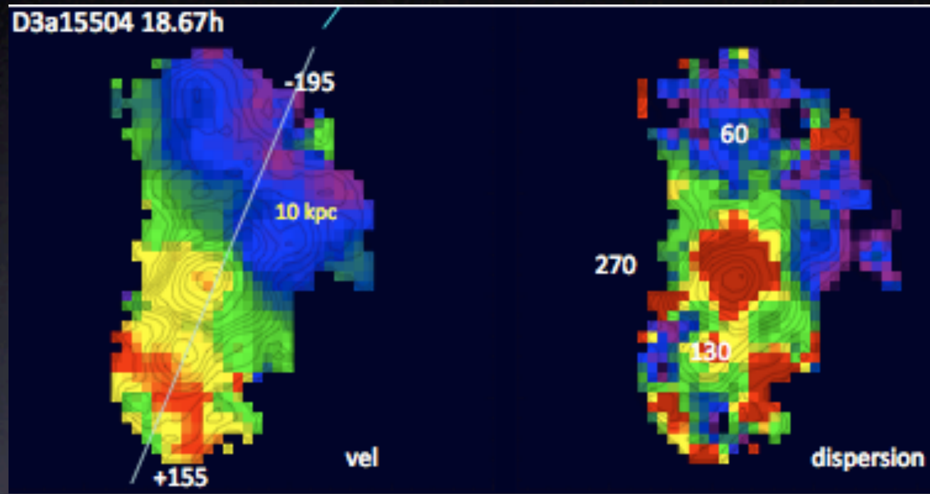
- High-z disks, unlike local spiral galaxies, are:
  - ✓ Clumpy
  - ✓ Gas rich
  - ✓ Thick
  - ✓ "turbulent"

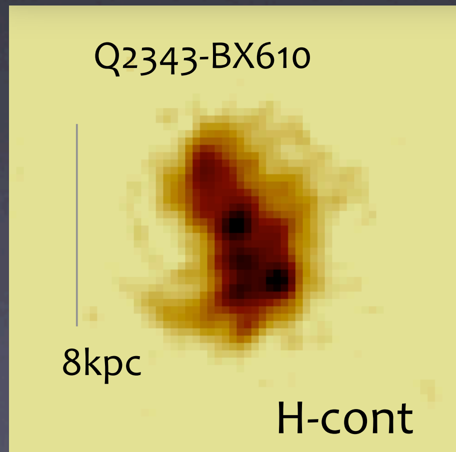


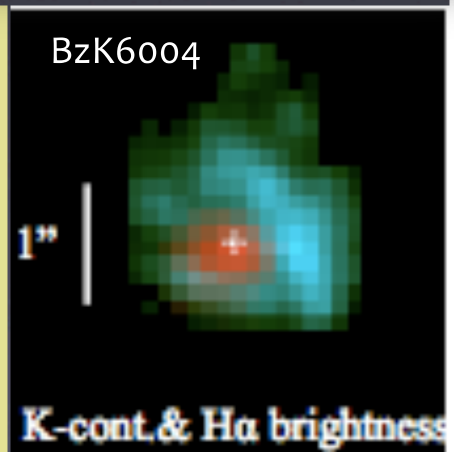
Förster Schreiber et al. 2009

Things we'd like to know

- What drives the high velocity dispersion in z~2 disks? Is it 'real' turbulence?
- How long do the clumps survive? Do they migrate inwards to form a bulge?







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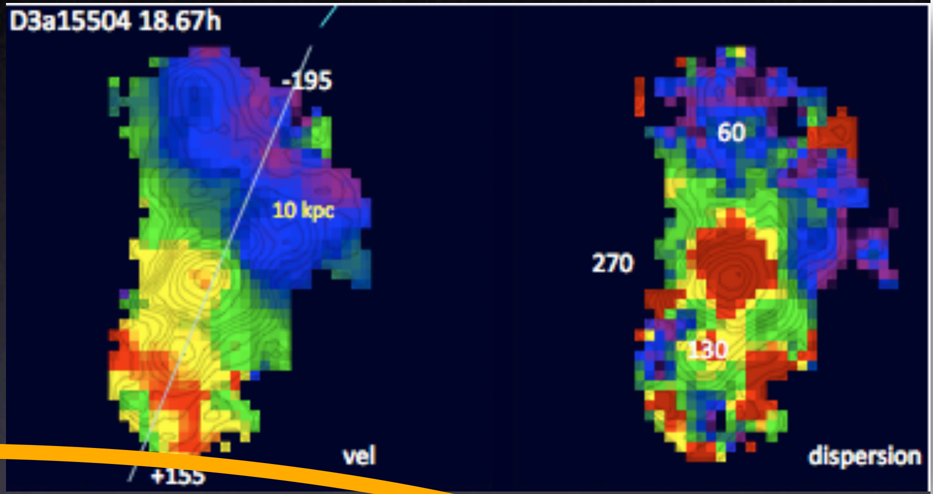

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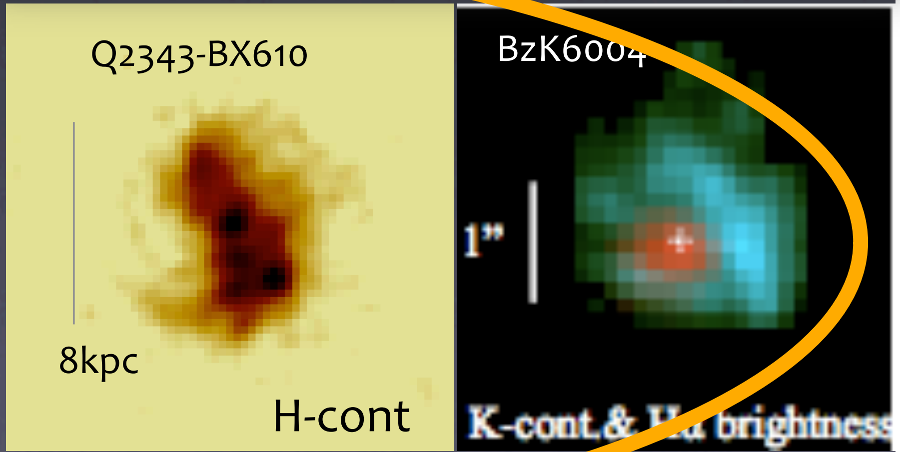


The simulation setup

- Cosmological zoom-in simulations in a 100 Mpc box
- Resolution levels : M_{gas}=6e6M_{sun} (200 pc @ z=2) ; M_{gas}=7e5M_{sun} (100 pc) ; M_{gas}=1e5M_{sun} (50 pc)
- Halos of ~1e12 M_{sun} @ z=2, selected by halo formation history:
  - (1) no >1:3 merger @ 2<z<3
  - (2) halo growth rate > 500M_{sun}/yr
  - These criteria represent ~15% of the halos of ~1e12 M_{sun}

The model

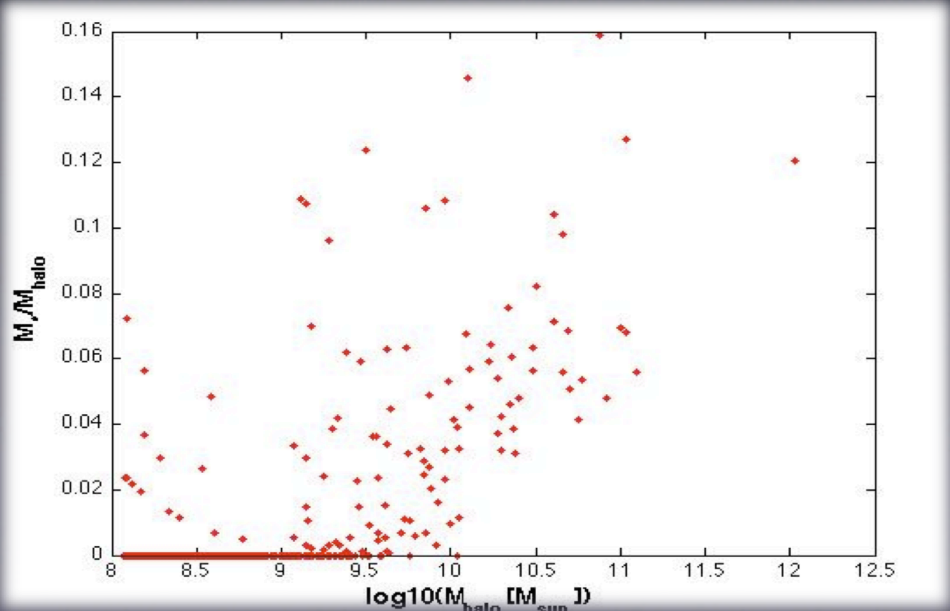
- Gadget-2 (Springel+ 2005) version from Davé, Oppenheimer, Finlator (2006..2010) :
  - Primordial + metal cooling
  - Haardt & Madau (2001) UV background
  - Momentum-driven super-wind (kinetic FB) model (following Murray, Quataert & Thompson 2005)
  - Metal and mass (gas recycling) feedback from: SNII,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

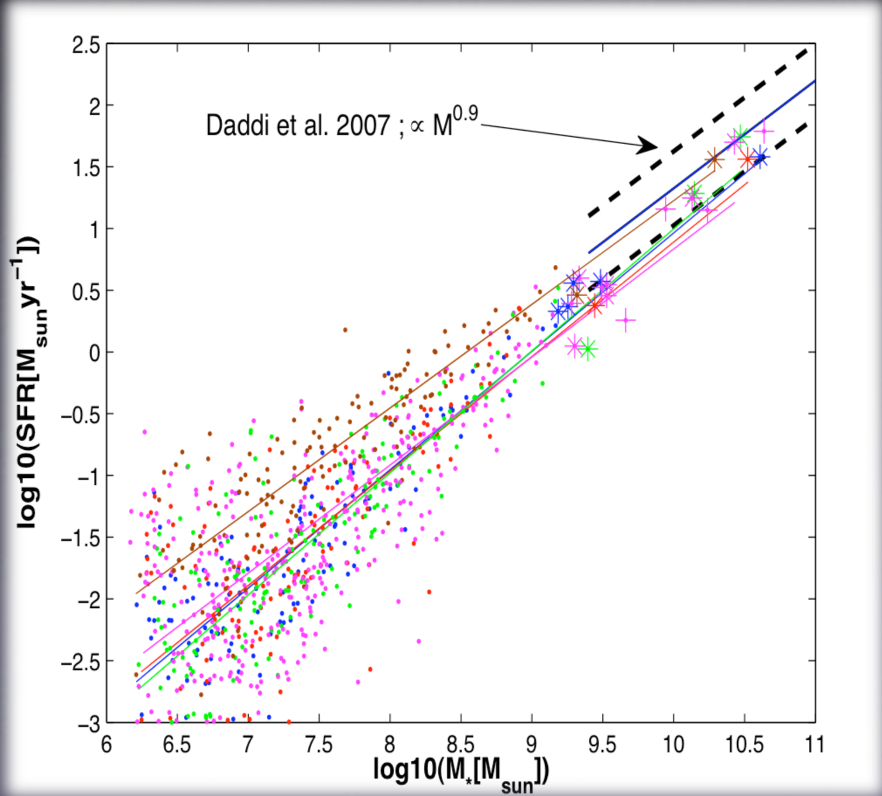
The model – modifications

- Effective EOS for star-forming gas:
  - Isothermal with a polytropic (γ_{eff}=4/3) pressure floor → Jeans mass resolved
- Schmidt law for star-formation
  - sSFR ~ ρ^n → Kennicutt 1998 star-formation law
- Explicit threshold on Σ_g for star-formation

The role of the wind

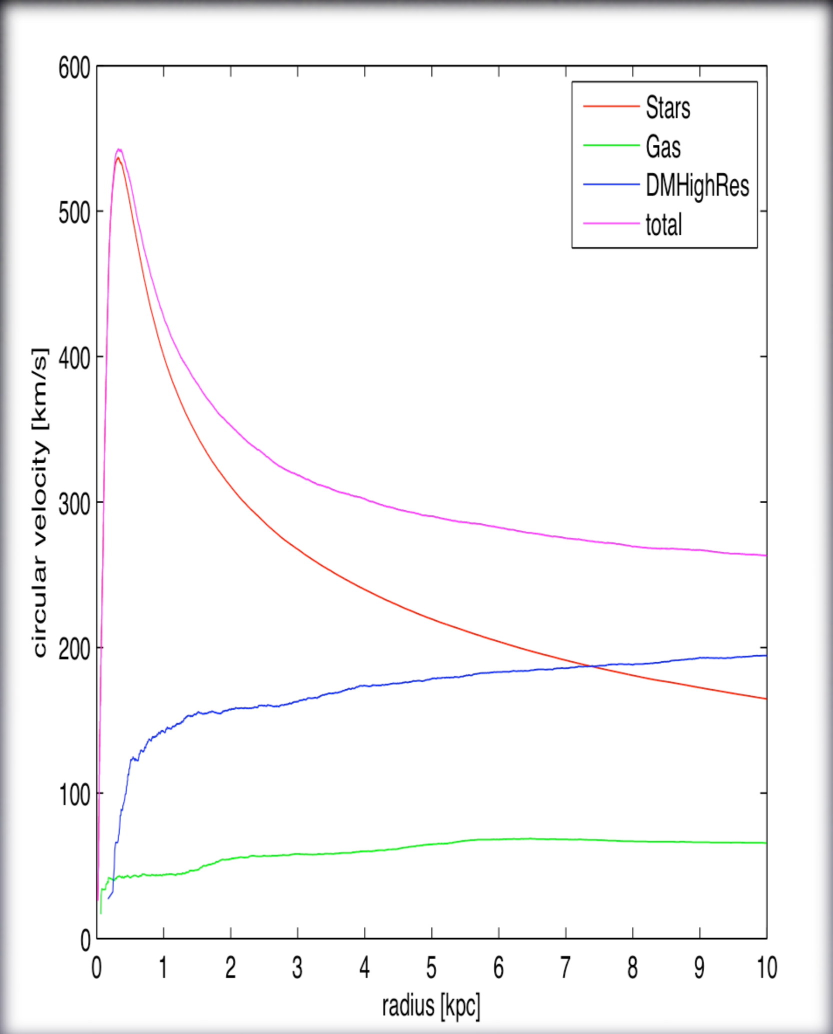
- Reduced M_*/M_h (‘galaxy formation efficiency’)
- Increased gas fractions
- Increased sSFR

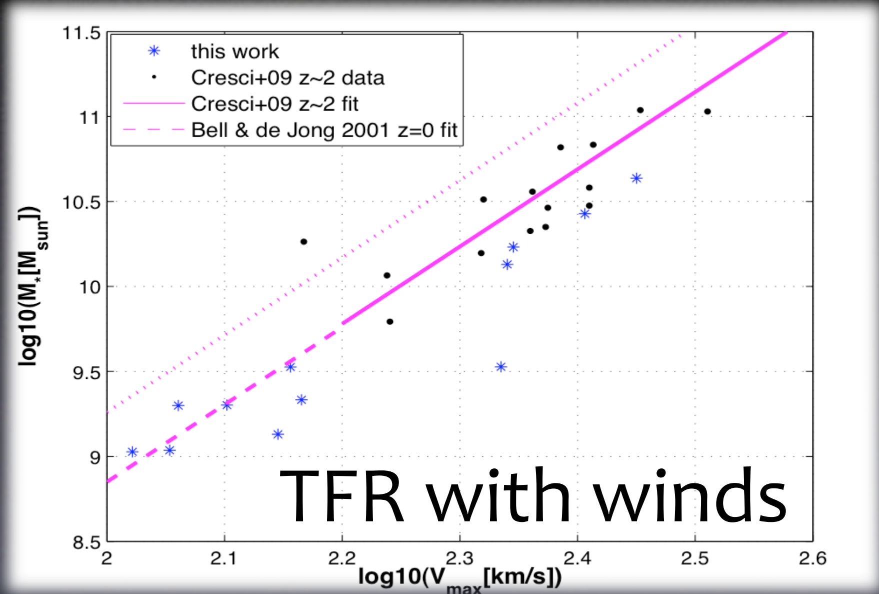


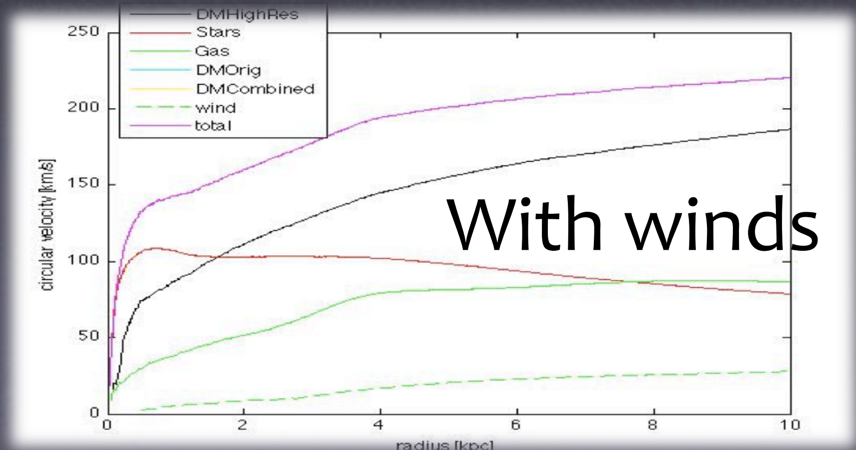


The role of the wind

- Flat rotation curves, TFR



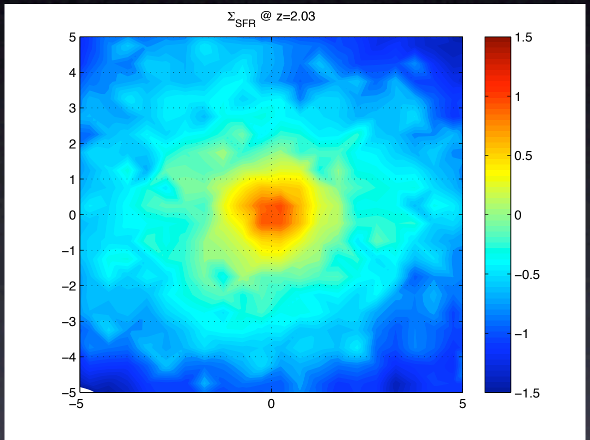




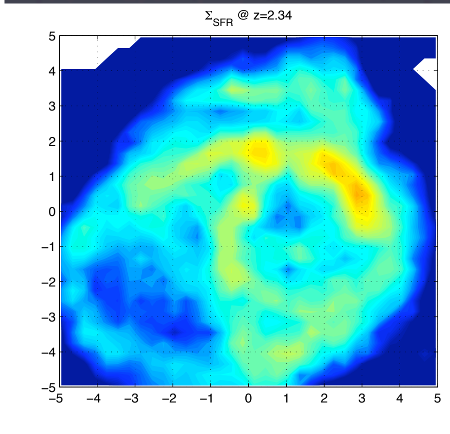
Disk stability

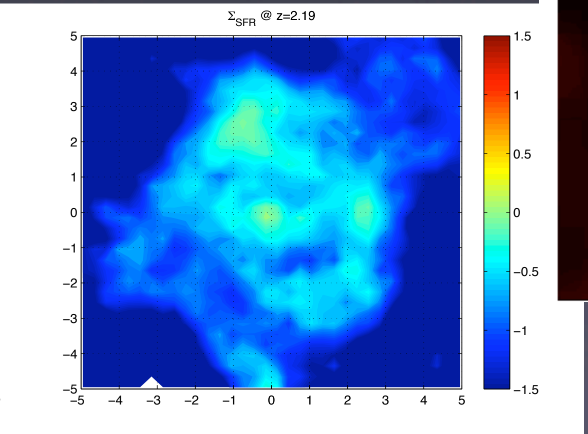
stiff EOS

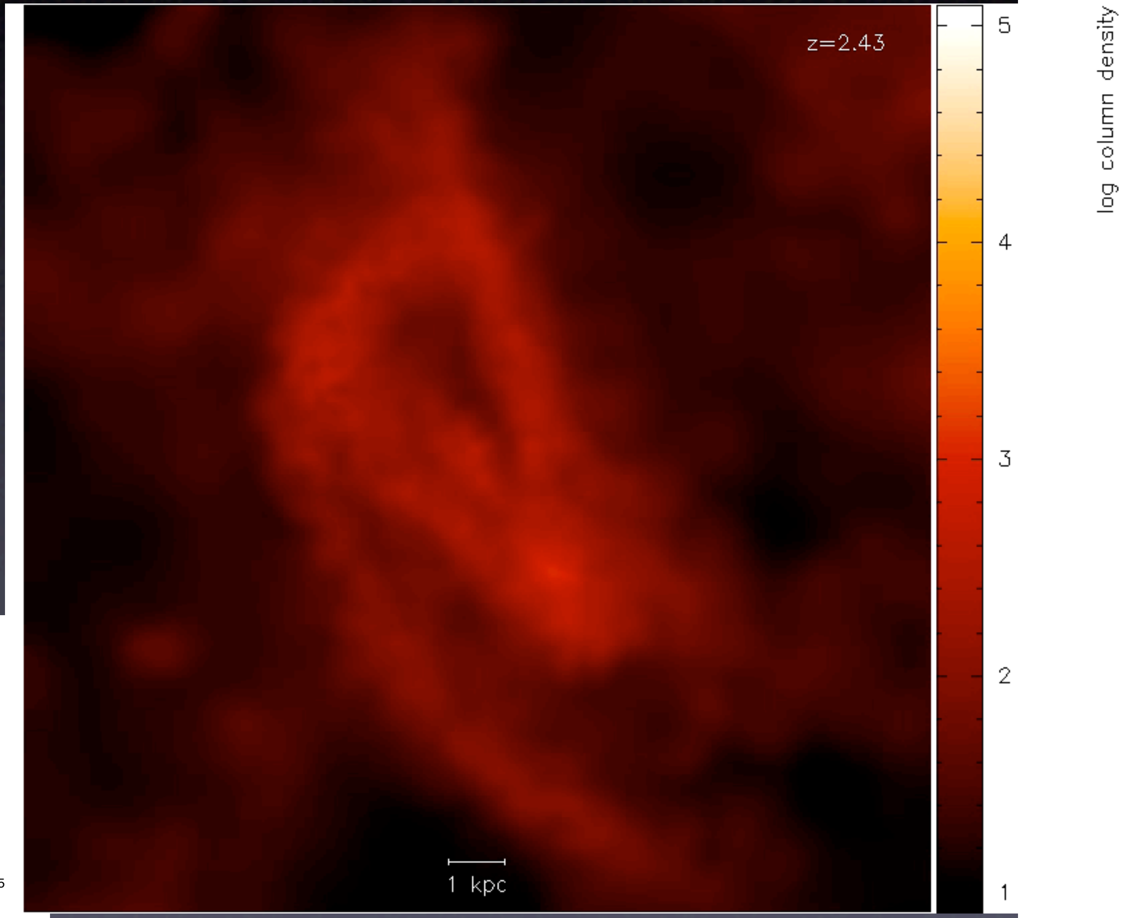
(Springel & Hernquist 2003)



γ=4/3 EOS

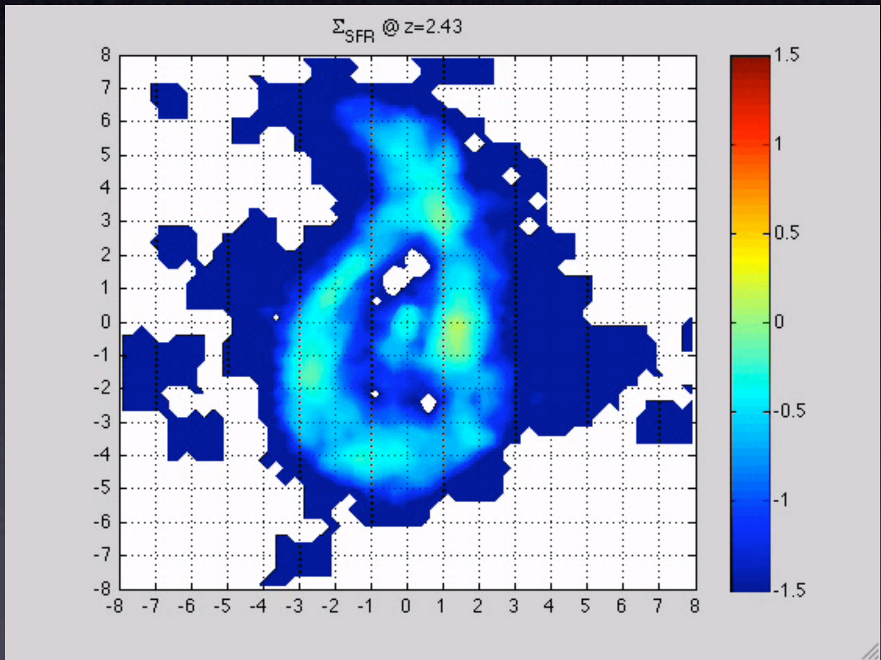


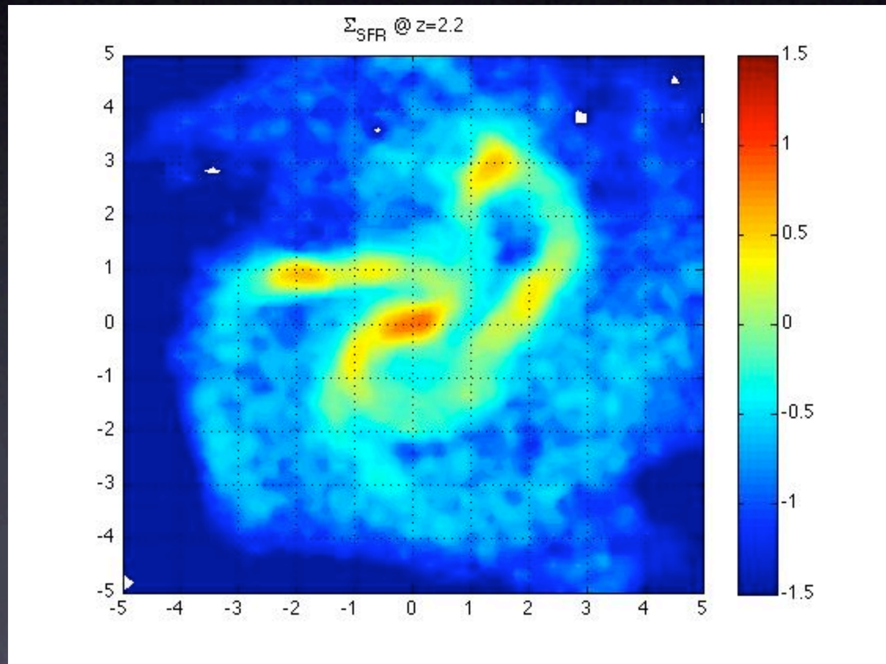




Clump survival and the SF law

- Interplay between T_{SF}/η and dynamical time:



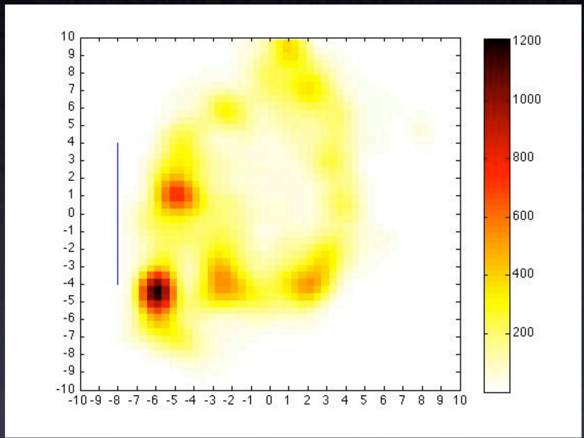


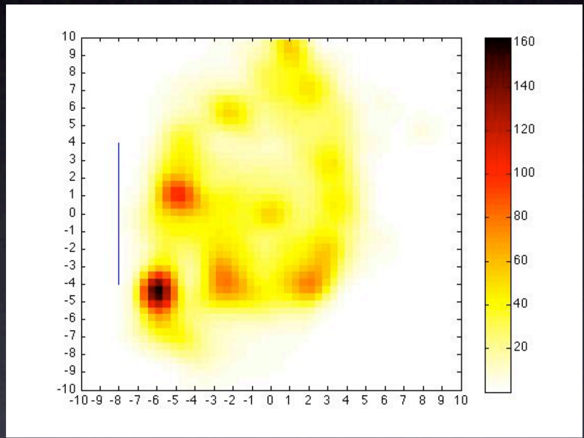
- Kennicutt 1998 law
  ⇒ Transient clumps

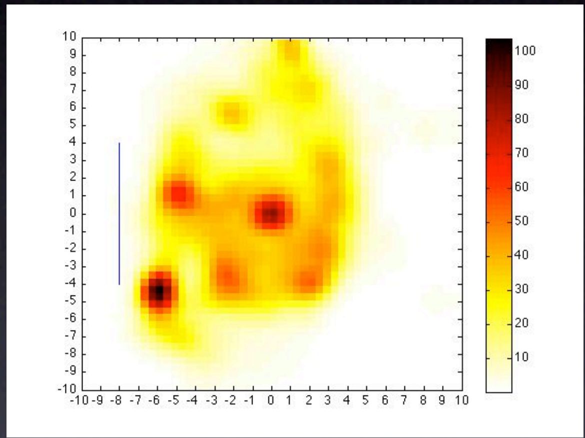
- Constant T_{SF} = 1Gyr
  (Genzel+ 2010, Daddi+ 2010)
  ⇒ Enough time to virialize

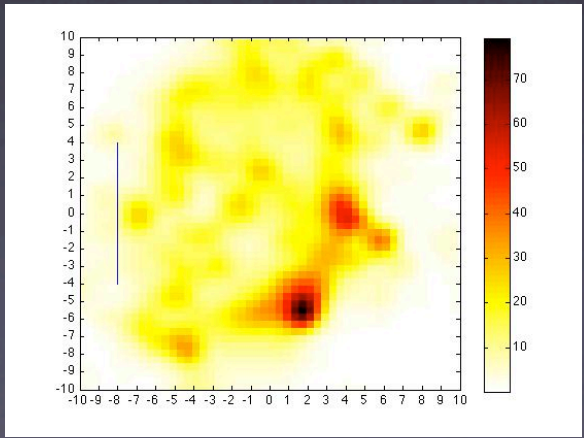
Mock images and dust

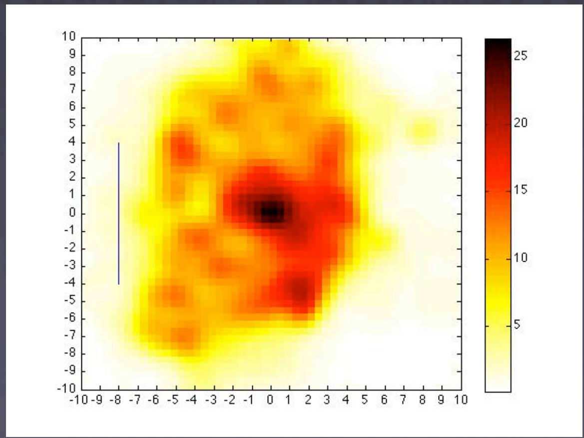
Observed optical | Observed J-band | Observed H-band

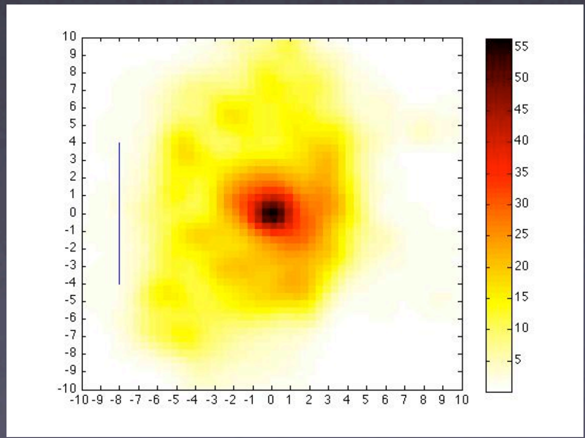












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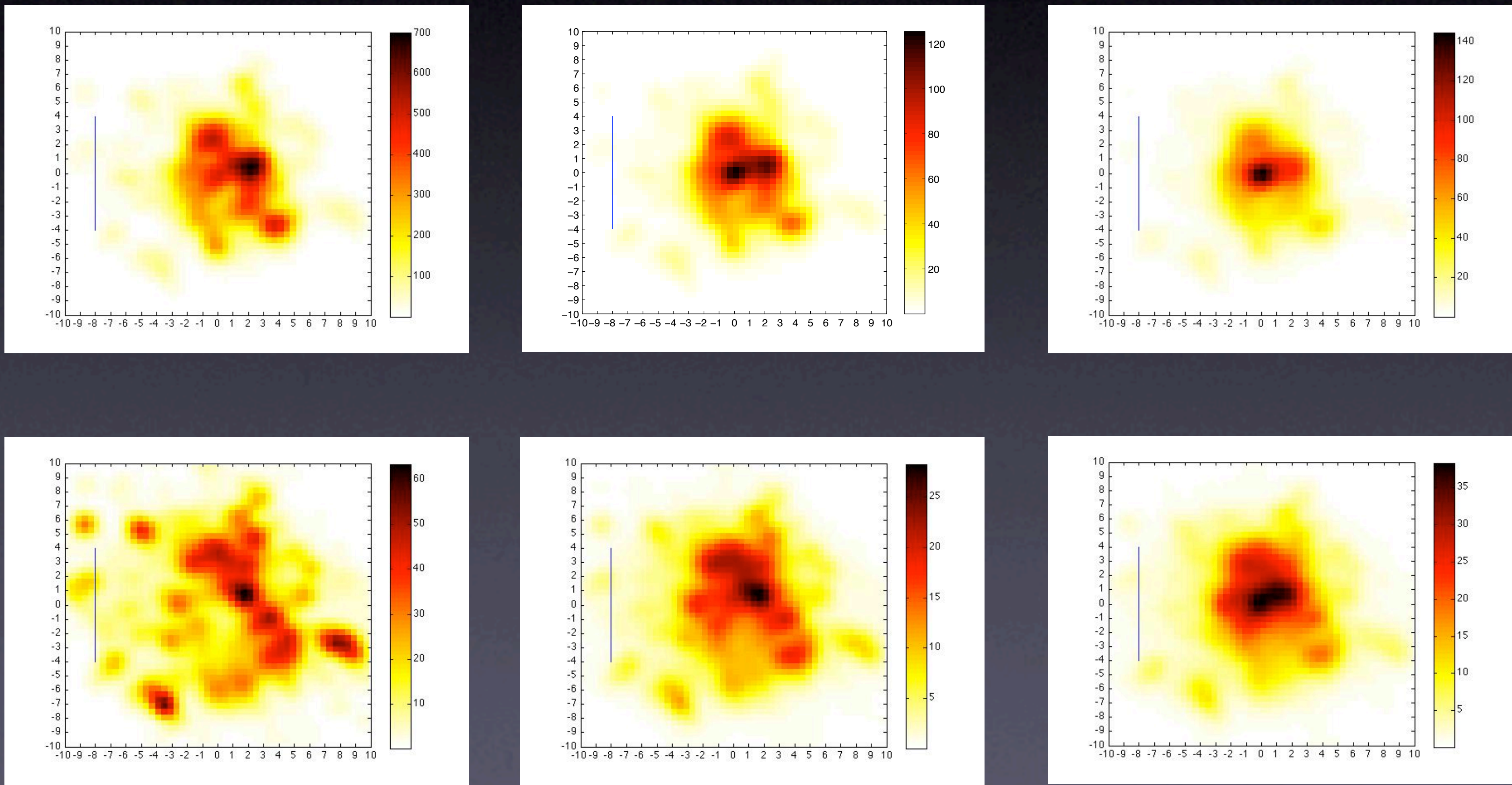
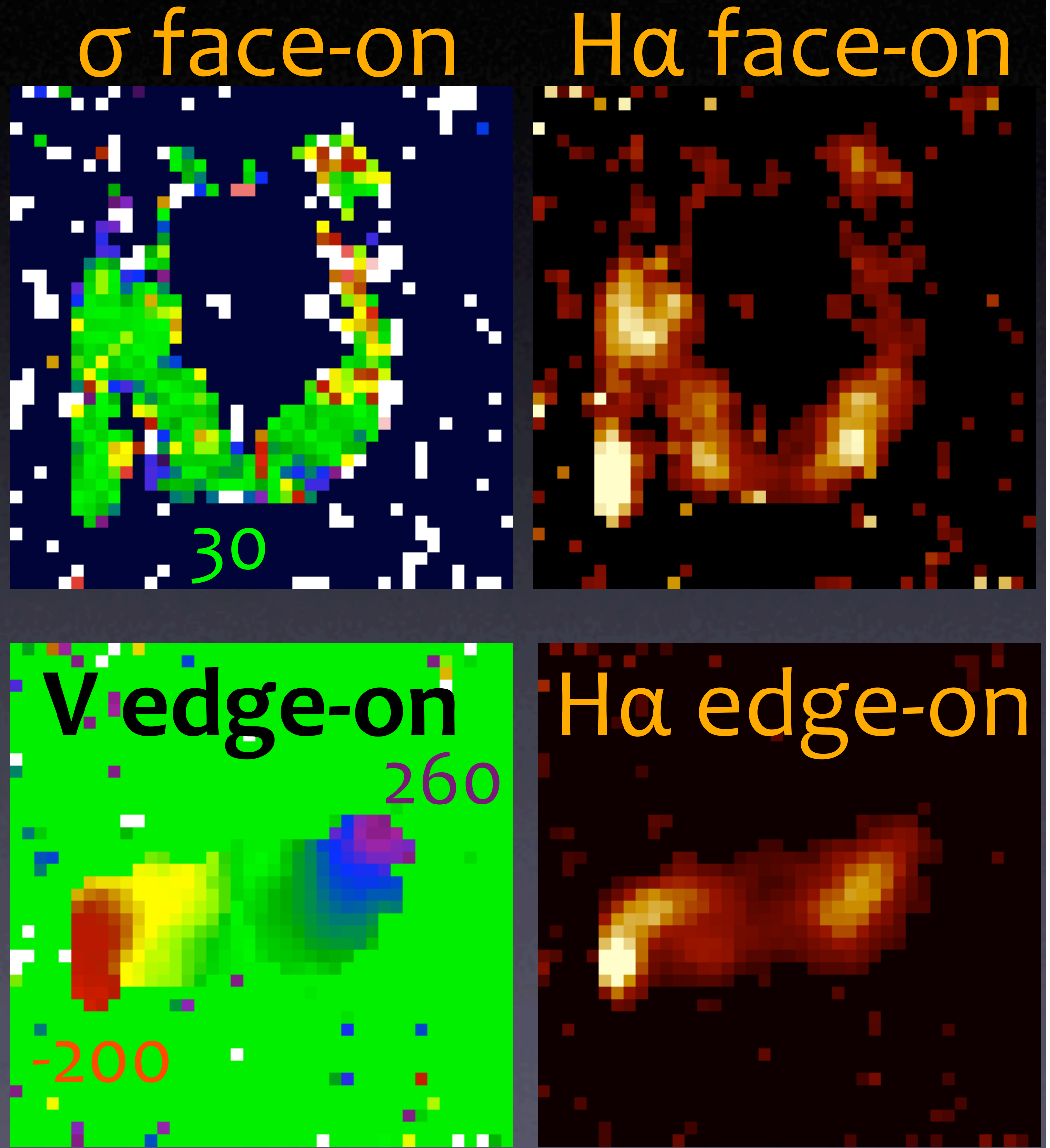


Clump kinematics

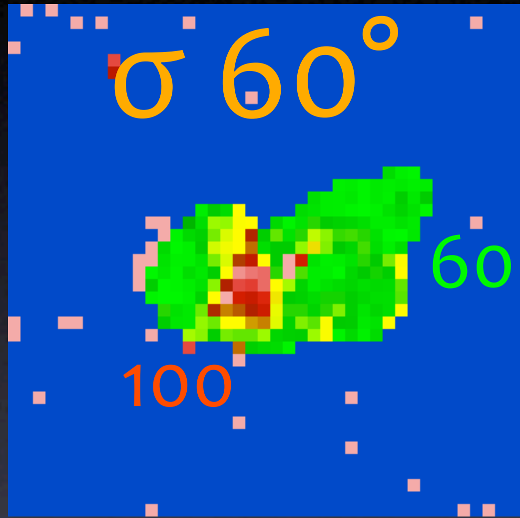
- Clumps are minima in vertical velocity dispersion, σ~20 km/s
- Clumps have circular velocities $(GM/R)^{0.5}$ ~50-100 km/s
- But these are hard to observe, because…

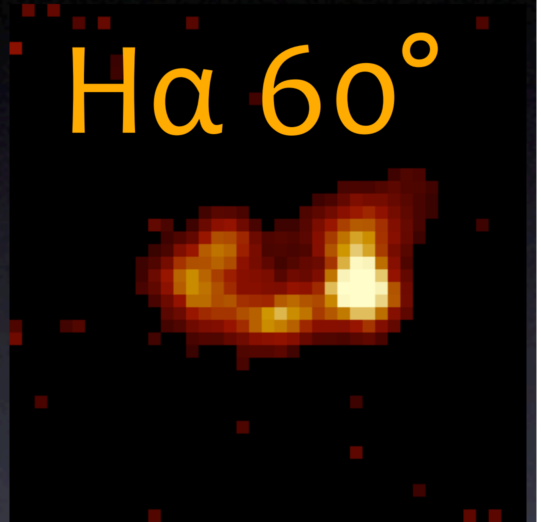


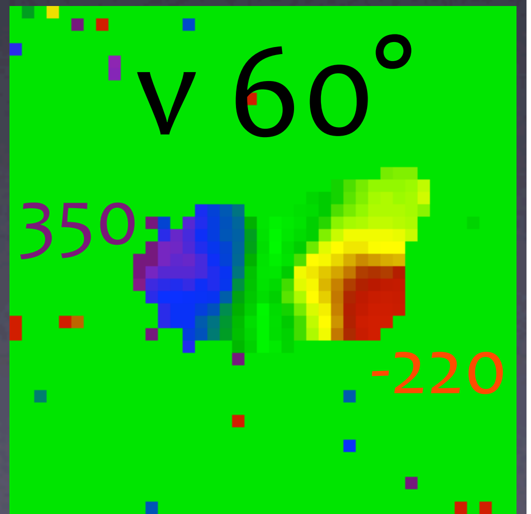
Clump kinematics

- 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 ~100pc make gas-rich star-forming disks at z~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