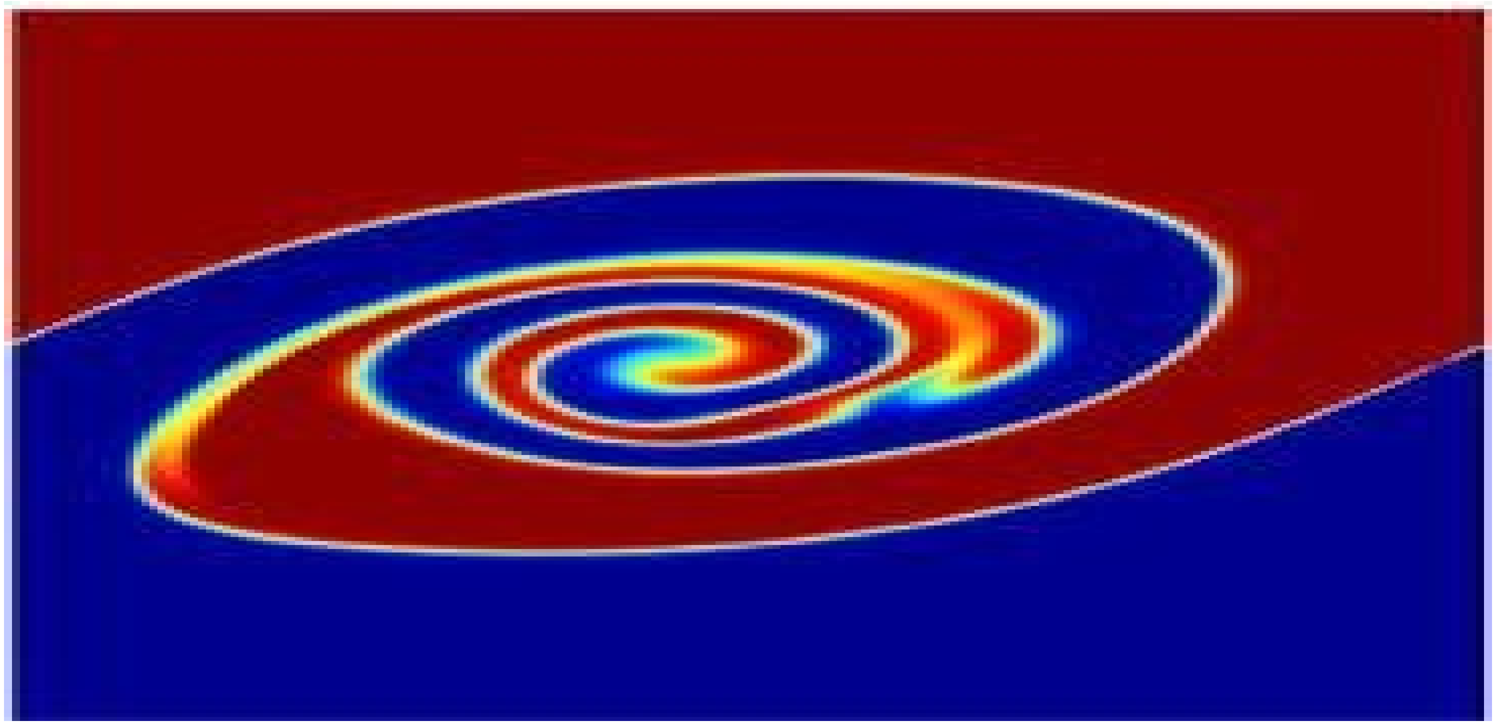
Large Scale Turbulence in Galactic Disks during Formation

Velocity Dispersion & Main Drivers

Contents

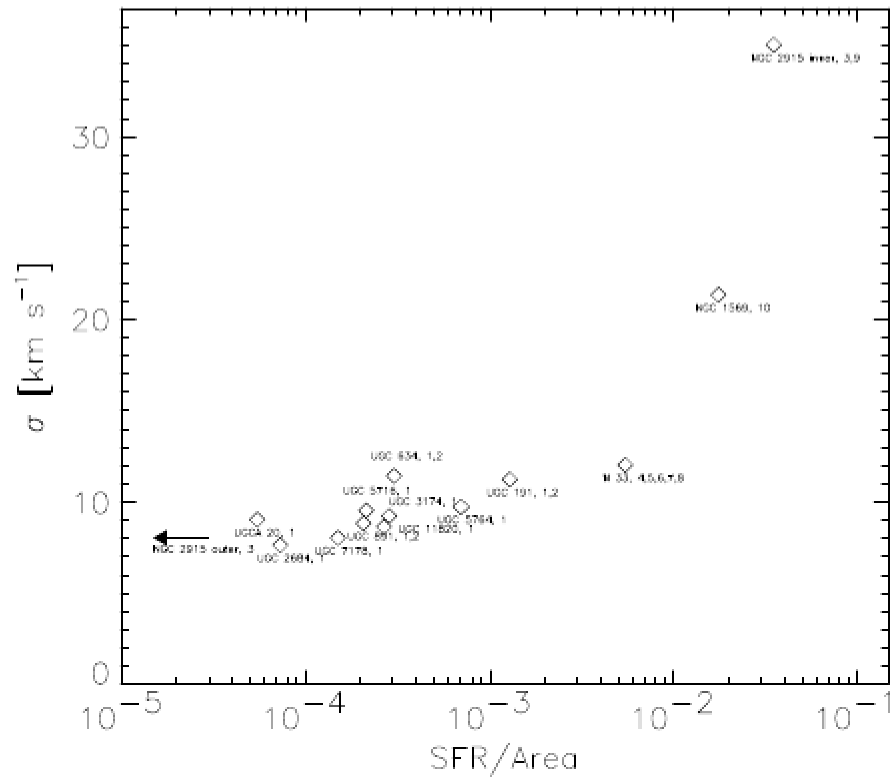
Turbulence



Source: http://fluid.stanford.edu/~fringer/movies/shear_convect/kh_rt_shear.jpg

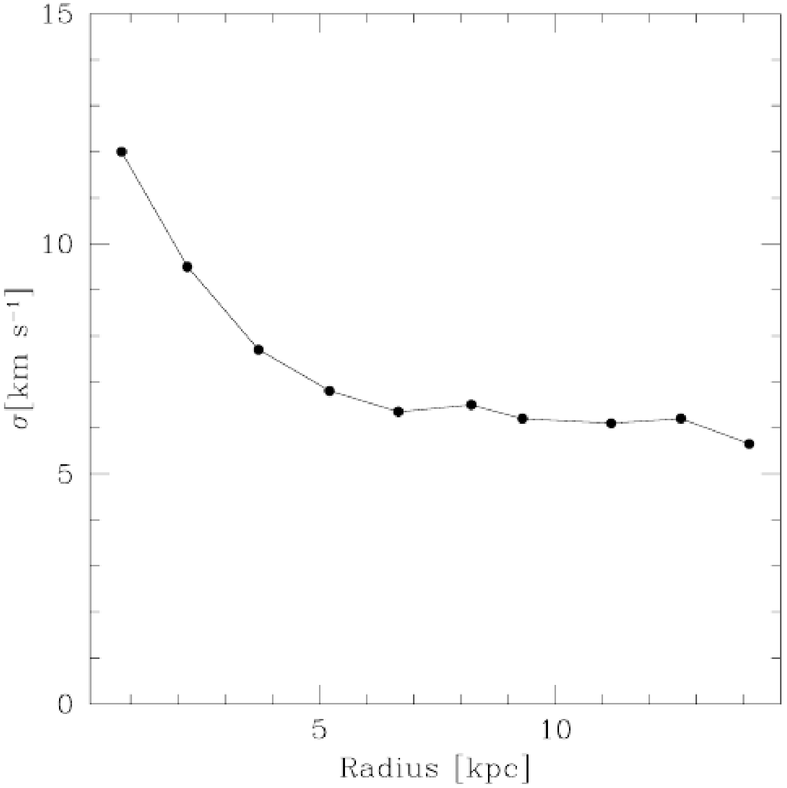
Observations

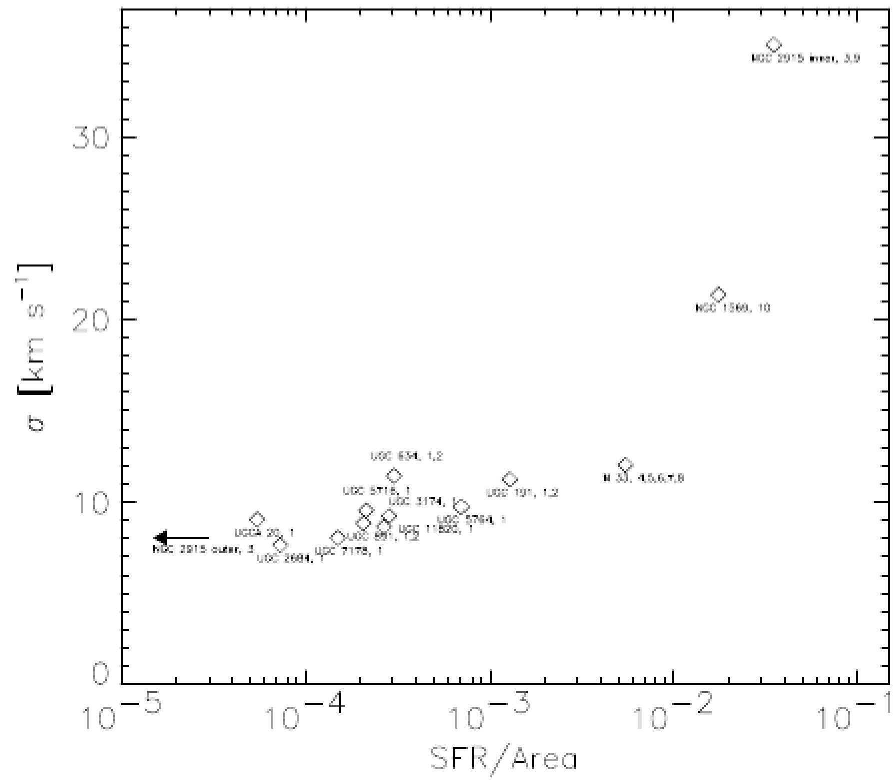
Observations



Source: Dib et al. (2006): The supernova rate-velocity dispersion relation in the interstellar medium; Figures 1 and 2

Observations





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Simulation

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Initial Conditions

Temperature, Density, Rotation Curve

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Temperature, Density, Rotation Curve

Recipes

Star Formation, Cooling, Poisson, Hydrodynamics, SNe

Evolution

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$$Q = \frac{\kappa c_s}{\pi G \Sigma}$$

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Time [Gyr]	Q (By Volume ~ Gas)	Q (By Mass ~ Clouds)
0	2 – 10 (all stable)	2 – 10 (all stable)
0.25	0.2 – 1 (fragmentation)	0.2 – 1 (fragmentation)

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0	2 – 10 (all stable)	2 – 10 (all stable)
0.25	0.2 – 1 (fragmentation)	0.2 – 1 (fragmentation)
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Time [Gyr]	Q (By Volume ~ Gas)	Q (By Mass ~ Clouds)
0	2 – 10 (all stable)	2 – 10 (all stable)
0.25	0.2 – 1 (fragmentation)	0.2 – 1 (fragmentation)
0.5	0.75 – 10 (tail to higher Q)	Peaks at 1 (tail to higher)
>1	0.8 – 100 (mostly stable)	0.9 – 4 (marginally stable)

Evolution

Evolution

Marginally Stable ($Q \sim 1.2$)

Evolution

Marginally Stable (Q ~ 1.2)

Swing Amplification, Coupling Stars & Disk

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Swing Amplification, Coupling Stars & Disk

Fully Unstable ($Q < 1.2$)

Evolution

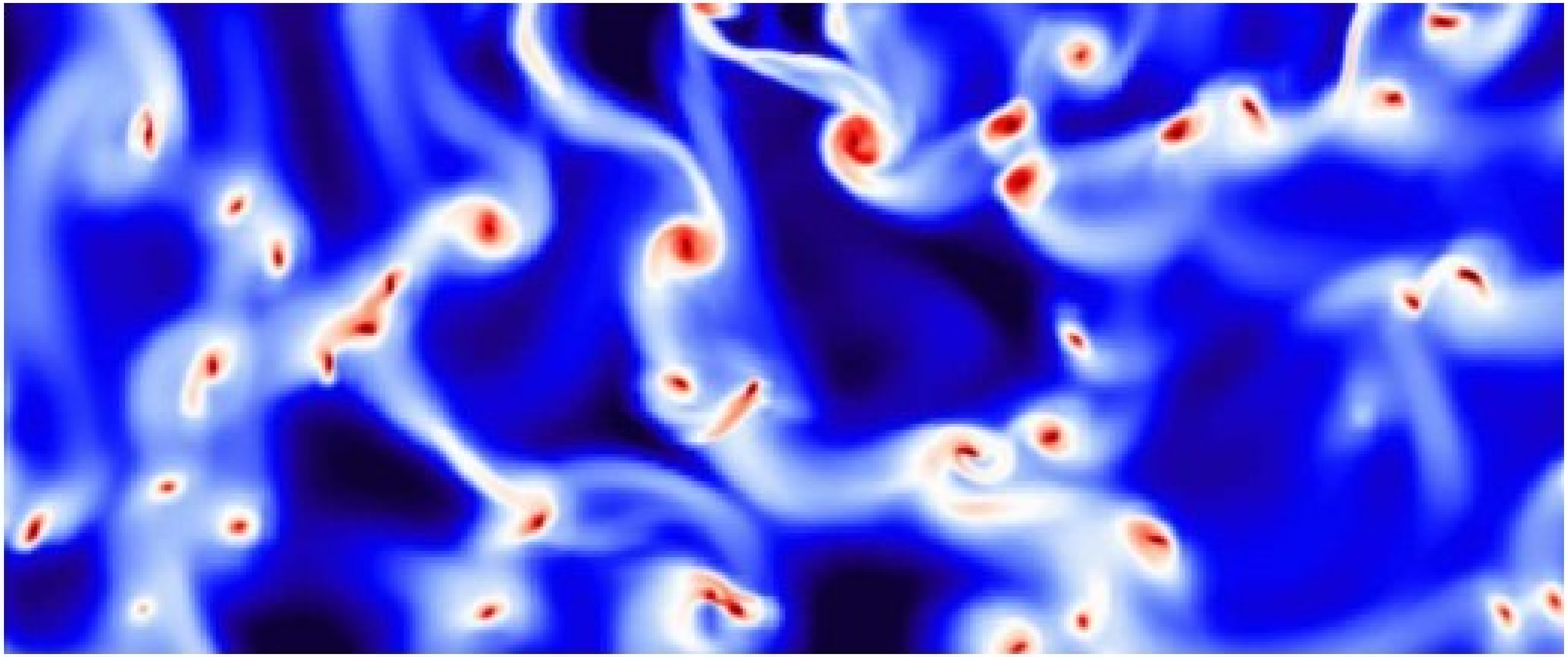
Marginally Stable (Q ~ 1.2)

Swing Amplification, Coupling Stars & Disk

Fully Unstable (Q < 1.2)

Cloud/Cloud Interaction, Stirring Diffuse Gas

Developed Turbulence



Source: Agertz et al. (2009): Large scale galactic turbulence: can self-gravity drive the observed HI velocity dispersions?; Figure 16

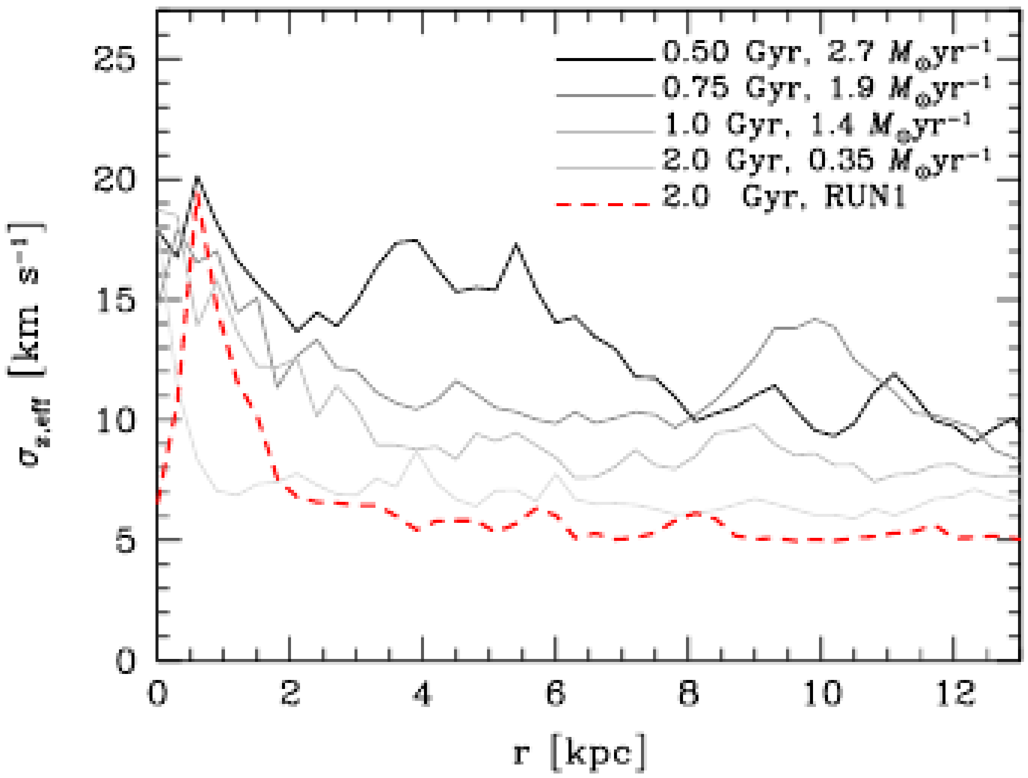
Main Driver

Main Driver

Biggest Energy Reservoir → Galactic Rotation

Starbursts

Starbursts and Supernovae



Source: Agertz et al. (2009): Large scale galactic turbulence: can self-gravity drive the observed HI velocity dispersions?; Figure 23

Limitations

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- Small Scale Effects Not Included:
  - MRI in Accretion Disks
  - Jets
  - Solar Winds
  - Fluid Instabilities (RT+KH)

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- Only Large Scale Effects
- Small Scale Effects Not Included:
  - MRI in Accretion Disks
  - Jets
  - Solar Winds
  - Fluid Instabilities (RT+KH)
- Heating
  - Only SNe
  - Could Include Stars (Uniform Radiation Field)

Conclusions

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- Later: Shear & Cloud/Cloud → Drag Thin Gas → Turbulence

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- Early: Cooling → Gravitational Instability → Fragmentation
- Later: Shear & Cloud/Cloud → Drag Thin Gas → Turbulence
- High SFR → SNe Feedback Main Driver

(Optional Contents)

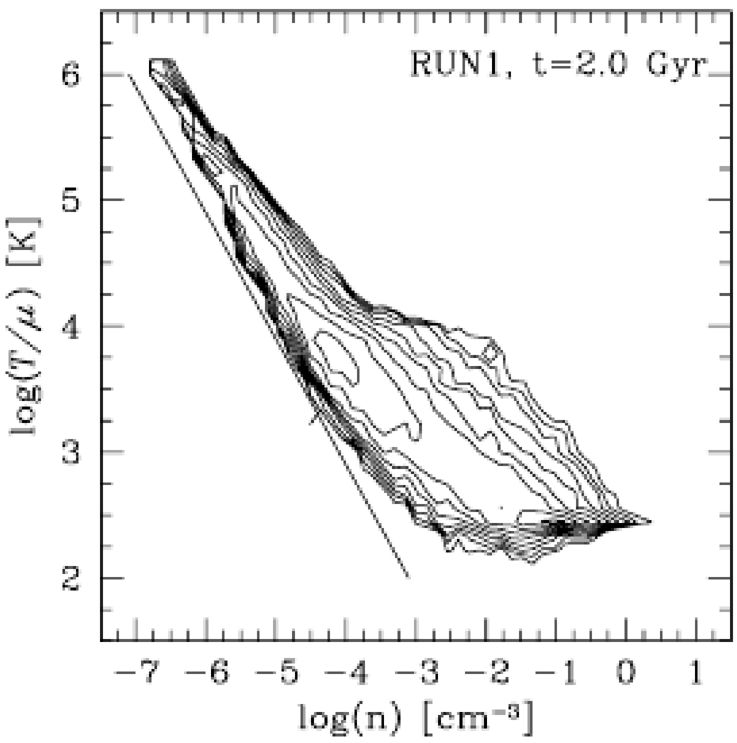
Density, Rotation Curve, Cooling

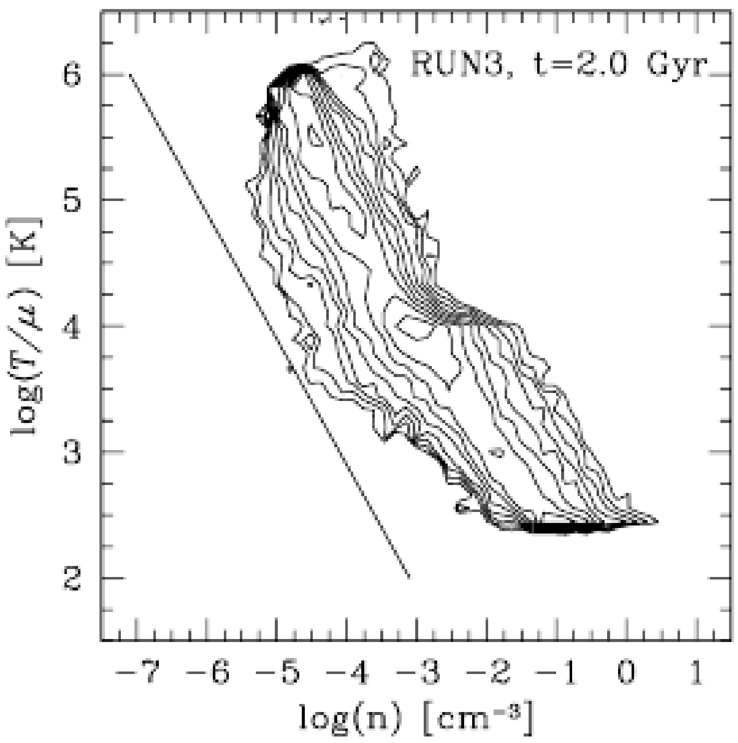
- Decrease Initial Mass Density → Less Clouds → Less Stirring and Cloud/Cloud Interaction → Smaller Veloicty Dispersion

- Flatter Rotation Curve (higher V_c at low R) → Shearing Instability stronger as more mass is dragged around

- Limits on T_{min} → Limit on Q_{min} → Less Turbulence

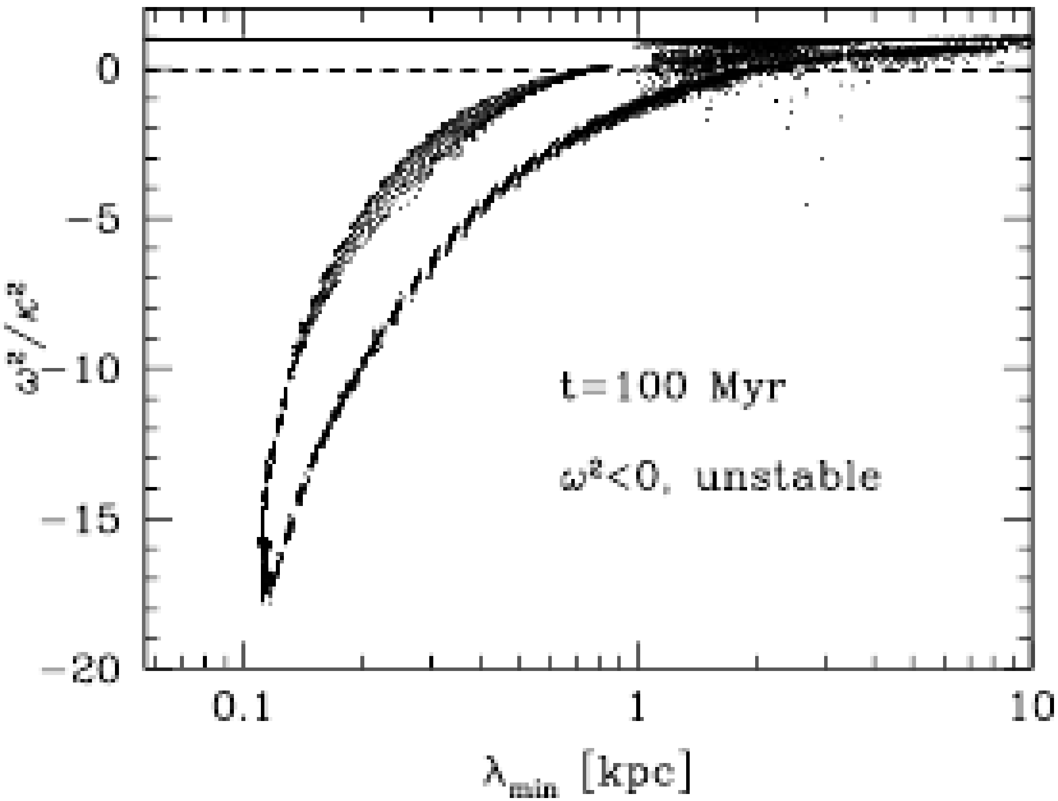
Phase Diagrams





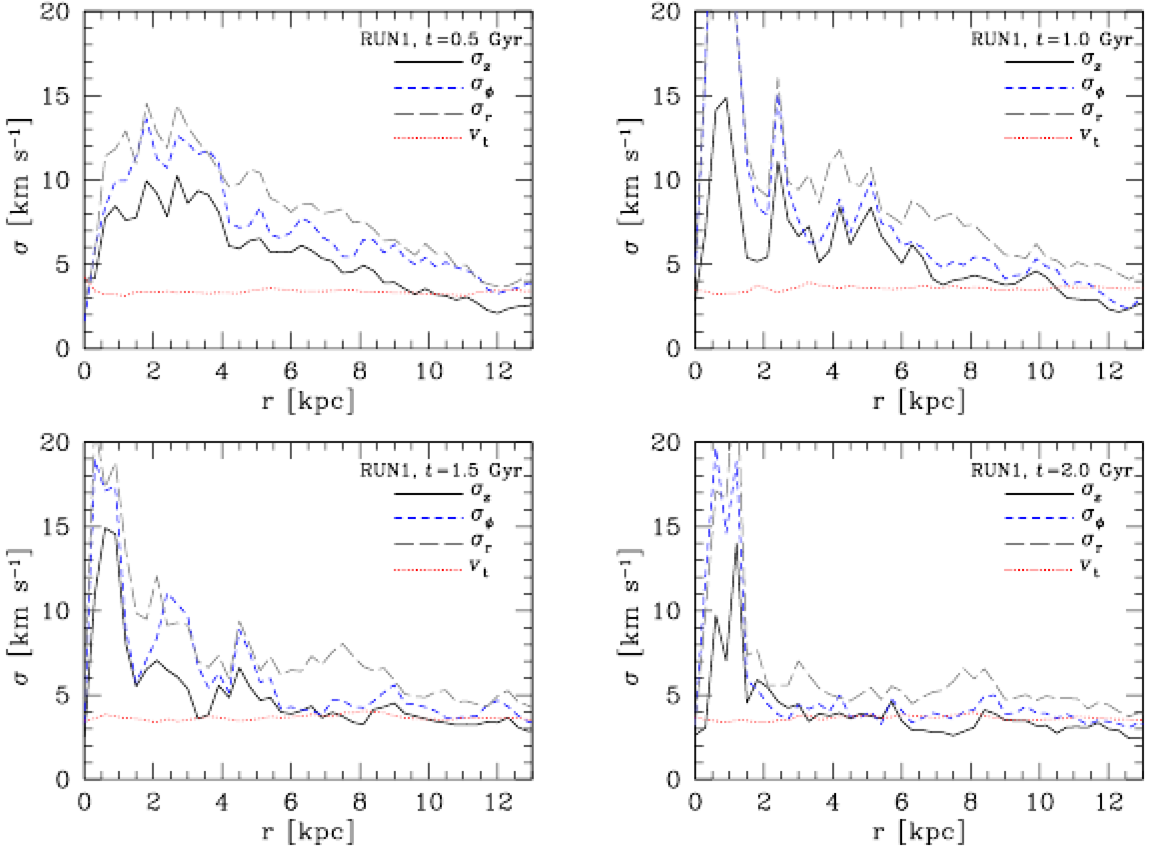
Source: Agertz et al. (2009): Large scale galactic turbulence: can self-gravity drive the observed HI velocity dispersions?; Figure 7

Scales of Instabilities



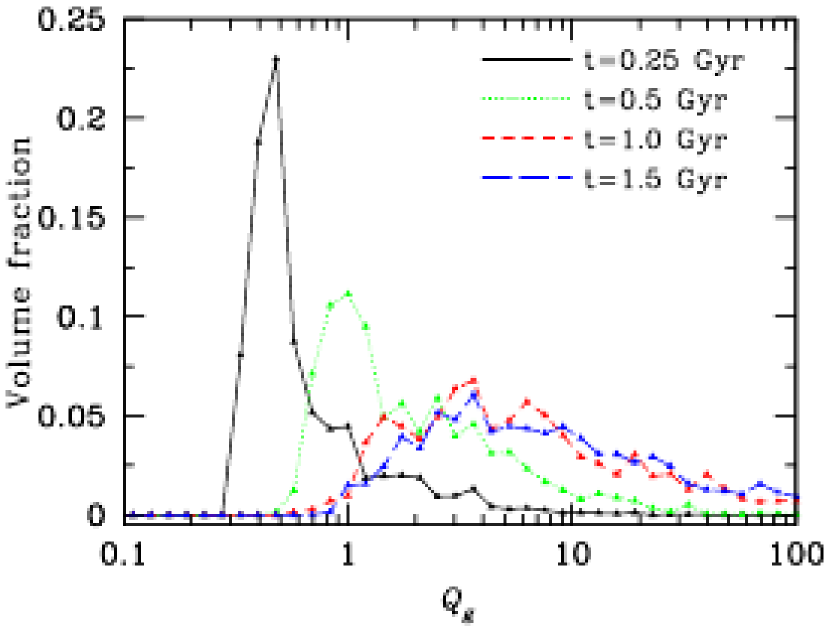
Source: Agertz et al. (2009): Large scale galactic turbulence: can self-gravity drive the observed HI velocity dispersions?; Figure 9

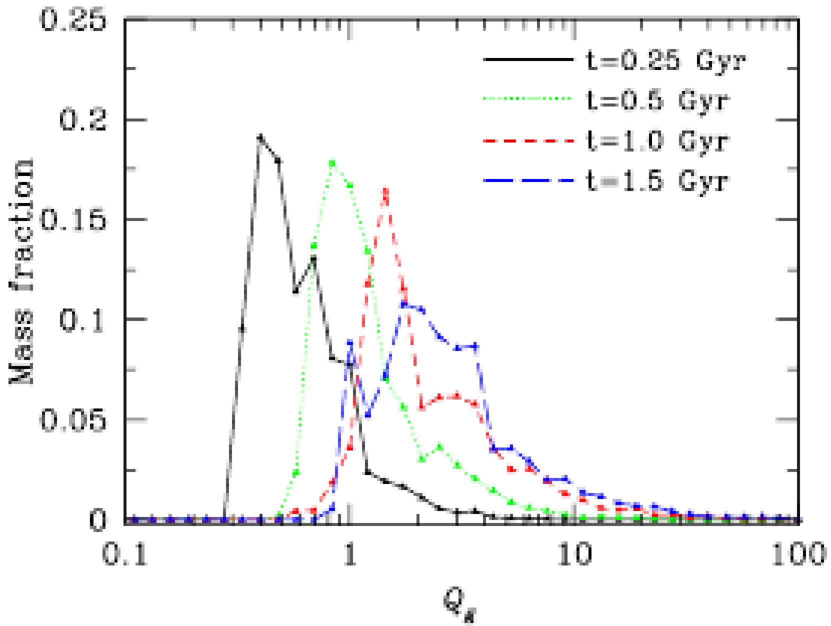
Velocity Dispersion vs. Radius



Source: Agertz et al. (2009): Large scale galactic turbulence: can self-gravity drive the observed HI velocity dispersions?; Figure 12

Evolution of Q





Source: Agertz et al. (2009): Large scale galactic turbulence: can self-gravity drive the observed HI velocity dispersions?; Figure 11