Gas Velocity Dispersions in the FIRE-2 Simulations: Gas Stability, Feedback, & Outflows

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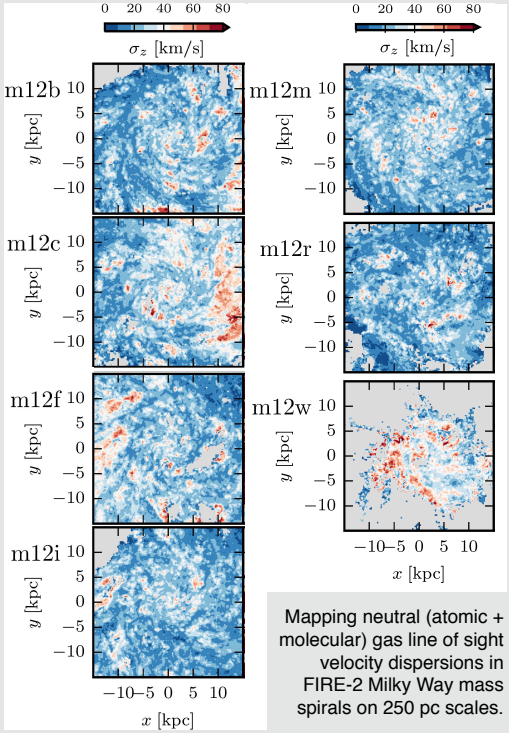
Understanding the gas velocity structure and the amount of turbulent support in the dense ISM in Milky Way-like galaxies is crucial for building complete picture of feedback-regulation and the emergence of low-efficiency star formation in galaxies.

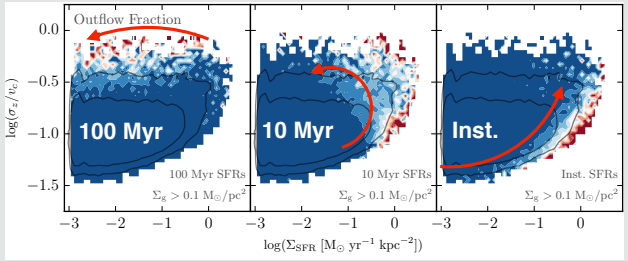
Velocity Dispersions in FIRE-2 Spiral Galaxies



Mapping neutral (atomic + molecular) gas line of sight velocity dispersions in FIRE-2 Milky Way mass spirals on 250 pc scales.

Spiral arm structure is discernible, with inter-arm regions having patches of high (~60 km/s) velocity dispersion. Variance across galaxies is relatively small, with little gas approaching 100 km/s dispersions.

Outflow-prone Fractions and the Limits of Feedback-driven Turbulence



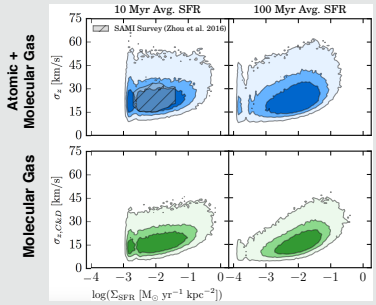
Condition for feedback-driven outflows:

Momentum injected by feedback (in a disk crossing time) = **Sufficient to accelerate patch of ISM to escape velocity** (in a disk crossing time)

$$\Sigma_{gas}^{max} = \frac{P}{m_\star} \frac{\Sigma_{SFR}}{\sqrt{2}\Omega r_{c,gal}}$$

The ability of feedback to drive outflows appears to naturally set the outer contours of the velocity dispersion—SFR relation. If SFRs are sufficiently high to accelerate gas to its local disk escape velocity, significant portions of the ISM will be driven out of the disk. These regions cannot then regulate themselves to an equilibrium, and will not appear in σ—SFR space.

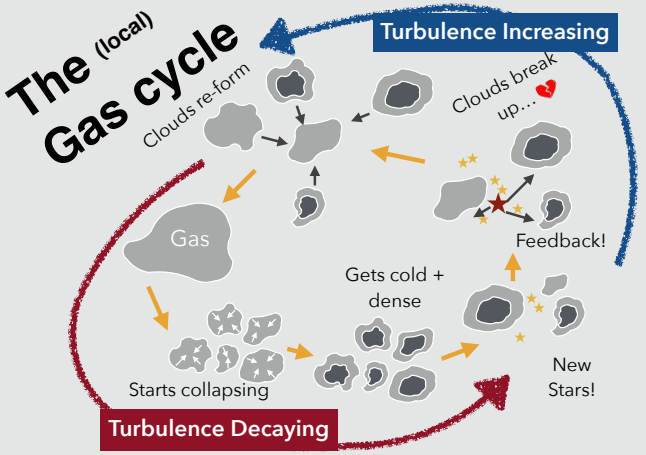
Various Tracers of Gas Dispersions and SFRs



Dispersions flat with 10 Myr SFR tracer, but rise with higher 100 Myr SFRs (and in cold & dense gas). Natural timescale to affect velocity dispersions ~$1/\Omega$ ~ 100 Myr in MW-like spirals.

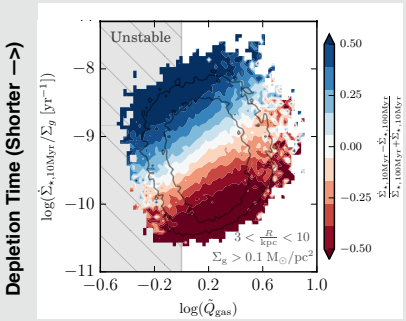
All gas/SFR tracer combinations have a lower envelope in dispersions with SFRs (see outflows panel).

The (local) Gas cycle



Conceptualizing the dynamical evolution of the turbulent ISM in a feedback-regulated model of star formation. Star formation tracers (e.g. H-alpha) only correspond to part of the cycle (where turbulence is increasing). Relations like Kennicutt-Schmidt may only be a window on part of this cycle, depending on the aperture size of observations in galaxies.

Evidence for star formation cycles?



Colored by star formation histories:

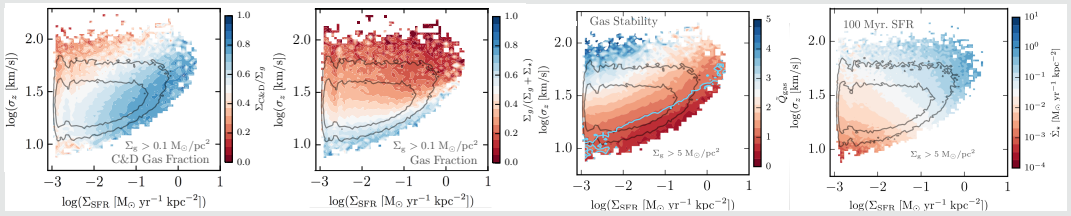
More recent star formation (less star formation 10-100 Myr ago)

More past (>10 Myr ago) than recent star formation

Kiloparsec-sized patches of the ISM in the FIRE-2 galaxies show evidence for on/off cycles of star formation. Regions having undergone significant feedback episodes in the last 100 Myr are more stable on-average, and have long depletion times. Regions without recent feedback episodes have shorter depletion times and are less stable (in many cases having Q < 1).

Gas Dispersion Dependencies on Gas Properties and Star Formation Histories

Dense gas fractions and gas stability are key for predicting SFRs at constant σ.



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