Discussion

The Role of Star Formation in Gas Cycling

- thermal instability
- warm neutral and ionized gas
- disruption of molecular clouds
- radiation shocks, mass loss
- formation of cold HI clouds
- formation of molecular clouds
- gravitational instability, turbulence, fractal structure
- star formation
- stellar evolution
Questions to Discuss

• What is the mass accretion history of a star forming molecular cloud from the overlying diffuse medium? How does this history impact the properties of the molecular gas (turbulence, dense gas distribution)?

• What is the role of feedback from newborn stars on the dynamics of molecular clouds? How can observations quantify these possible roles?

• What is the relationship, if any, between star formation laws measured on kpc scales and those derived from well-resolved molecular clouds and cloud fragments?

• What are the typical lifetimes of molecular clouds? Do these vary with environment?
Velocity Anisotropy Aligned with Local B field

Taurus

Models

\( (c/v_a)^2 = 0.01 \)  \( (c/v_a)^2 = 0.1 \)  \( (c/v_a)^2 = 1.0 \)
\( M_A = 0.5 \)  \( M_A = 1.5 \)  \( M_A = 5 \)

Parallel to B
Perpendicular to B
Arizona Radio Obs. 10m 12CO, 13CO J=2-1

P. Goldsmith, J. Pineda, U. Yildiz, E. Falgarone, R. Snell
$^{12}\text{CO} \ J=2-1$

Position (pc)

$V_{LSR}$ (km/s)

(7.14--7.47) km/s

(5.84--6.16) km/s
Striae are the result of a **compressional, magneto-sonic** wave propagating perpendicular to local magnetic field but inclined to the plane of the sky. Gas is distributed within a thin sheet.

\[
\text{Displacement, } s = s_0 \cos(kx - \omega t) \\
\text{Velocity } = \frac{ds}{dt} = -s_0 \omega \sin(kx - \omega t)
\]

- \(k=\text{wavenumber}=\frac{2\pi}{\lambda}\)
- \(c=\text{phase velocity}\)
- \(\omega=\text{angular frequency}=c*k\)
Taurus Model Parameters

Length = 1.5 pc
C = 1.0 km/s
λ = 0.3 pc
S0 = 0.025 pc
σ_v(1D) = 0.5 km/s
θ = 30 degrees

- Fill sheet with particles
- Propagate compression wave perpendicular to B
- Blue test particle allows one to follow motion
Far-IR images of the cold ISM
• What is the mass accretion history of a star forming molecular cloud from the overlying diffuse medium? How does this history impact the properties of the molecular gas (turbulence, dense gas distribution)?

• What is the role of feedback from newborn stars on the dynamics of molecular clouds? *How can observations quantify these possible roles?*

• What is the relationship, if any, between star formation laws measured on kpc scales and those derived from well-resolved molecular clouds and cloud fragments?

• What are the typical lifetimes of molecular clouds? Do these vary with environment?
Mass accretion history of a star forming molecular cloud

- How do molecular clouds form? Colliding flows? Instabilities in spiral shocks? Agglomeration of pre-existing \( \text{H}_2 \) clouds?
- Affects on turbulence and angular momentum?
- Does it matter? Memory of how cloud formed after a eddy turnover or crossing time?
- Does continued accretion sustain star formation beyond a crossing-time?
Role of feedback from newborn stars on the dynamics of molecular clouds

Driving Turbulence
Triggering Star formation
Quenching star formation
Destroying the cloud

Evaluating feedback

$E_{\text{grav}} \sim E_{\text{kin}} \sim E_{\text{fb}}$

20cm radio continuum
$^{12}\text{CO } J=1-0$
$^{13}\text{CO } J=1-0$
Star Formation “Law” on different scales

Disk Averaged

Kennicutt & Evans 2012

Log $\Sigma$ SFR

$\log \Sigma_{gas}$

$SFR (M_\odot \text{ year}^{-1})$

$M_{\text{dense}}$
Star Formation “Law” on different scales

Sub-kpc apertures
\[ \Sigma_{\text{mol}} = < \Sigma_{\text{GMC}} > \left( \frac{\Omega_{\text{GMC}}}{\Omega_{\text{aperture}}} \right) \]

Indices for individual galaxies range from sub-linear to linear to super-linear. **WHY?**
Star Formation “Law” on different scales

Resolved Molecular Clouds and Clumps

$$\Sigma_{\text{mol}} = \Sigma_{\text{MC}} \text{ or } \Sigma_{\text{Clump}}$$

- Displaced 10-50x above extragalactic relationship for same surface density
- Star formation threshold \( \sim 130 \, M_{\text{sun}} / \text{pc}^2 \)
- \( \Sigma_{\text{SFR}} \) scales as \( \Sigma_{\text{gas}}^2 \)
Star Formation “Law” on different scales

Resolved Molecular Clouds and Clumps

$$\Sigma_{\text{mol}} = \Sigma_{\text{MC}} \text{ or } \Sigma_{\text{Clump}}$$

Heyer+ 2016 Mipsgal/Atlasgal
Star Formation “Law” on different scales

Resolved Dense, Clumps in MW

\[ \Sigma_{\text{SFR}} = \varepsilon_{\text{ff}} \frac{\Sigma_{\text{H}_2}}{\tau_{\text{ff}}} \]
\[ \varepsilon_{\text{ff}} = 0.006 \]

\[ \Sigma_{\text{SFR}} = \varepsilon_{\text{cross}} \frac{\Sigma_{\text{H}_2}}{\tau_{\text{cross}}} \]
with \[ \varepsilon_{\text{cross}} = 0.01 \]
What is the relationship, if any, between star formation laws measured on kpc scales and those derived from well-resolved molecular clouds and cloud fragments?

• Does the extragalactic K-S relationship say anything useful about HOW stars form? If so, what?
• Resolution and time scale differences? Undersampling the IMF ... If $\tau_{\text{GMC}} \sim 30$-50 Myr, what does it mean to sample SF over 200 Myr?