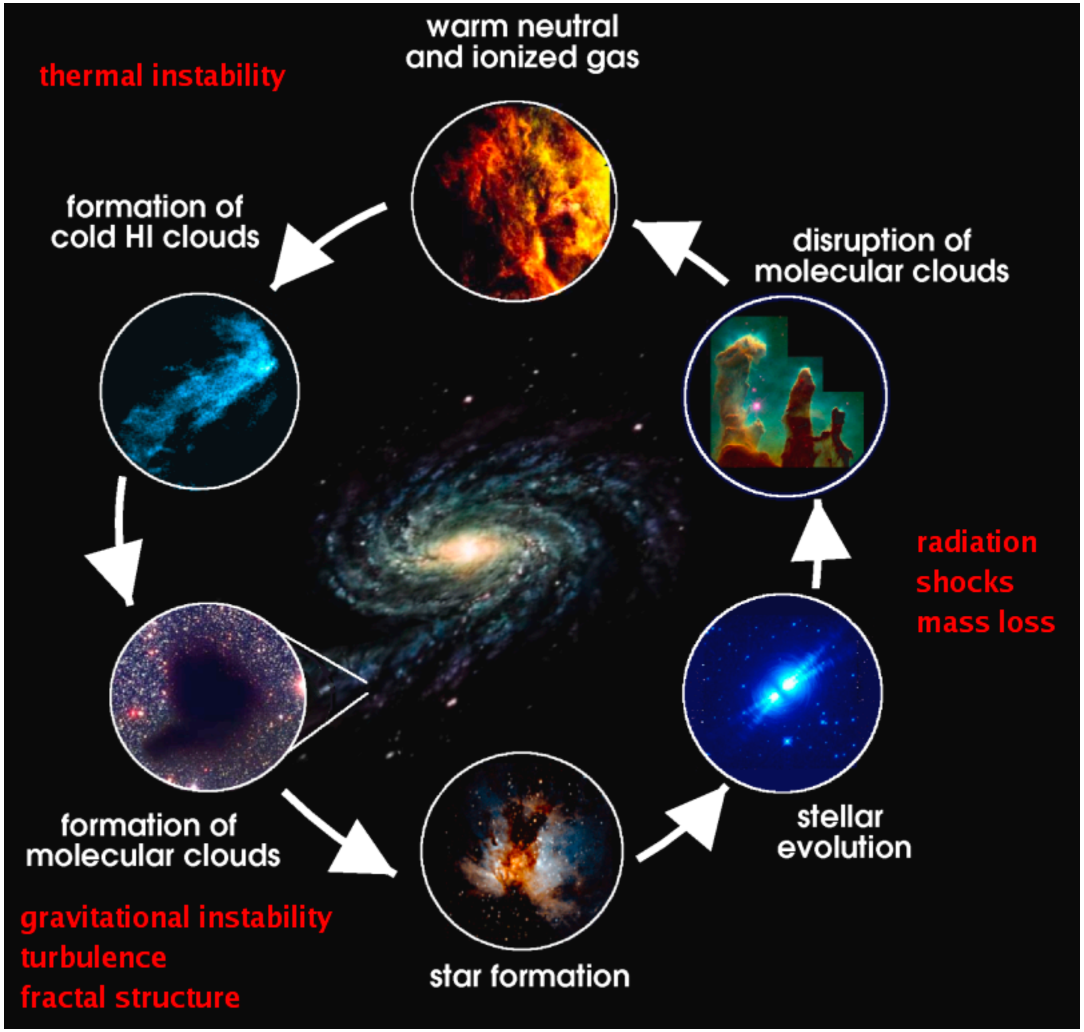
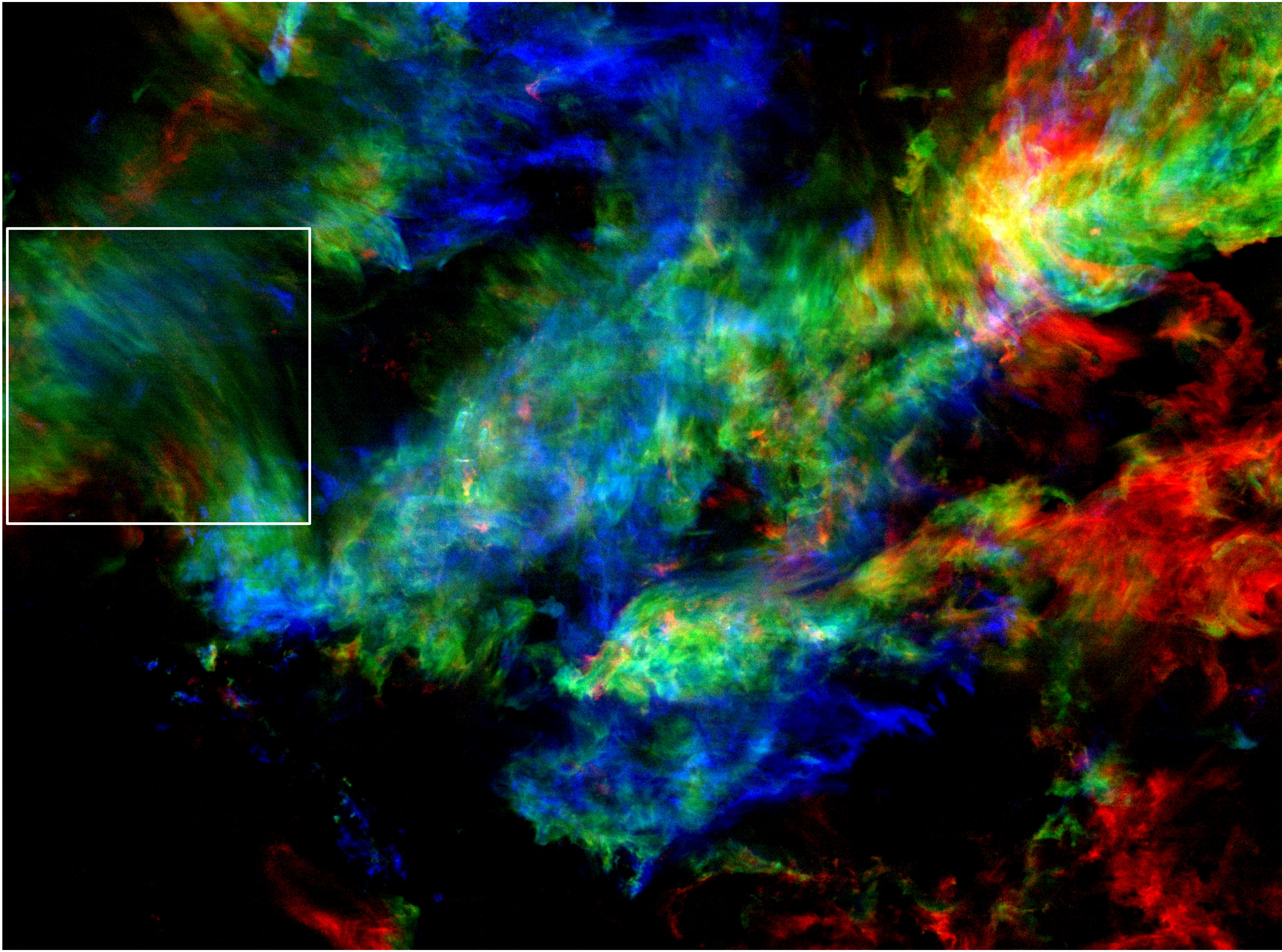
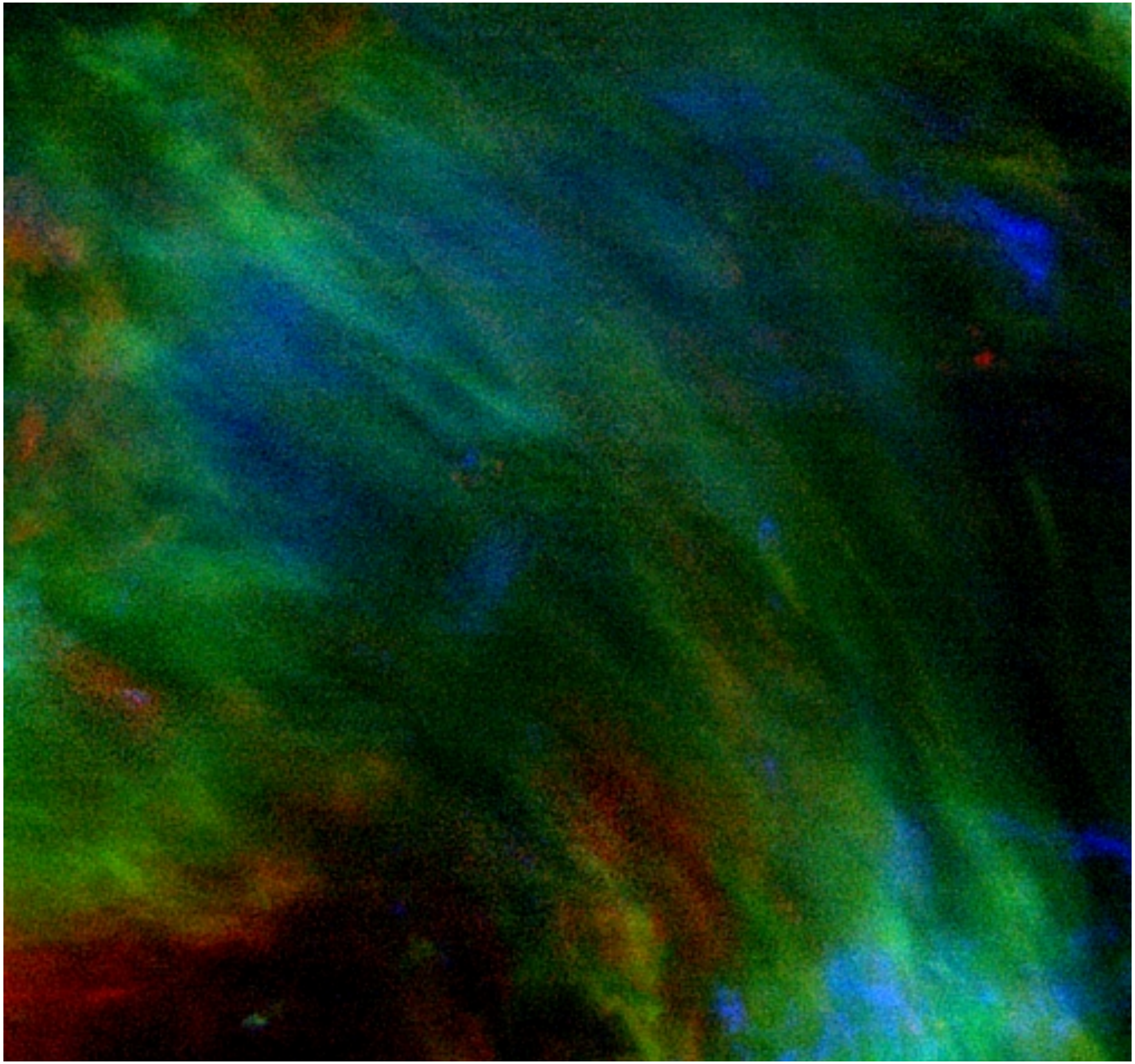
# Discussion
# The Role of Star Formation in Gas Cycling



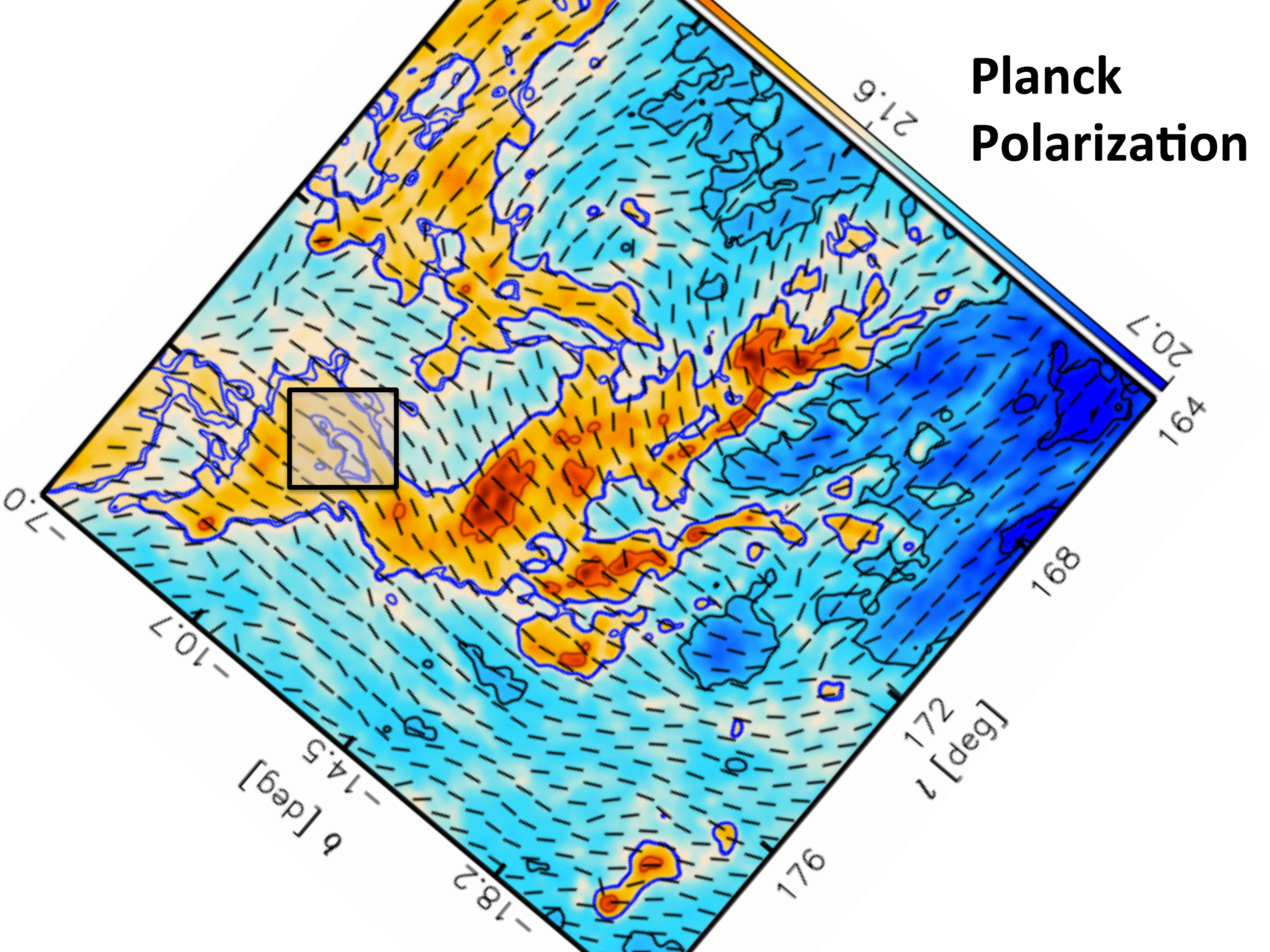
# Questions to Discuss

- **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?**



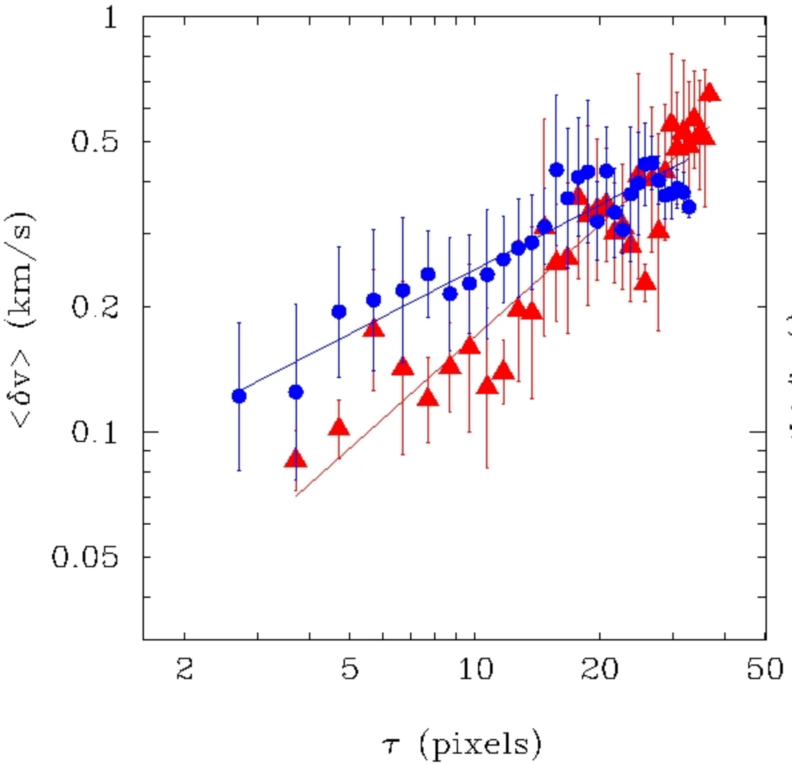


# Planck Polarization



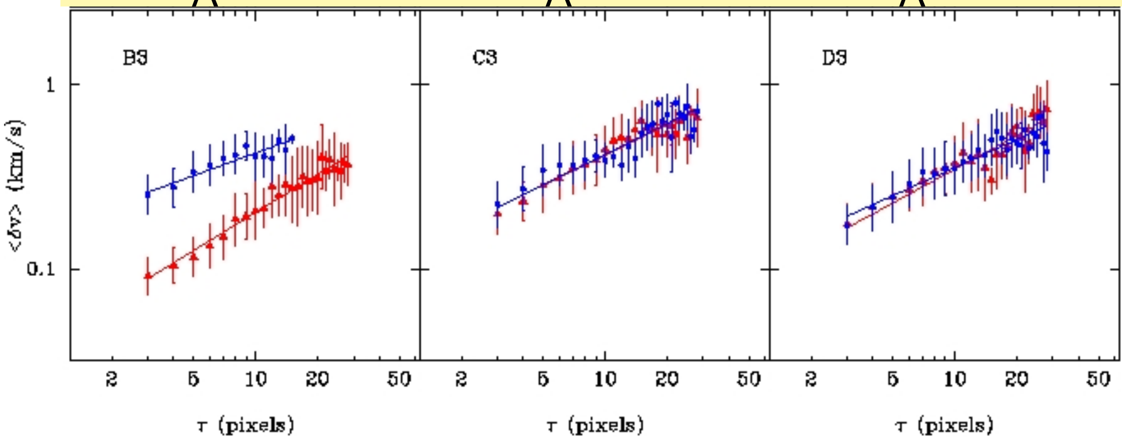
# Velocity Anisotropy Aligned with Local B field

## Taurus



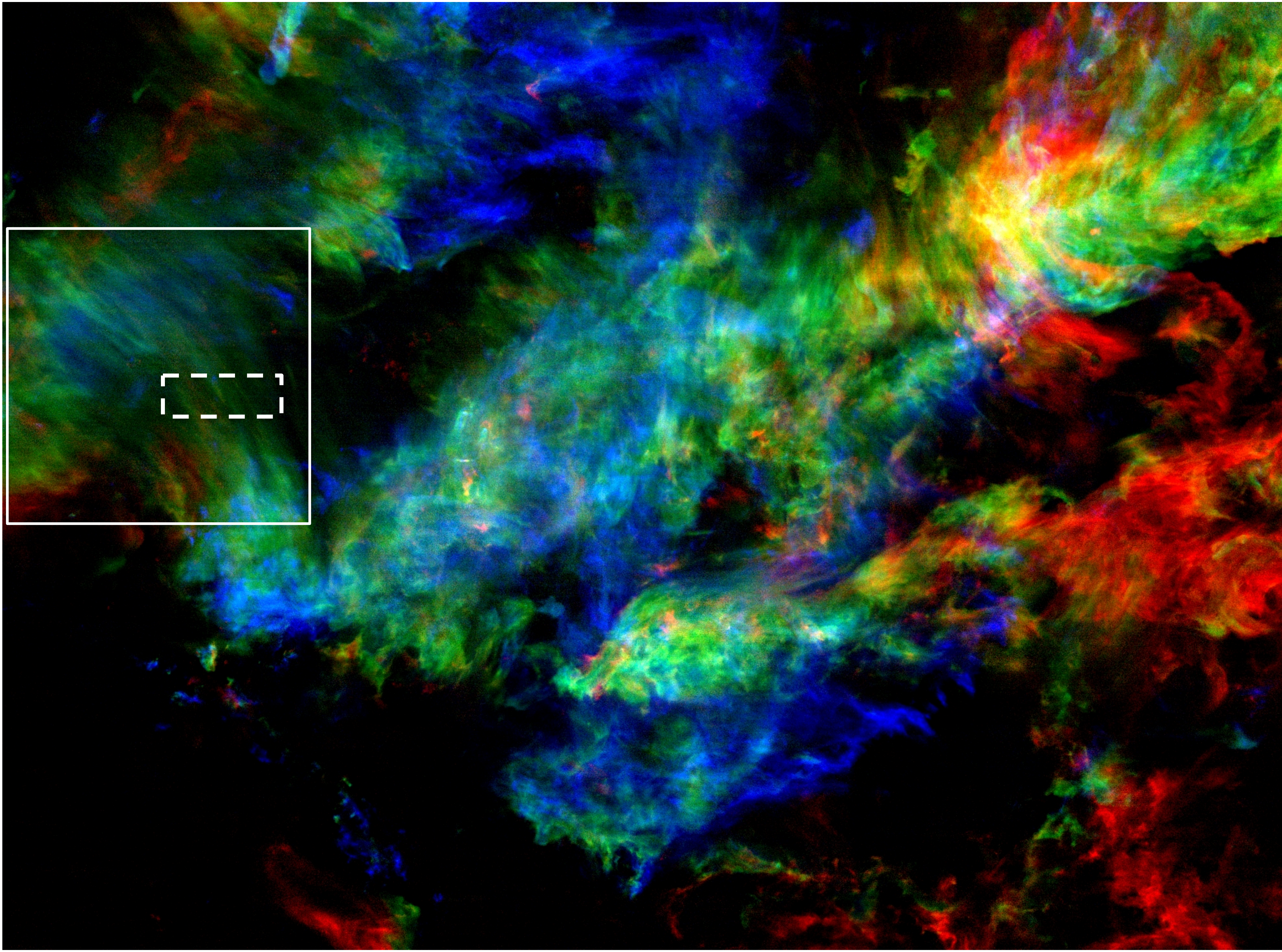

## Models

| $(c/v_a)^2=0.01$ | $(c/v_a)^2=0.1$ | $(c/v_a)^2=1.0$ |
|---|---|---|
| $M_A=0.5$ | $M_A=1.5$ | $M_A=5$ |



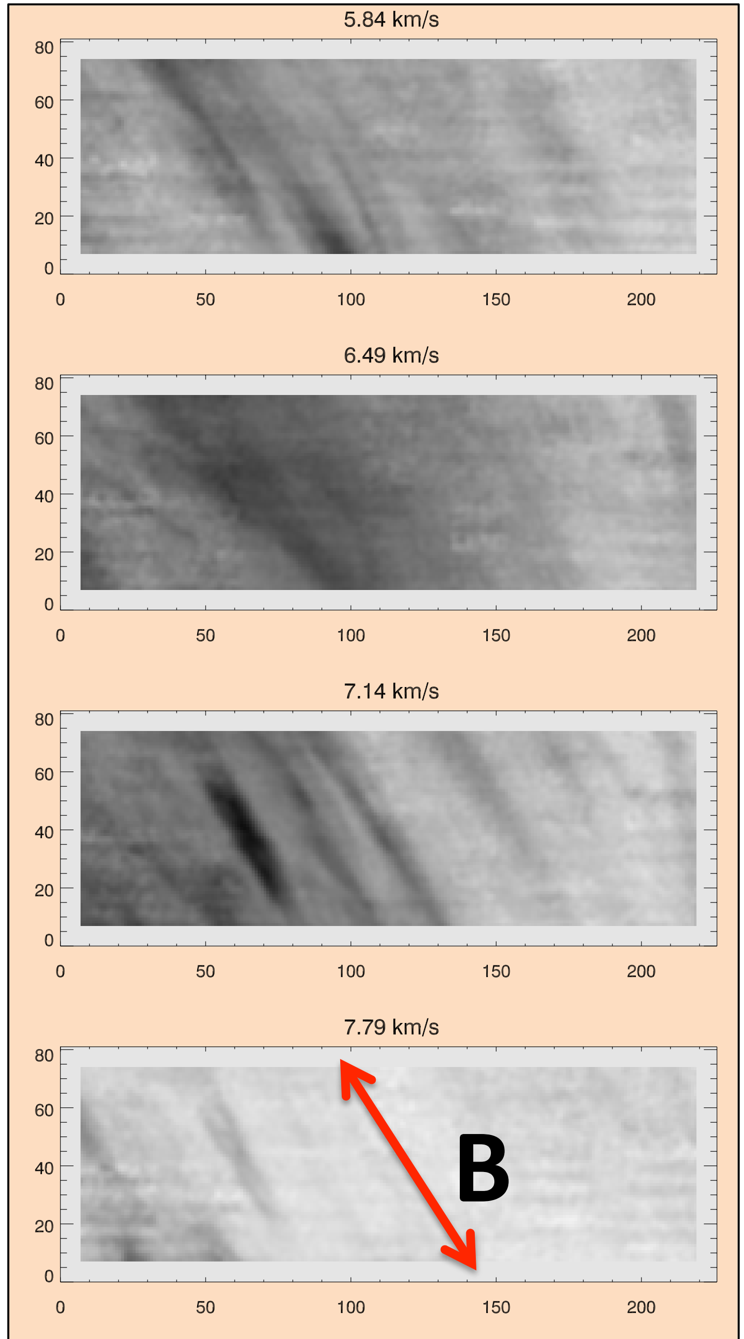

**Parallel to B**

**Perpendicular to B**



**Arizona Radio Obs. 10m**
**$^{12}CO$, $^{13}CO$ J=2-1**

P. Goldsmith, J. Pineda, U. Yildiz, E. Falgarone, R. Snell



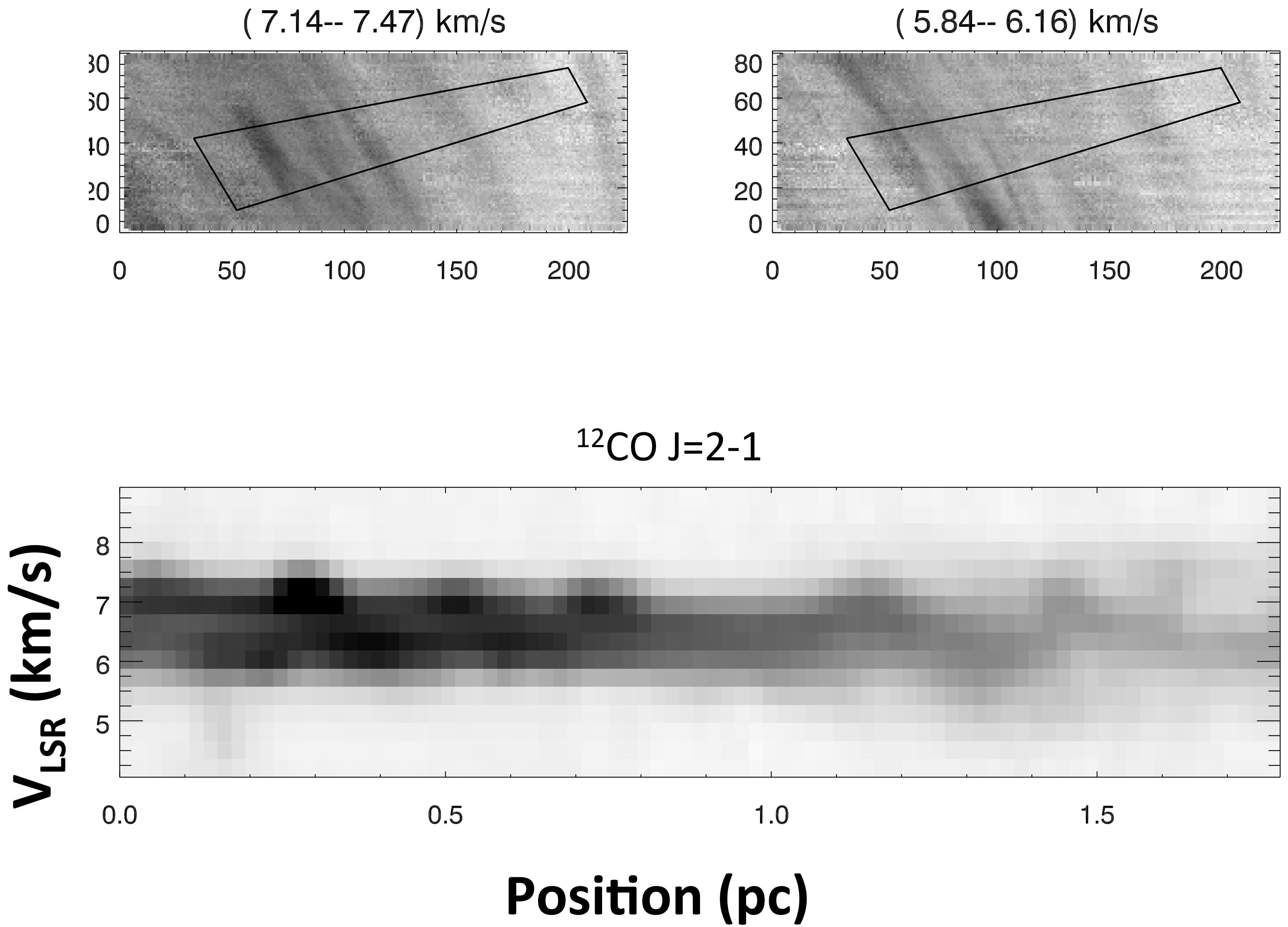

$V_{lsr}$

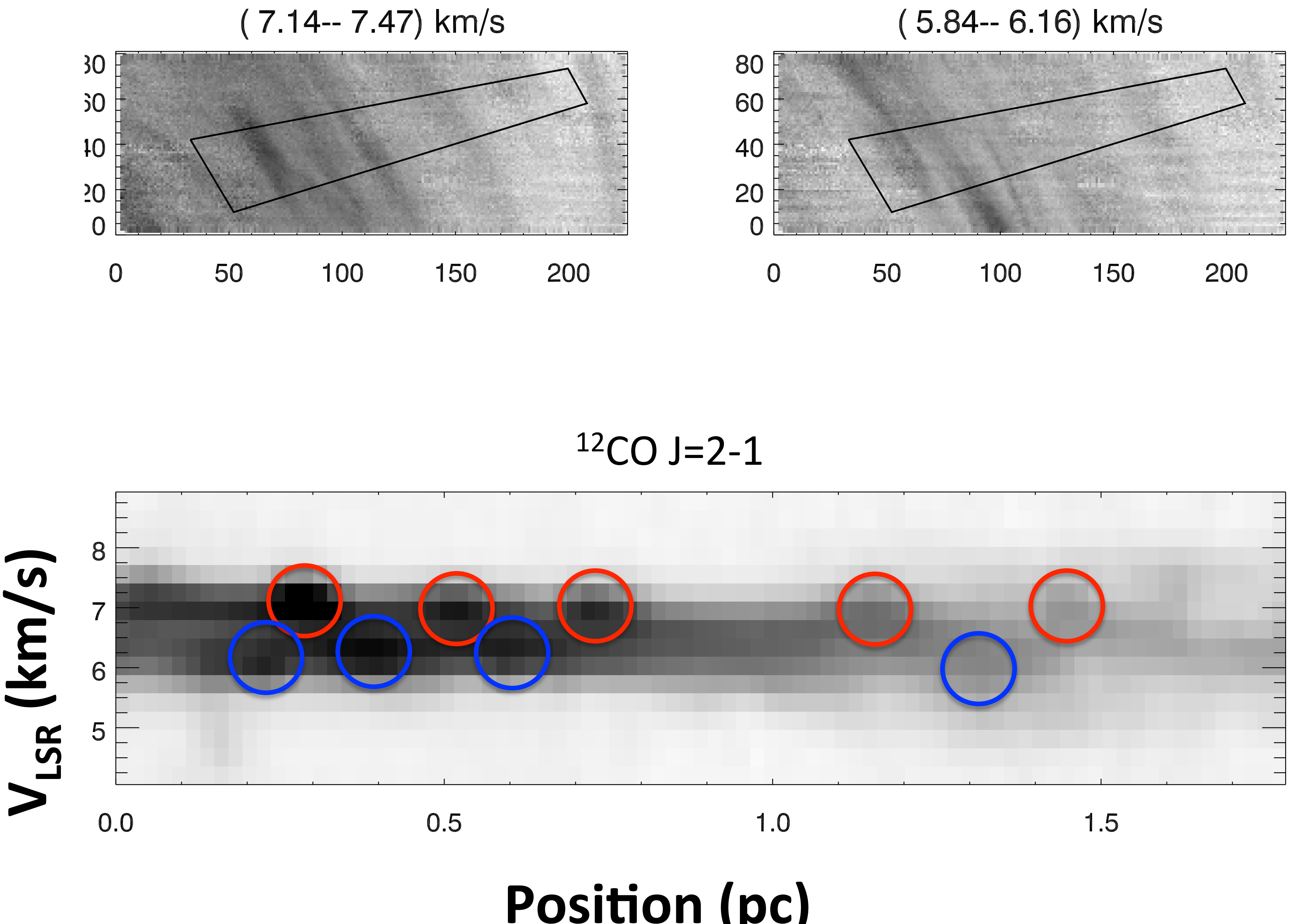
**5.9 km/s**

**6.5 km/s**

**7.1 km/s**

**7.8 km/s**


( 7.14-- 7.47) km/s
( 5.84-- 6.16) km/s
80
60
40
20
0
0
50
100
150
200
$^{12}$CO J=2-1
$V_{LSR}$ (km/s)
8
7
6
5
0.0
0.5
1.0
1.5
Position (pc)



( 7.14-- 7.47) km/s
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$^{12}$CO J=2-1
$V_{LSR}$ (km/s)
8
7
6
5
0.0
0.5
1.0
1.5
Position (pc)

# Cartoon Wave Model

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.

Displacement, $s = s0 \cos(kx-\omega t)$

Velocity = $ds/dt =- s0\ \omega \sin(kx-\omega t)$

$k$=wavenumber=$2\pi/\lambda$

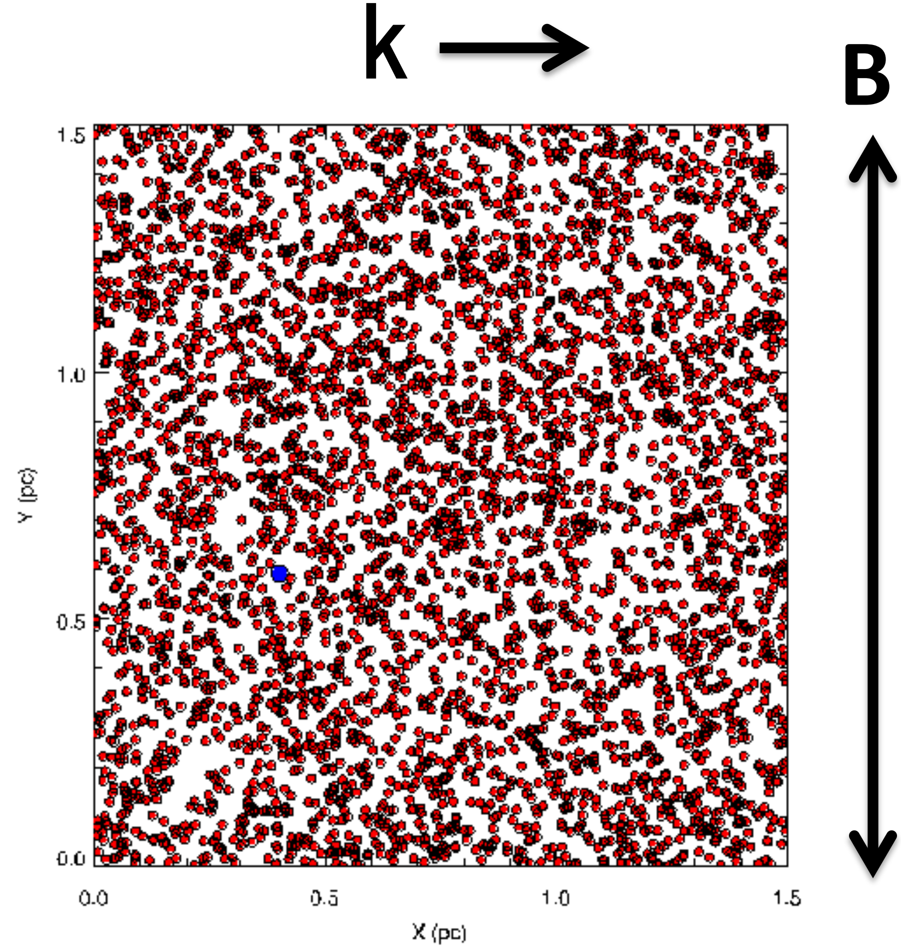
$c$=phase velocity

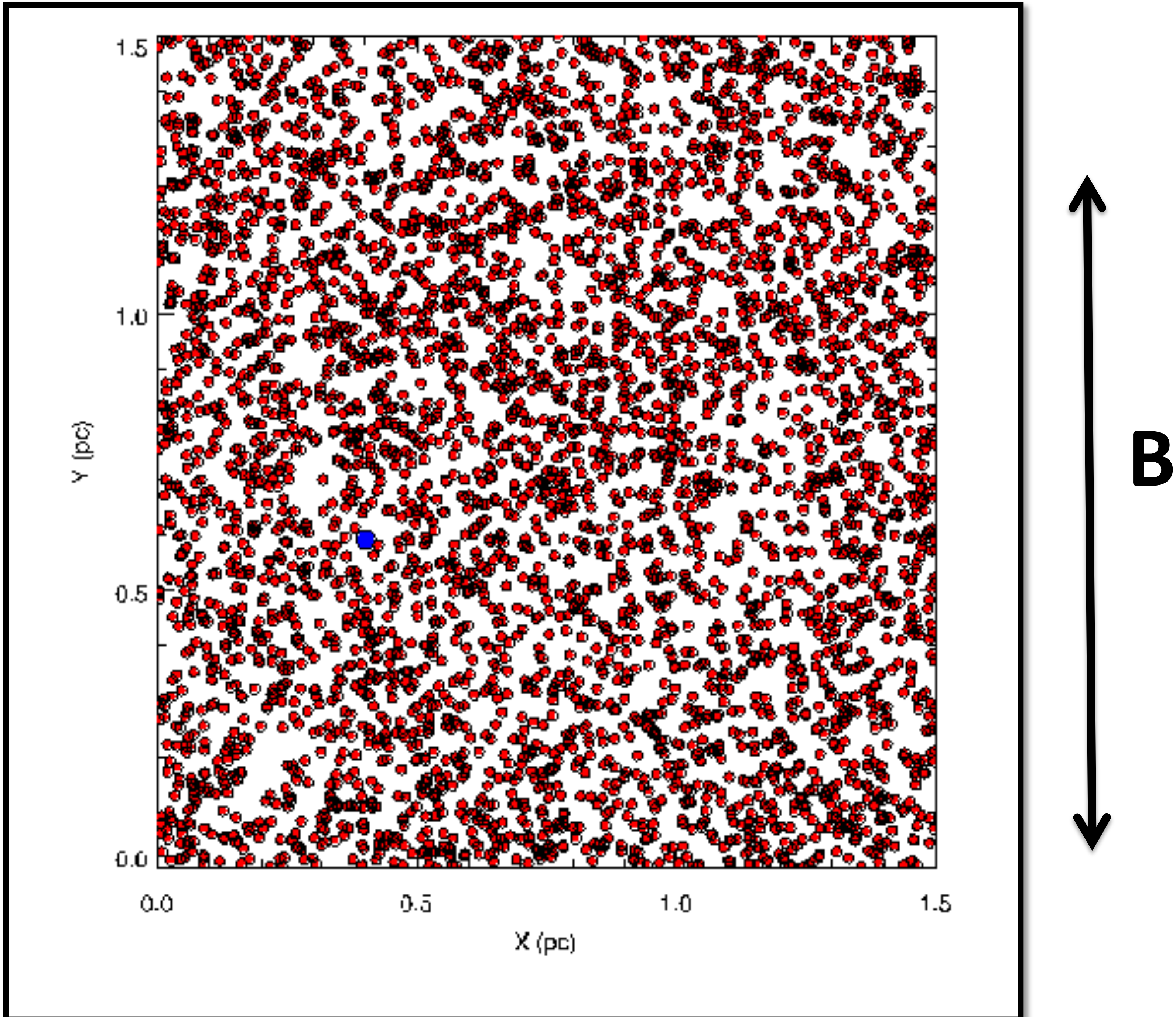
$\omega$=angular frequency=$c*k$

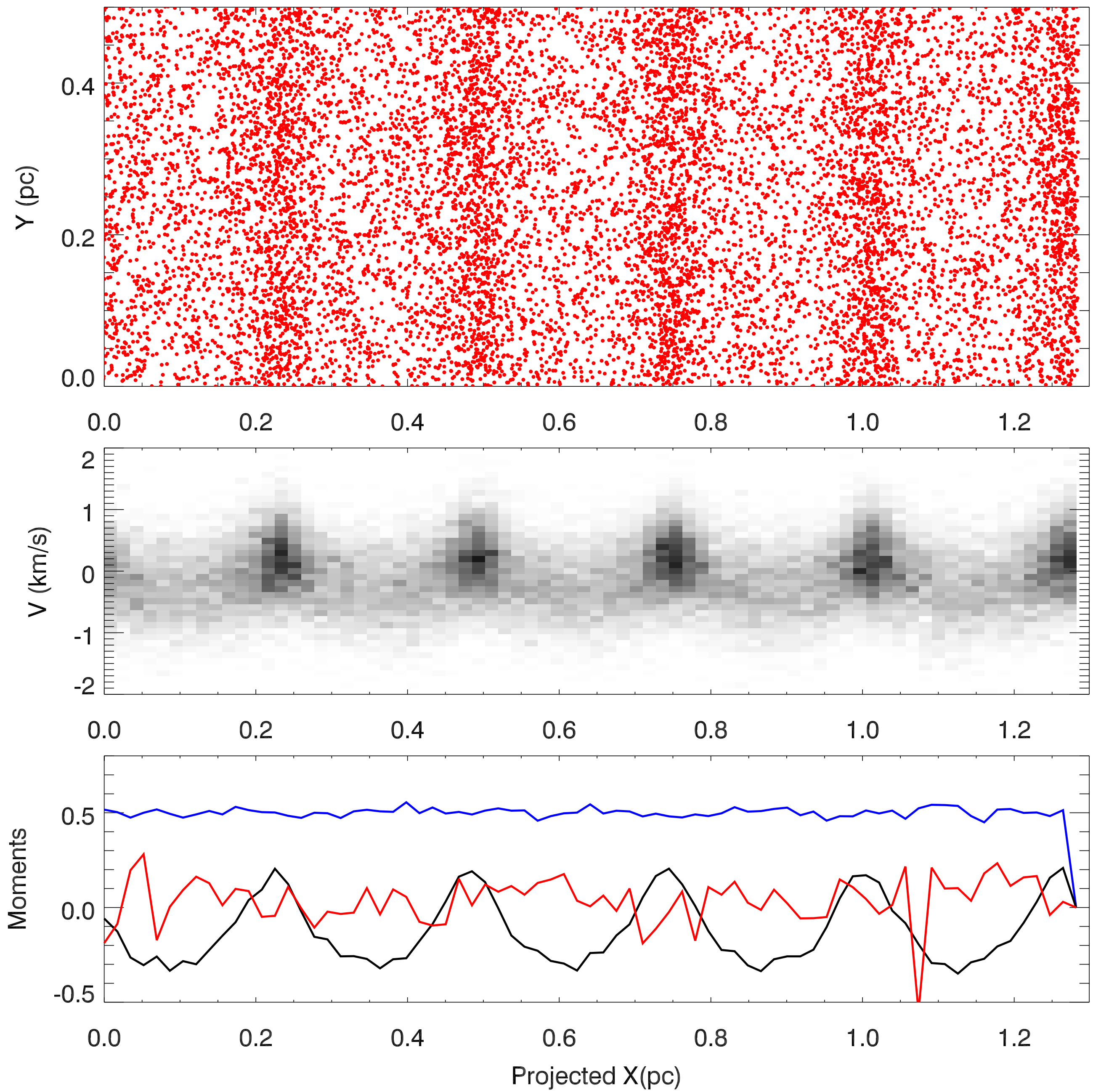
# Taurus Model Parameters

Length=1.5 pc
C=1.0 km/s
$\lambda$ = 0.3 pc
S0=0.025 pc
$\sigma_v$(1D) = 0.5 km/s
$\theta$=30 degrees

- Fill sheet with particles
- Propagate compression wave perpendicular to B
- Blue test particle allows one to follow motion

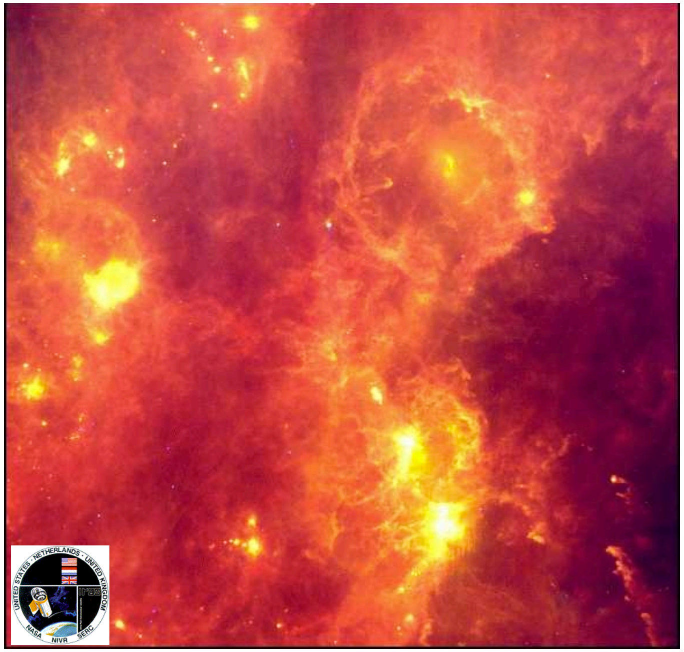


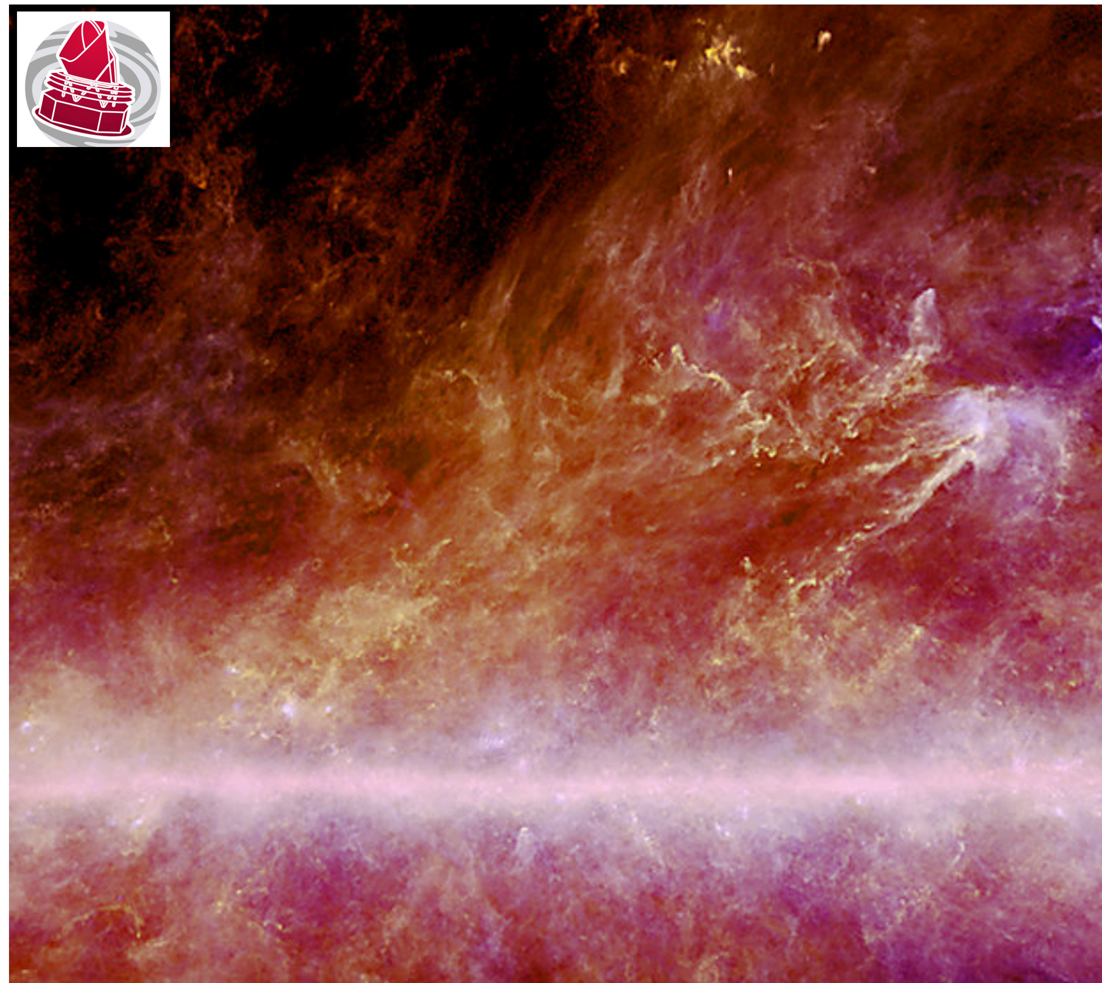

1.5
1.0
0.5
0.0
Y (pc)
0.0
0.5
1.0
1.5
X (pc)
B



Y (pc)
0.0
0.2
0.4
0.0
0.2
0.4
0.6
0.8
1.0
1.2
V (km/s)
2
1
0
-1
-2
0.0
0.2
0.4
0.6
0.8
1.0
1.2
Moments
0.5
0.0
-0.5
0.0
0.2
0.4
0.6
0.8
1.0
1.2
Projected X(pc)

# 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?***

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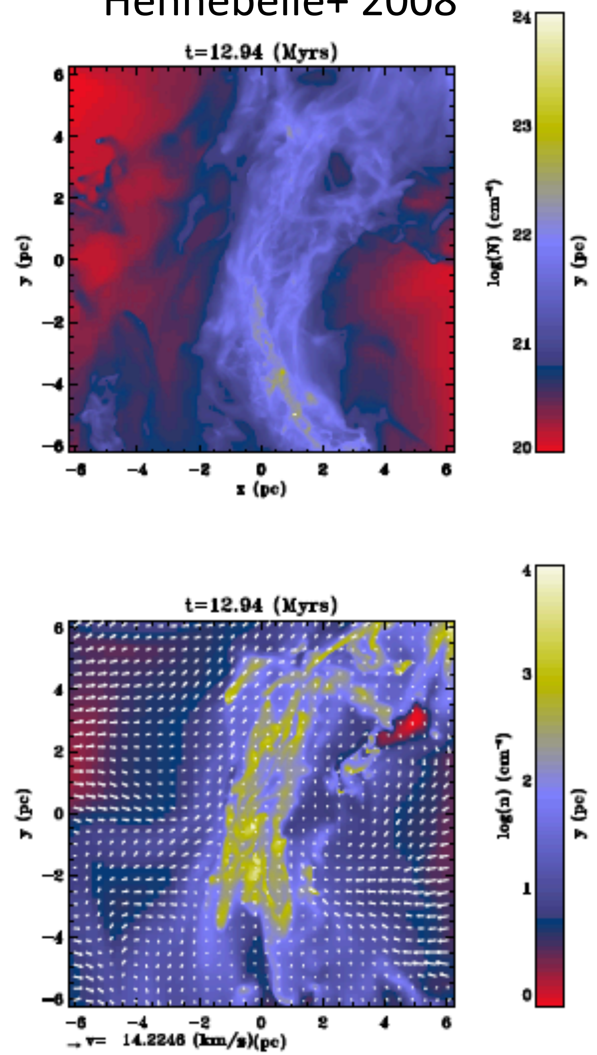
# Mass accretion history of a star forming molecular cloud

- How do molecular clouds form? Colliding flows? Instabilities in spiral shocks? Agglomeration of pre-existing $H_2$ 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?

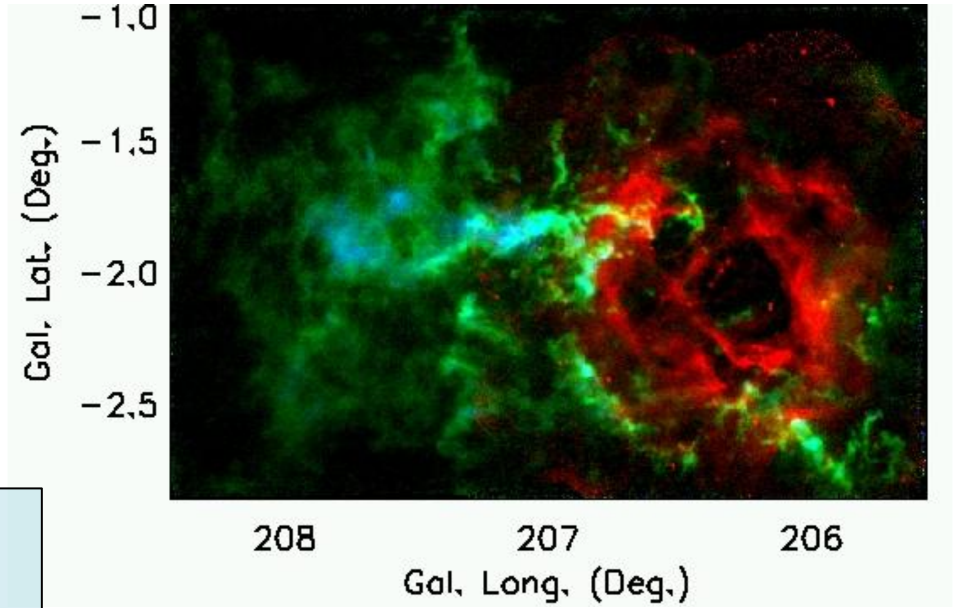
Hennebelle+ 2008



# Role of feedback from newborn stars on the dynamics of molecular clouds

Driving Turbulence
Triggering Star formation
Quenching star formation
Destroying the cloud

**Rosette Molecular Cloud**




**20cm radio continuum**
**$^{12}$CO J=1-0**
**$^{13}$CO J=1-0**

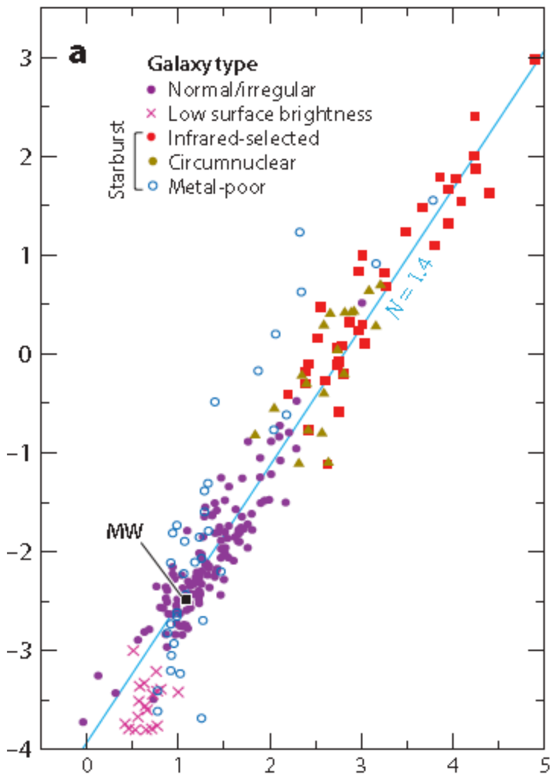
Evaluating feedback

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

# Star Formation "Law" on different scales

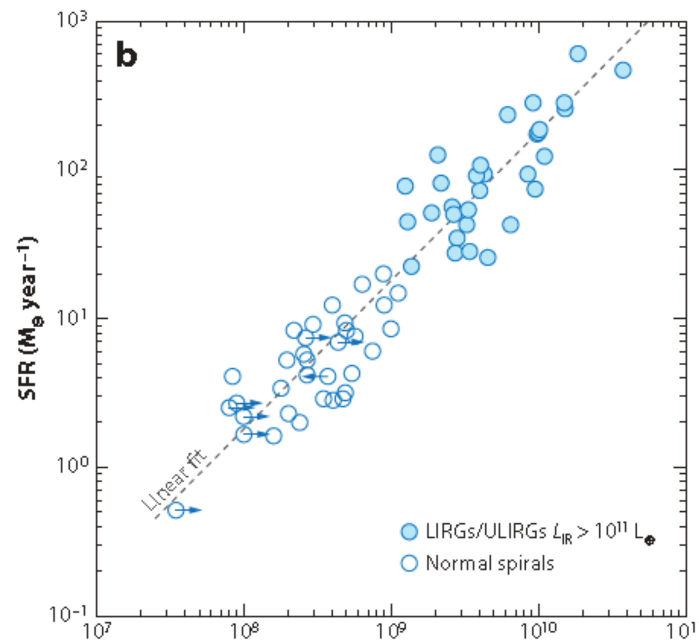
## Disk Averaged

$\log \Sigma_{SFR}$




$\text{Log } \Sigma_{gas}$

Kennicutt & Evans 2012




$M_{dense}$

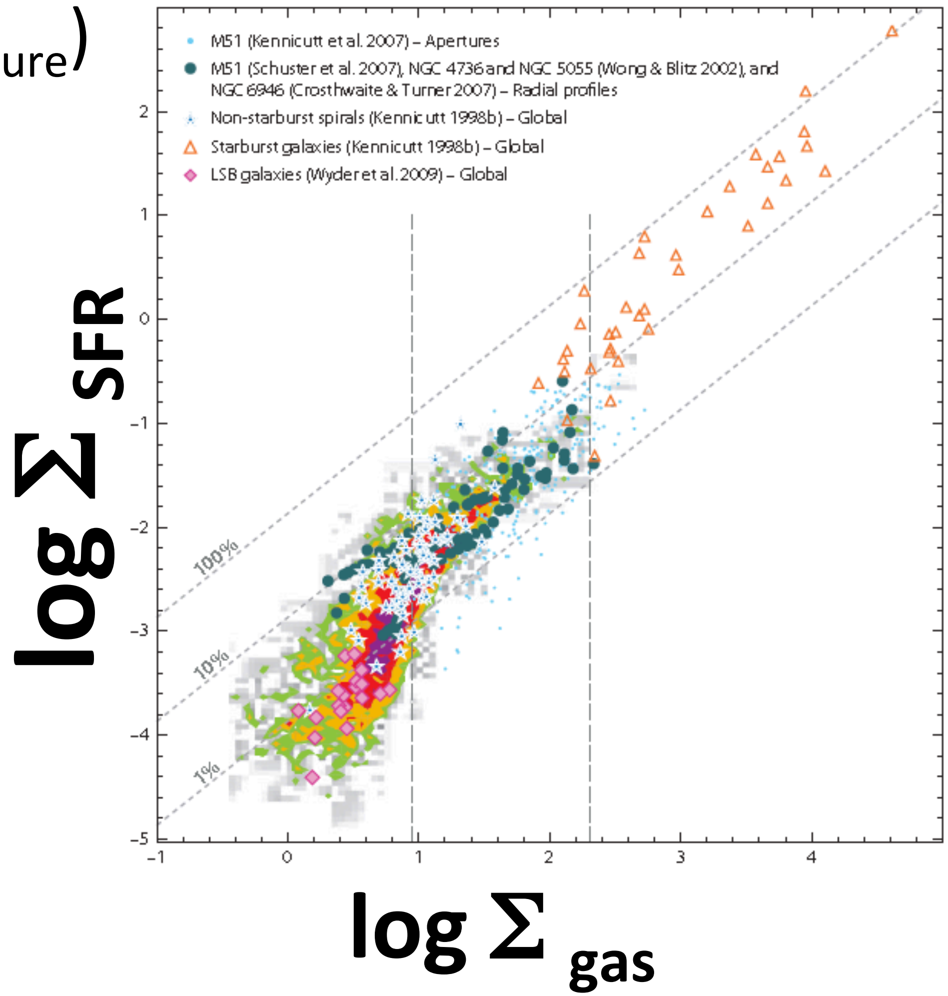
SFR

# Star Formation “Law” on different scales

Sub-kpc apertures

$\Sigma_{mol} = < \Sigma_{GMC} > (\Omega_{GMC}/\Omega_{aperture})$

Indices for individual galaxies range from sub-linear to linear to super-linear. **WHY?**

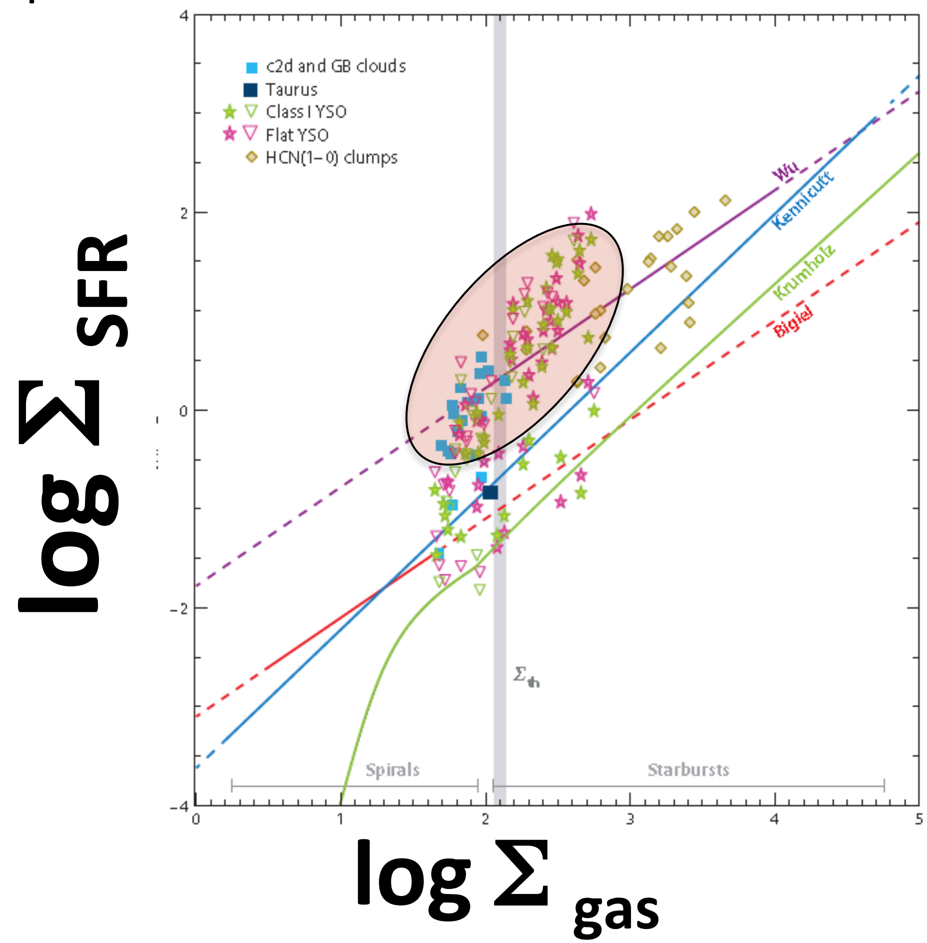


# Star Formation “Law” on different scales

## Resolved Molecular Clouds and Clumps

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

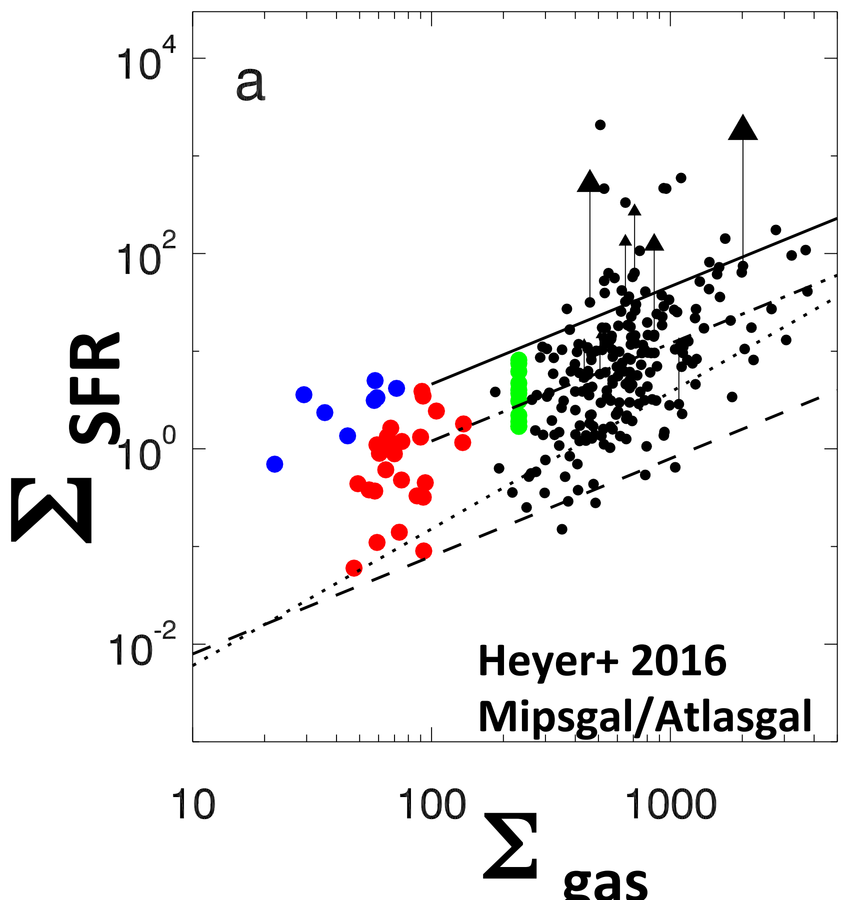
- Displaced 10-50x above extragalactic relationship for same surface density
- Star formation threshold ~ 130 $M_{sun}/pc^2$
- $\Sigma_{SFR}$ scales as $\Sigma_{gas}{}^2$

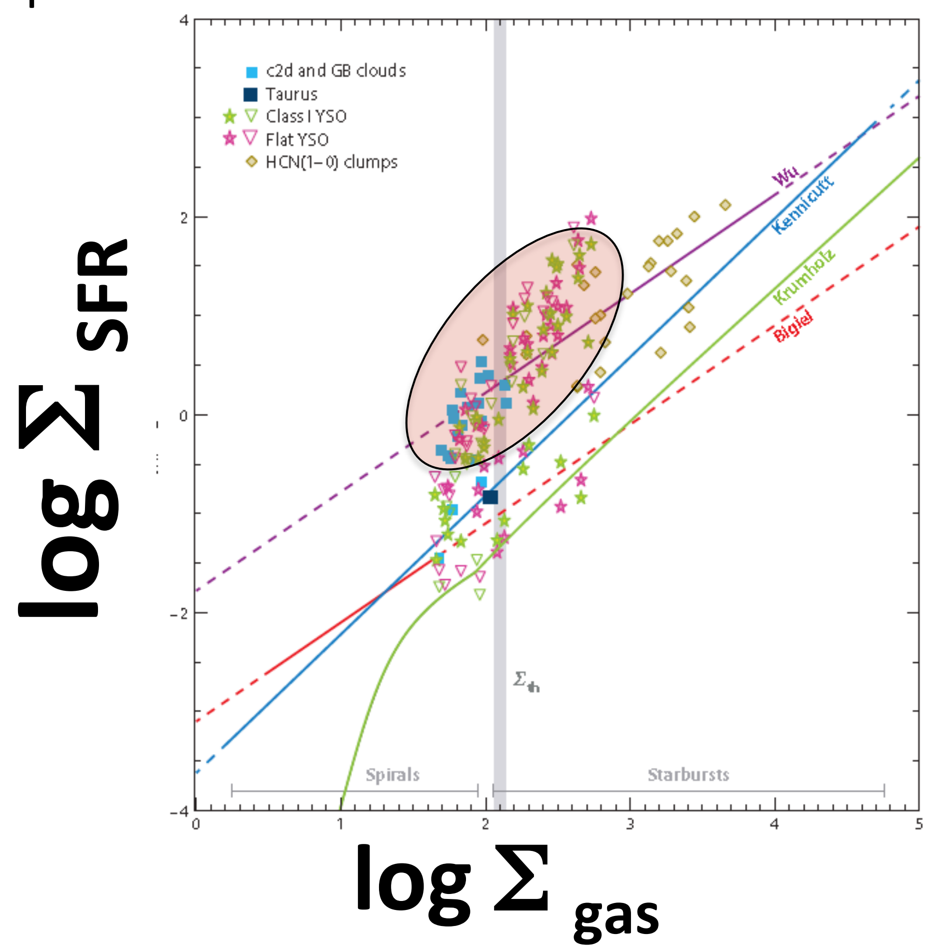


# Star Formation “Law” on different scales

## Resolved Molecular Clouds and Clumps

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



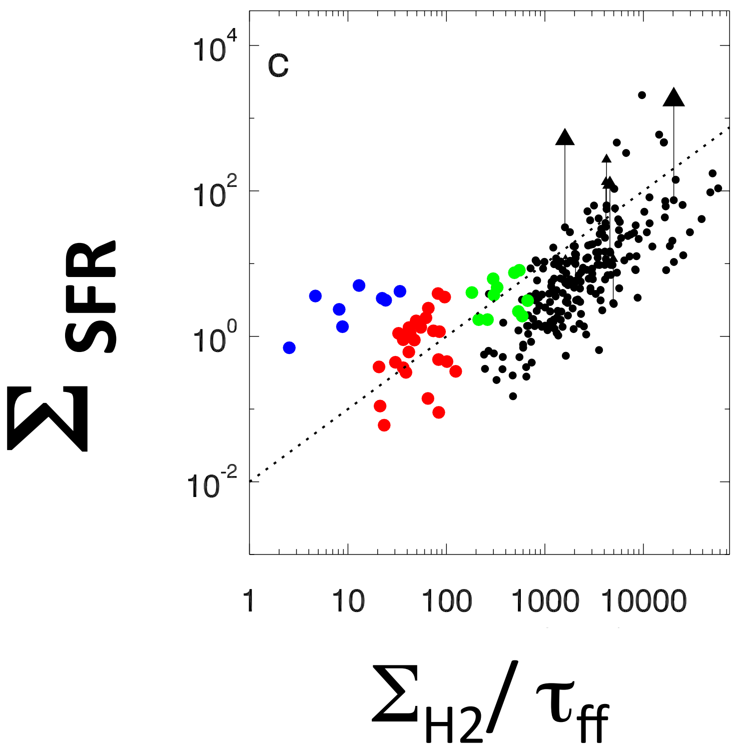



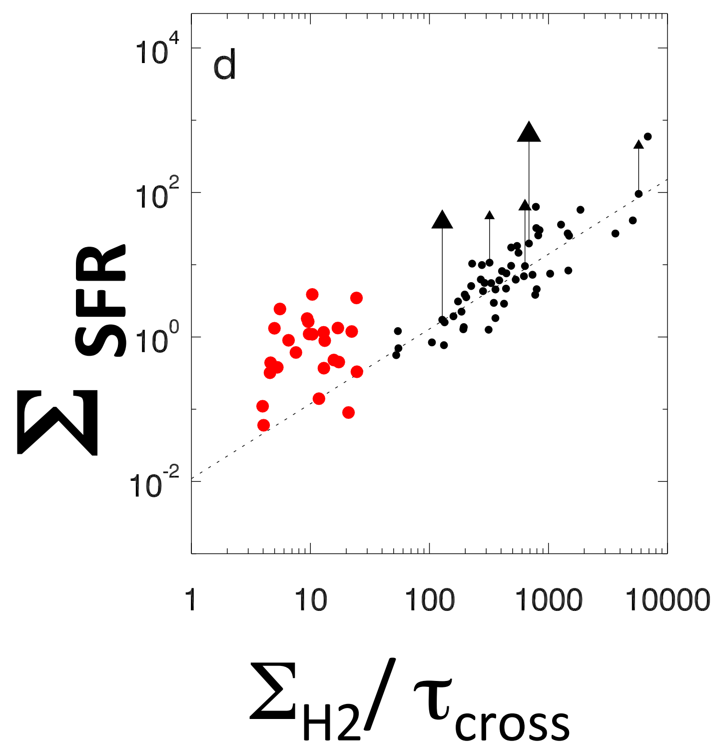
# Star Formation "Law" on different scales

## Resolved Dense, Clumps in MW

$$\Sigma_{SFR} = \varepsilon_{ff} \, \Sigma_{H2}/\tau_{ff}$$
$\varepsilon_{ff} = 0.006$

$$\Sigma_{SFR} = \varepsilon_{cross} \, \Sigma_{H2}/\, \tau_{cross}$$
with $\varepsilon_{cross} = 0.01$



**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 $\tau_{GMC}$ ~ 30-50 Myr, what does it mean to sample SF over 200 Myr?