KS Workshop “Summary”

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General Comments

- This is an active area of research➔generating controversy
- Excellent speakers and talks➔kudos to the organizers
- New observations are better addressing old questions, and raising new questions
- Substantial activity in num. sims., both applying and investigating KS law(s)
- Are sims. more puzzling than data?

What was this WS about?

- Observational status, Explanations, and high redshift Tests of the KS law(s)
- Statistics of presentations
  - O=6 (some theorists, e.g. B.E.)
  - E=7 (some observers, R.A.)
  - T=3 (observers and theorists)
- This is a sign of vitality

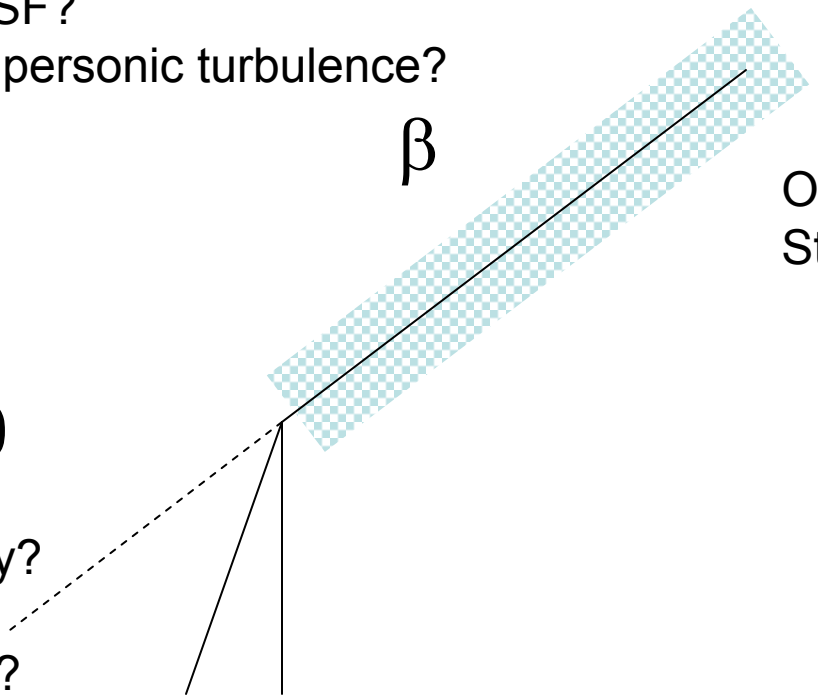
What can KS law tell us?

Gravitational instability?
SN-regulated SF?
Statistics of supersonic turbulence?
Other?

σ

β

Obs. errors?
Statistics of nonlinear GI?



$\Sigma_{SFR}0$

Star formation efficiency?
MC turbulence?
Gas velocity dispersion?

$\Sigma_g 0$

Molecular fraction?
Toomre threshold?
Shear threshold?
Stellar velocity dispersion?

Key Question: What is cause and effect?

- Conventional view

$$\Sigma_g \rightarrow GI \rightarrow \Sigma_{SFR}$$

- Contrarian view (Allen)

$$\Sigma_{SFR} \rightarrow rad.feedback \rightarrow L_{CO} \propto \Sigma_{SFR}$$

Are we plotting X versus X?

Explanations we heard

- What is the physics behind the KS-law?
  - Conservations of mass (Toomre instability)
  - Conservation of momentum (Silk)
  - Conservation of energy (Allen)
  - Conservation of velocity dispersion (Schaye)
- Cautionary tales (Elmegreen talk)
  - Counter-examples to Toomre instability explanation (M33)
  - different mechanisms (GI, pdf, shocks, cloud collisions) give similar rates in Q~1 disks
    - All involve nonlinear GI + turbulence

Scale-dependence of KS law

- Global averages (K98)
  - $1.3 < n < 1.6$
- Local KS law (M51; Calzetti et al.)
  - $n \sim 1.56$
- Dense gas, small scales (Gao & Solomon)
  - $n \sim 1$
- KS law is emergent phenomenon
  - Depends on averaging scale
  - Significance of this result unclear (to me)
  - Theory of global KS law must link MC scale and galaxy scale (Krumholz & McKee 2005)

High-z tests

- Critical tests of the simplest interpretation of KS law
- DLAs (Wolfe)
  - SFR reduced by ~20x in extended HI disks
  - Plausible dynamical and chemical explanations
- LBGs (Erb)
  - Reassuring consistency between Mdyn and Mstar+Mgas using KS-law
- Two results are not inconsistent, as LBG SFR in the regime where KS law is well-observed

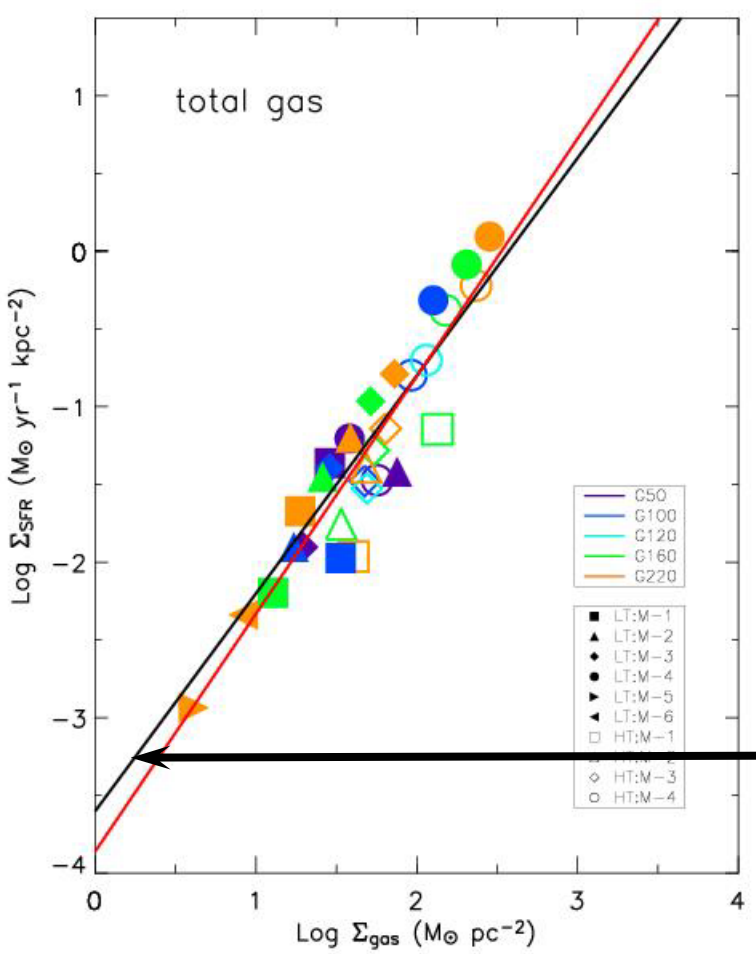
Numerical Simulations

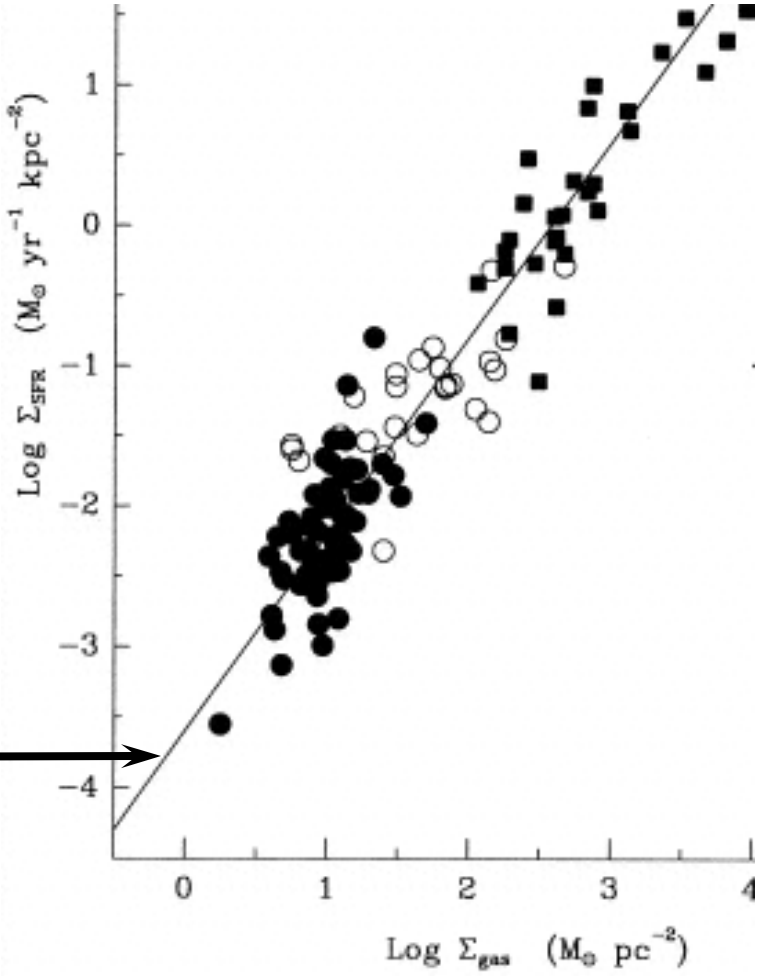
- Simulations results stimulated the most vigorous discussion (and confusion!)
- Confusion (by audience) about what is *input*, and what is *output*
- Simulations of two basic types
  - numerical experiments, designed to isolate physical mechanisms
    - Reduced physics
    - First principles ; resolved
    - Hypothesis tested, but may have limited relevance
  - astrophysical models, designed to engage observations
    - Complicated physics
    - Parameterized recipes, calibrated to observations
    - unresolved
    - What hypothesis is being tested?

Li, MacLow & Klessen

models

observations





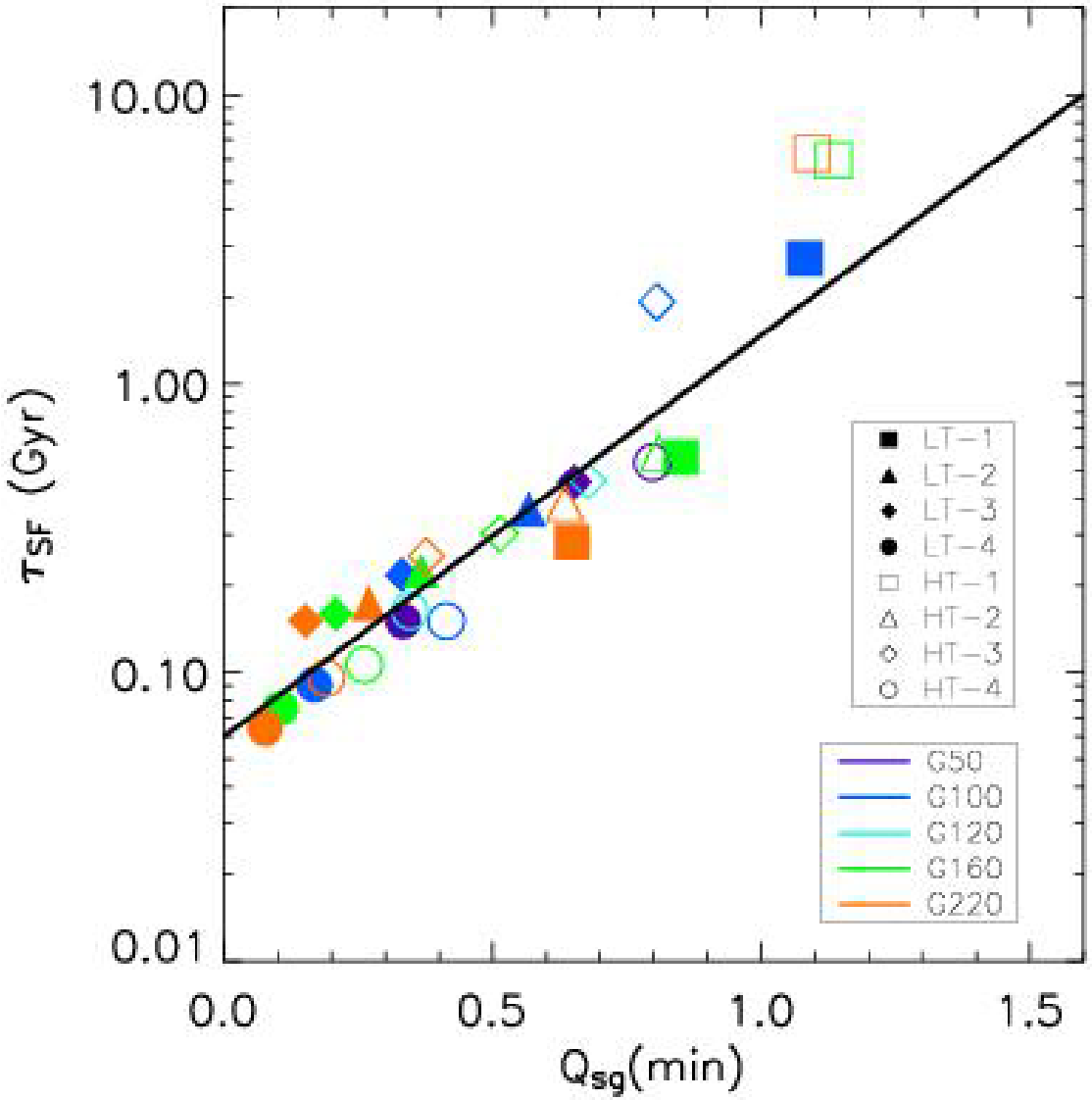
Li, Mac Low, & Klessen 2005, ApJLett, 2006, ApJ

Kennicutt 1998

Output: Instability drives SF

$$\tau_{SF} \propto e^{\alpha Q_{sg}}$$

$$\alpha \sim 3$$



Elements of a complete theory (things I heard I liked)

- Gravitational instability, more generally (not just Toomre) (Elmegreen, Schaye)
- Turbulent statistics (Krumholz & McKee 2005)
- Thermodynamics and chemistry
  - pressure-regulated SF (Blitz)
  - effective EOS (Schaye)
- Radiation shielding (Schaye, Kravtsov)
- B-fields (Shu)
- External perturbers (Madore)
- Cosmic infall (Blitz, Silk)

Final impression

- Question is morphing before our eyes
- Was:
  - What regulates global SFR?
  - ➔supply of gas
- Is becoming:
  - What regulates SF in molecular clouds?
  - What regulates molecular cloud formation in galaxies?
- New observations and models will drive this field in new, promising directions