ITC Pizza Lunch: Introduction to (Current Open Issues) in Star Formation

Alyssa Goodman, February 1, 2012

Quick Intro to Scales/Background/Measurement Techniques (worldwidetelescope.org)

Jeans?.. not really... "turbulence"/dendrograms, clusters, (coherent) cores (maybe Jeans applies there?). Role of magnetic fields? Role of feedback/winds? Importance of simulations. Virial Equilibrium/Larson's "Laws." (Understanding *p-p-v* spectral-line data cubes.)

Disks?...yes, really. But, what do they accrete *from* (cores, cluster gas?)? How do binaries (and multiples) form? Importance of answers re:planet formation.

Time evolution... Outflows are clearly episodic, meaning accretion likely is too...
But how much of an effect does episodicity have? Competitive Accretion?

Stars/Measuring Ages. VERY inexact science (see many Spitzer studies), mostly based on spectral energy distributions. (Definition of Class 0, I, II, III, etc.) Models of evolution of young stars very imperfect, plus separating effects of disk/envelope/l.o.s. reddening, plus variability, is very tricky.

Origin of IMF. Log-normal? Is it from the CMF, which is also log-normal? Does the CMF come from turbulence+gravity, or any set of random processes? Interesting bits of IMF are turnover (peak) and deviations at high/low ends.

Galactic:Extragalactic connection--can we refine Kennicutt-Schmidt relation? Is there really just a star-formation "threshold" in (column) density, or is it possible to identify self-gravitating (or truly star-forming) gas?

What to do now? More taste-testing (statistical comparison of synthetic observations of simulations with "real" data), with more predictive diagnostics. Critical need for improved understanding of chemistry and dust.

New instruments: Herschel/Spitzer/WISE (more source catalogs, morphological structure, temperature measurements), eVLA & ALMA (more tracers, meaning more chemistry, kinematics, density, and time-evolution if we can interpret chemistry!, more disks), SOFIA (even more chemistry), and JWST (more dust, disks). Plus, all will improve resolution & sensitivity for extragalactic studies... but *never* to what we have nearby. GAIA will be important for getting full 3D (*p-p-p-v-v-v*) stellar motions & we will better understand how stars "leave home" and migrate within galaxies.

finding more + slides online...www.cfa.harvard.edu/~agoodman, www.cfa.harvard.edu/COMPLETE

To study for your "Ph.D. Exam" ... (a list in semi-random order)

1. Kennicutt-Schmidt relations
2. Molecular Line Maps, CO, HINSA, "tracers," spectral-line cubes, *p-v* diagram, *p-p-v* space
3. Larson's "Laws"
4. Virial Theorem, virial parameter
5. CLUMPFIND, dendrograms
6. column density/PDF
7. extinction, reddening (law), NICE/NICER/NICEST/GNICER/GNICEST
8. thermal emission, column temperature, β-T relation (controversy)
9. spectral energy distribution
10. "cloud," "clump," "core"
11. coherent core, kernel
12. cluster
13. competitive accretion, turbulent fragmentation, (M)HD simulations
14. radiative feedback
15. [HII region]
16. IMF, CMF
17. stellar wind: PMS/MS spherical, bipolar outflow
18. disks: pseudo, accretion, protostellar/protoplanetary, debris
19. YSOs, "Class 0 Source," Class I, II, III
20. spectral and wavelength-specific features of protostars & disks
21. disk gaps [planets]
22. polarimetry: background starlight, dust emission, Goldreich-Kylafis effect
23. Zeeman splitting: thermal lines, masers
24. masers
25. galactic fountain
26. gas-grain chemistry, ion-neutral chemistry
27. freeze-out
28. depletion
29. sublimation

(New) Instruments you Should Know About

Spitzer, SOFIA, WISE, Herschel, JWST, ALMA(SMA, CARMA), eVLA,
+many new ground-based hi-res O/IR spectrometers & IFUs

Table 2: **Reading Nature's Menu** This table shows which tools are best for deteriming particular physical quantities. Grey shows possible wavelengths, and darker grey emphasizes the best wavelengths. Green means "yes," and yellow means "yes, but not usually very well." *Many subtleties cannot be shown here.* For example: stellar mass determinations are always model-dependent unless an orbit is known; some techniques give line-of-sight velocity, while others give plane-of-the-sky; chemistry is always very model dependent, and so-on.

Notes: C=included in COMPLETE; S=included in Spitzer c2d; +=included in both COMPLETE & c2d; Magnetic Fields: P=by polarimetry; Z=(primarily by) Zeeman, at same wavelengths shown

		optical	NIR	MIR	FIR	sub-mm	mm	cm	**Density or Mass**	**Chemical Composition**	**Temperature**	**Velocity**	**Magnetic Fields**
Extended Material (Clouds & Cores)	Broadband Emission (Dust)			S	+	C	+						P
	Spectra (Dust)												P
	Spectra (Gas)						C	C					Z
	Background Starlight (Extinction)		C	S									P
	Scattered Light ("Cloudshine")		C	S									
Disks & Envelopes (spatially filtered obsv'ns.)	Broadband Emission (Dust)			S	S	+							
	Spectra (Dust)			S	S								
	Spectra (Gas)												Z
Optically-Revealed (Proto) Stars	Broadband Emission			S									
	Spectra			S									Z
	Astrometry												