The ALMA Era: What Would Phil Do? Doug Johnstone - NRC:HIA / UVic



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'Phil'osophy

Review important Phil Myers papers ('phil'ology - humanistic study of language and literature)

Think like Phil !!

Ø Devise a game Plan

If all else fails ...

Turbulent Phil (Mid-Life Crisis?!?)

Turbulent Cooling Flows in Molecular Clouds

- ApJ, 1998, Myers and Lazarian
- On the Turbulent Velocity Dispersion in Molecular Clouds
 - ApJ, 1998, Myers and Gammie
- Growth of an IMF cluster in a turbulent dense core
 - ApJ, 2000, Myers

Turbulent Phil ApJ, 1998, Myers and Lazarian

observed extended inward motions (0.1pc) suggest more than gravitational infall

- Cooling flow' model suggest lower pressure on inside, dissipation of turbulence
- pressure mediated collapse is quicker than ambipolar diffusion

Turbulent Phil

ApJ, 1998, Myers and Gammie

observed 'Larson Law' relation for spatial size versus line width correlation

similar result seen for self-gravitating and non-self-gravitating clouds suggests turbulence

 ${\it {\it o}}$ correlation depends critically on scales measured, with respect to λ_{min} and λ_{max}

Turbulent Phil ApJ, 2000, Myers

start with low-mass, pressure confined, thermal 'kernels' in turbulent cores

- accrete mass, proportional to kernel mass, and turbulent energy to retain support
- stop growth, through collapse, randomly
- attain an IMF-like solution

Turbulent Phil



Thanks to Alyssa ...

Thanks to internet ...

Quasi-Static Phil (Calm and Wise)

Centrally Condensed Collapse of Starless Cores

ApJ, 2005, Myers

Protostar Mass Due to Infall and Dispersal

ApJ, 2008, Myers

Filamentary Structure of Star-Forming Compexes

ApJ, 2009, Myers

Quasi-Static Phil ApJ, 2005, Myers

- Pressure-free Gravitational Collapse for equilibrium layers, cylinders, and spheres
- During first phase the structures remain self-similar (starless infall phase) with flat inner density profiles

Hard to distinguish equilbrium and initial collapse using density profile alone

Velocity field provides the key measure

Quasi-Static Phil ApJ, 2008, Myers

- protostellar growth via infall and dispersal of an isothermal core in a uniform background
- In high contrast core/background or short dispersal time - `self-limiting'
- Iow contrast and long disperal time 'run away' growth

These two regimes may apply to different molecular cloud conditions (high/low mass)

Quasi-Static Phil ApJ, 2009, Myers

- Observed hub-filament structure to nearby star-forming regions
- Filaments may arise from fragmentation of a layer and may be modelled quasi-statically
- Simplest models are too uniform
 e.g. Schmid-Burgk

But, how about combining spherical clump geometry and a Schmid-Burgk layer ...

Quasi-Static Phil







Consider the Pre-Stellar Core ...



 $R_J \propto \left(\frac{T}{c}\right)$

 $M_J \propto \left(\frac{T^3}{o}\right)$

 $ho(r) \propto r^{-}$

 α ~ importance of self-gravity

But, shouldn't the environment determine the core properties?!?

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An Enlightening Example ...



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An Enlightening Example ...



2

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An Enlightening Example ...

Padoan & Nordlund simulation (turbulence and self-gravity)

 mach 9 turbulence, with many initial Jeans masses

• observed density barrier due to ram pressure from turbulence $\rho_{max} \sim M^2 \rho_{init} \sim 80 \rho_{init}$

 requirement of observational high spatial and dynamic range



Note: this analysis only reveals that the environment sets collapse conditions

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An Observational Example ...



Ophiuchus, observed with SCUBA at the JCMT (Johnstone et al.)

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The ALMA Advantage

- 1) At least fifty (and officially sixty-four) 12-meter antennas for sensitive, high resolution imaging
- 2) Twelve 7-meter antennas comprising the ALMA Compact Array (ACA), for high fidelity wide field imaging
- 3) Imaging in all atmospheric windows from 3.5 mm to 300 microns
- 4) Array configurations from 150 meters to 15 km, maximum baseline
- 5) Imaging of sources many arc-minutes across at arc-second resolution
- 6) Top spatial resolution of 5 milli-arcseconds
- 7) Top velocity resolution better than 0.05 km/s

The ALMA Advantage



The ALMA Advantage







QUIZ 1: Which of the following best describes a pre-/proto-stellar core density profile? a) flat on the inside b) peaked on the inside c) depressed on the inside d) flat or peaked on the inside e) chocolatey on the outside, creamy on the inside

Pre-/Proto-stellar Core



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Pre-/Proto-stellar Core

Being a smart man, Phil already knows that cores are either flat in the middle or peaked. And, that gravity is responsible for the peaked nature of some cores. While ALMA will teach us more about this, in Phil's mind this is B-O-R-I-N-G!!

Pre-/Proto-stellar Core



QUIZ 2: Which of the following best describes the physics of the central infall in a proto-stellar core? a) turbulent flows b) what infall, it's all outflow c) freefall collapse (gravity, man) d) magnetic fields (electric, man) e) thermal instability (cool, man)

Proto-stellar Core



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Proto-stellar Core



See, Phil also knows that the infall velocity near the centre of the core is due to gravitational collapse. Measuring this velocity with ALMA will also be B-O-R-I-N-G!!

Pre-/Proto-stellar Core

QUIZ 3:

Which of the following best describes the chemistry at the centre of a pre-stellar core?
a) like Doug's garage, all CO
b) like the morgue, all H₂CO
c) as Paola said, deuterium rules!
d) mostly H₂ and N-species
e) like Phil's desk, dust-free

Proto-stellar Core

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Proto-stellar Core

See, Phil even understands the chemistry at the centre of a pre-stellar core.

So, what then does Phil need ALMA to do for him?!?

Proto-stellar Core

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Phil knows that the power of ALMA will be found in its spatial resolution, sensitivity and fidelity.

Thus, ALMA will be the best instrument to probe the structure surrounding the core – precisely the region Phil doesn't **yet** fully understand.

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x'

S. Basu

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If All Else Fails ...

Hire an excellent pre- or post-doc!
 (Phil's not so secret weapons)
 [and source of many, many et al. references]

How Is Phil like ALMA?

 Both Phil and ALMA are extremely sensitive.
 Both are connoisseurs of high fidelity. Both are world class.
 Neither likes the Yankees. Although official documents may claim they are about 64, in reality both Phil and ALMA appear much closer to 50!!