## Updates on FIRE & other work



Stars, protostellar disks

Supernovae blastwaves

**Star-Forming Regions** 

Dust: Actual Micro-Physics

The Setup: SQUIRE & HOPKINS '17 (SH; arXiv:1706.05020)

Gas equations = (anything that supports a linear mode)

Dust equations = continuity + momentum:



#### What Does This Look Like? (TALK TO ME ABOUT NUMBERS)

 $|\mathbf{w}|_{\mathrm{drift}} \approx 10 \, c_s$ 



Х

 $\Delta t \sim 80 \langle t_s \rangle$  $L_{\rm box} \sim 100 \, c_s \langle t_s \rangle$ 





# The IMF & Sub-Cloud Scales

### Feedback vs. Gravity

Guszejnov, Hopkins, & Krumholz 2015, 2016, 2017



EVERY VARIABLE-IMF MODEL USED EXTRA-GALACTICALLY IS WRONG (arXiv:1702.04431)



#### Why Is Star Formation Clustered? INEVITABLE IN GRAVITATIONAL COLLAPSE







# GMC & Star Cluster Scales

#### What Determines Cloud Star Formation Efficiencies? FEEDBACK VS. GRAVITY











Andrew Wetzel (arXiv:1602.05957)

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"Triple Latte" (A. Wetzel): Cosmological MW with ~800  $M_{\text{sun}}$  , sub-pc resolution

#### **GMCs: Turbulence+Gravity+Feedback** RESOLVING "TOP SCALE" OF FRAGMENTATION







~kpc Scales: Kennicutt-Schmidt

#### KS Law Emerges Naturally FEEDBACK VS. GRAVITY

Matt Orr (1701.01788) Agertz+14, PFH+ 11,12,14 Shetty & Ostriker '08.11, Kim & Ostriker '11,13





#### No dependence on MHD, conduction, viscosity, etc. ONLY SEE IF FEEDBACK IS ARTIFICIALLY WEAK



Kung-Yi Su

1607.05274)

(arXiv:

#### Giant "Clumps" JUST AN EXTENSION OF GMCs



2.5

2.0

SFRs + masses

#### Giant "Clumps" Blow Up, Don't Sink JUST AN EXTENSION OF GMCs



Antonija Oklopcic (arXiv:1603.03778)





Galactic/Cosmological SFRs: Driving Winds

#### Remember Stellar Clustering? THIS MATTERS, A LOT!

Martizzi+ '16 Walch+, Kimm+, many others

Winds "by hand" ~SFR



#### Burstiness & SFR-M<sub>stars</sub> Relation





Bursty/Calm Star Formation & Galactic Structure

#### *Direct* Consequences for Structure BURSTY SF = STARS MIXED, JUST LIKE DM

- If DM orbits perturbed, stars are too!
  - Radial anisotropy
  - Gradients "wiped out"
  - Galactic radii oscillate





Kareem El-Badry arXiv:1512.01235

#### New Classes of Galaxies ULTRA-DIFFUSE SYSTEMS: THE NEW "NORMAL"

#### TK Chan (prep)





#### Transition from Feedback-Dominated to "Calm" (Gravity-Dominated) BUILDUP OF METALLICITY GRADIENTS



Xiangcheng Ma (arXiv:1610.03498)



#### Transition from Feedback-Dominated to "Calm" (Gravity-Dominated) THICK -> THIN DISK





Xiangcheng Ma (arXiv:1608.04133) Ana Bonaca (arXiv:1704.05463)

Detailed vertical+radial abundance gradients & kinematics of thin/thick disk populations



Thin Disks Emerge Naturally... but when/where?

The Milky Way



10 kpc

Garrison-Kimmel et al., in prep

#### Angular Momentum of Gas+Stars WHY DO DWARFS NOT HAVE (THIN) DISKS?

22.4 SAMI atoms SAMI median 10<sup>2</sup> 21.6 FIRE 20.8  $V_{\rm rot, \ gas}$ ź 20.4 20.0 8 240 10<sup>1</sup> 180 120 Tully-Fisher -120 -180 5 11 8 9 10 6 240  $\log(M_{\rm star}/M_{\odot})$  $\langle j_{\text{mock obs}}^{\circ} \rangle (\text{kpc km s}^{-1})$  $10^{4}$ R+F12, S0s R+F12, spirals F+R13, pure disks LMC 10<sup>3</sup> SMC Stellar A.M. Gas A.M.  $10^7 \ 10^8 \ 10^9 \ 10^{10} \ 10^{11}$  $10^7 \ 10^8 \ 10^9 \ 10^{10} \ 10^{11}$ 10<sup>6</sup>  $M_{\rm star}$  (M $_{\odot}$ )  $M_{\rm star}$  ( $M_{\odot}$ )

- Thick/irregular [clumpy+bursts+pressure]
- Suppressed late-time accretion [UVB+FB]

Kareem El-Badry (arXiv:1705.10321)  $\langle j_{\rm DM} \rangle$  $\langle j \rangle$ all baryons,  $r < R_{200m}$ 0.1 0.1 all baryons,  $r < 0.1 R_{200m}$ 0.1 gas 0.01 stars 8 9 10 11 7 12 6

 $\log(M_{
m star}/M_{\odot})$ 

#### Halo Structure Mock GAIA Catalogues with ~100,000,000 Stars in the (Simulated) Galaxy







Sanderson et al. (in prep)



What About AGN?

Lumpiness + SNe Need big seeds or "anchors"





D. Angles-Alcazar arXiv:1707.03832

#### Accretion Disk Winds: 0.01-10,000 pc

#### No BAL Winds

7 Myr



Torrey et al.

in prep

Gas



10 pc

1 Myr

 $\dot{M}_{
m launch}(0.1\,{
m pc})=0.5\,\dot{M}_{
m BH}$  $v_{\rm launch}(0.1\,{\rm pc}) = 10,000\,{\rm km/s}$ 

Gas



## Accretion Disk Winds: 0.01-10,000 pc

Torrey et al. in prep

#### Mrk 231 (+all other warm ULIRGs) Neutral Gas V<sub>5055</sub>





#### Molecular (CO)

X-Rays

- Dust-Gas Mixtures Inherently Unstable (Squire+ 17)
- IMF: Feedback or Galaxy-Scale Models are Wrong (Guszejnov+ 17)
- Stellar clustering is Universal (Guszejnov+ 17)
- Realistic clusters: Cloud surface density determines properties (Grudic+ 17)
- ➢ Globulars resolved(?) (Kim+ 17)
- KS=feedback: dense laws; SF 'starts' with instability (Orr+17)
- ➢ Weak dependence of ISM/SF on MHD, etc (Su+ 17)
- Giant clumps ~ scaled GMCs (Oklopcic+ 17)
- Bursty SF important to observed SFR relations (Sparre+ 16)
- Bursty SF perturbs dwarfs (El-Badry+ 16), disk settling key (Ma+16)
- Halo structure (Sanderson+) & AGN (Torrey, Angles-Alcazar) in prep...