Simulations of Gas-Rich Isolated Disk Galaxies

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AstroFIT
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Ann Almgren; Lawrence Berkeley National Laboratory

The Low-Metallicity ISM; Göttingen 9. Oct. 2012

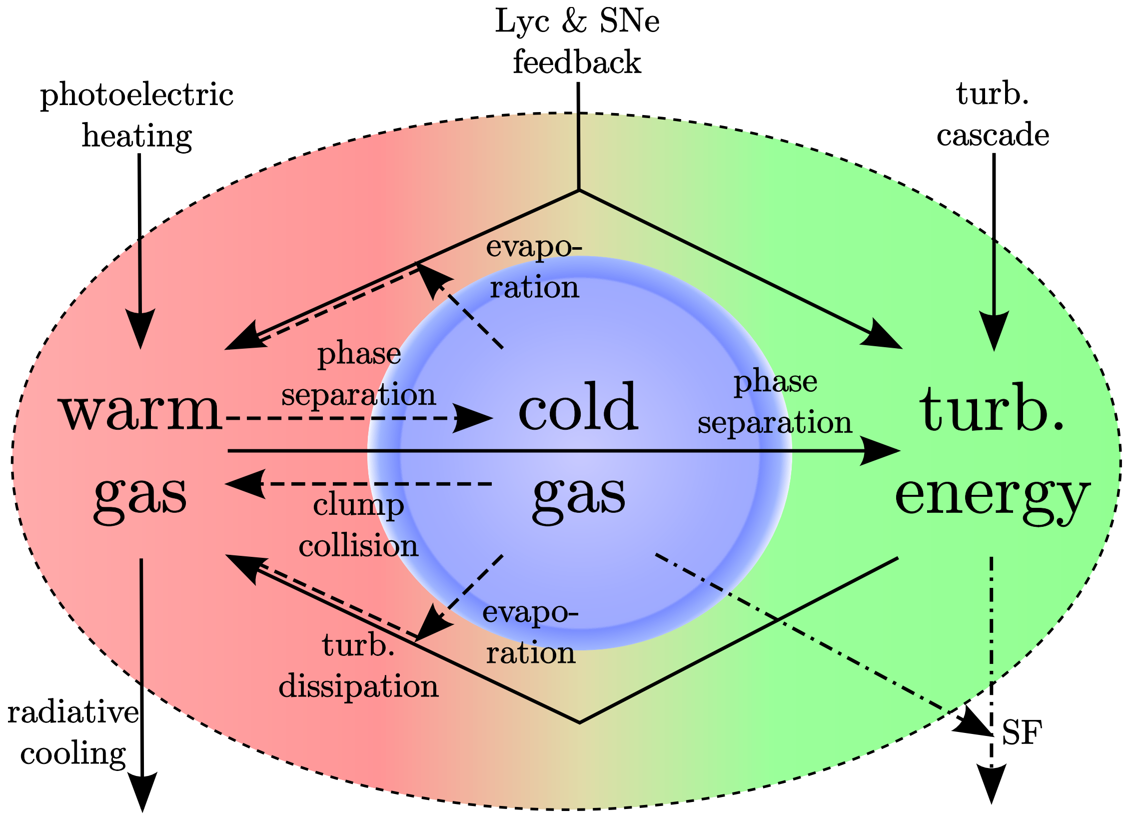
Simulations of an Isolated Disk Galaxy

NGC 1300 (HST)

Subresolution Processes

30 Dor (HST)

Turbulent Multiphase Model of the ISM



- split mass contents of a subvolume into cold and warm phases ρ_c and ρ_w with separate thermal energy budgets
- assume the phases in equilibrium of **effective** pressure (thermal + turbulent) at 'clump'-scale l_c

Institut für Astrophysik Göttingen

Star formation & stellar feedback

- Stars are allowed to form of molecular cold gas f_{H2} (Krumholz et al. 2009-alike)

- Rate depends on how much of the density PDF of the cold gas exceeds a critical density (Padoan & Nordlund 2011), and ε_{core}

$$\dot{\rho}_s = \varepsilon_{core}\varepsilon_{ff}\frac{f_{H_2}\rho}{\tau_{ff,c}} = \frac{\rho_{H_2}}{\tau_{sf}}$$

- Stars act back on the gas via Lyc-radiation and SNe accordingto their evolutionary stages

Sources of Turbulence Energy

Sources of mean turbulent energy on the length scale:

$$\dot{e}_{\mathrm{t}} = (\varepsilon_{\mathrm{SN}} u_{\mathrm{SN}} - e_{\mathrm{t}}) \frac{\dot{\rho}_{\mathrm{SN}}}{\rho} + \varepsilon_{\mathrm{tt}} \Lambda_{\mathrm{eff}} \frac{\rho_{\mathrm{w}}}{\rho} + \frac{\Sigma}{\rho} - C_{\varepsilon} \frac{e_{\mathrm{t}}^{3}}{l}$$

Internal Driving:

- Production by thermal instability
- Production by **supernova** feedback

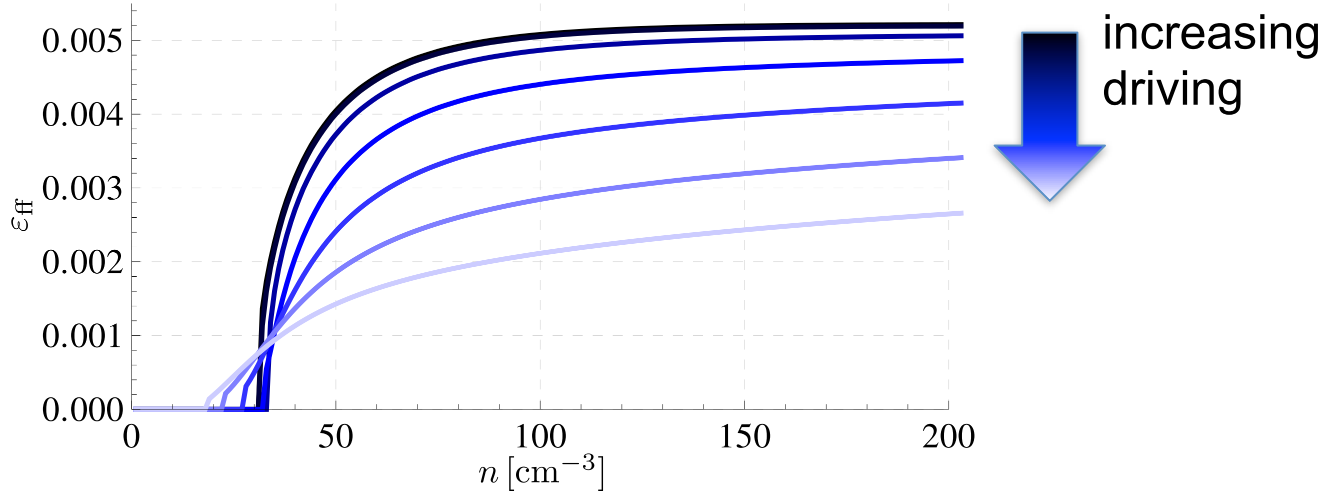
External Driving:

Turbulence energy flux (via turbulent cascade) from length scales due to grav. instabilities and shear of galactic disk...

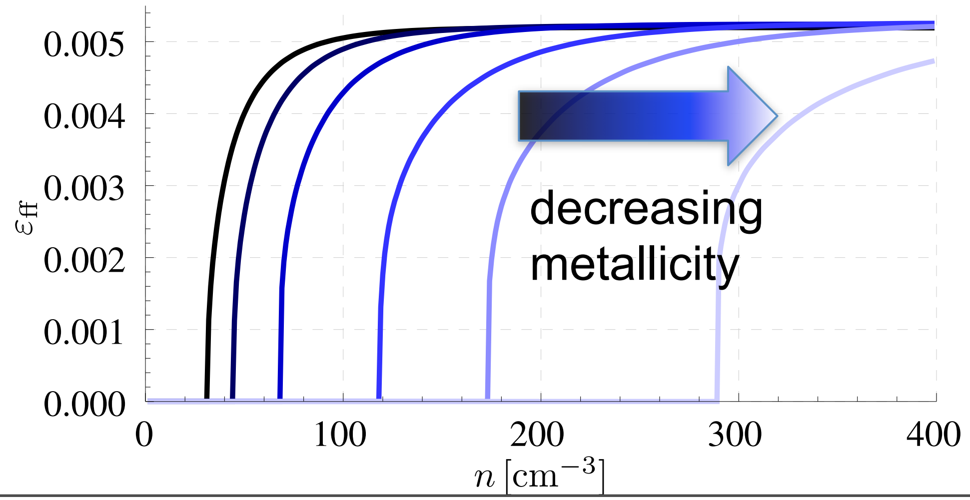
Dissipation

Equilibrium Solutions

The influence of external driving:

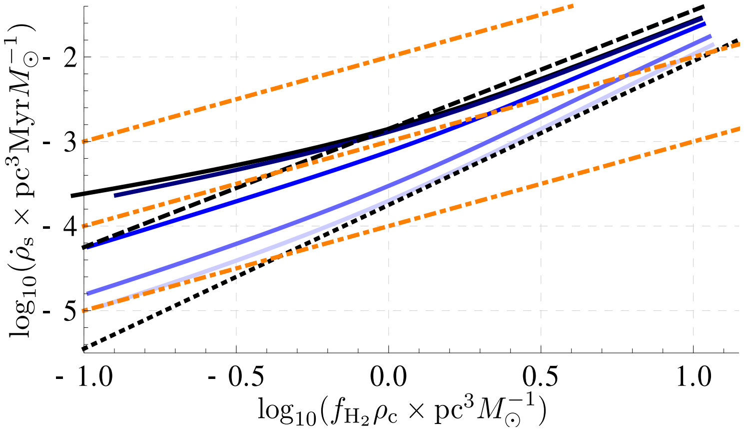


The influence of metallicity:

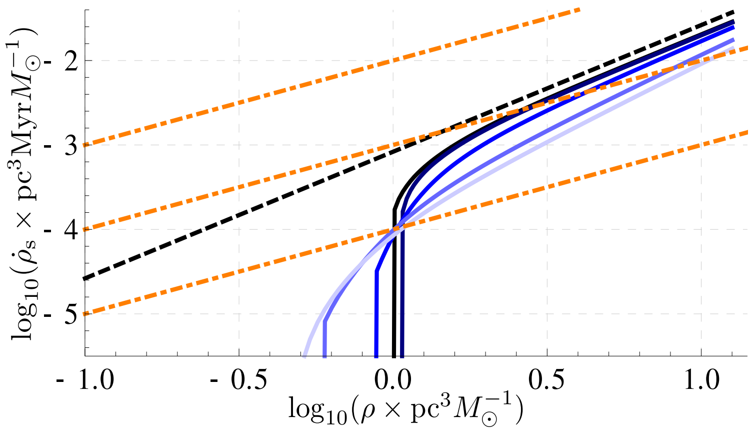


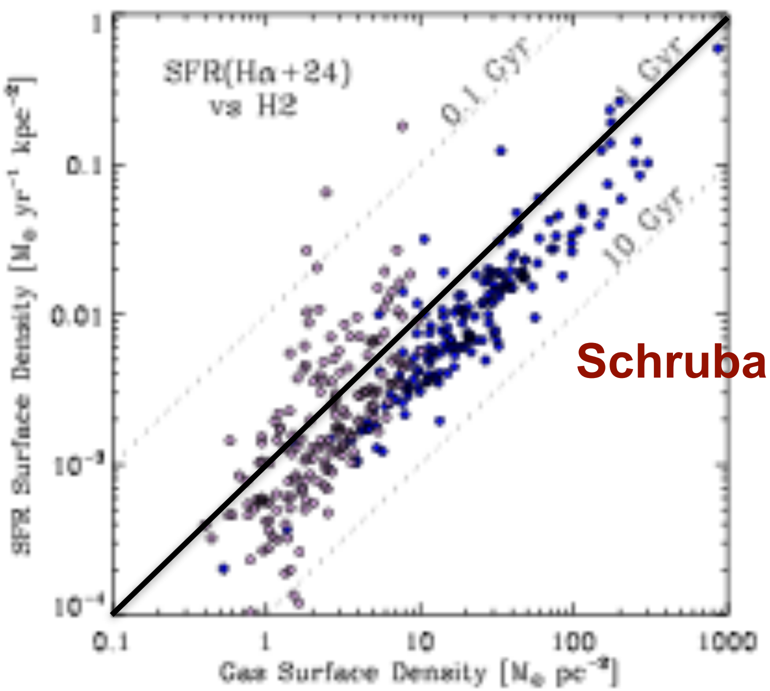
Calculated and observed SFR

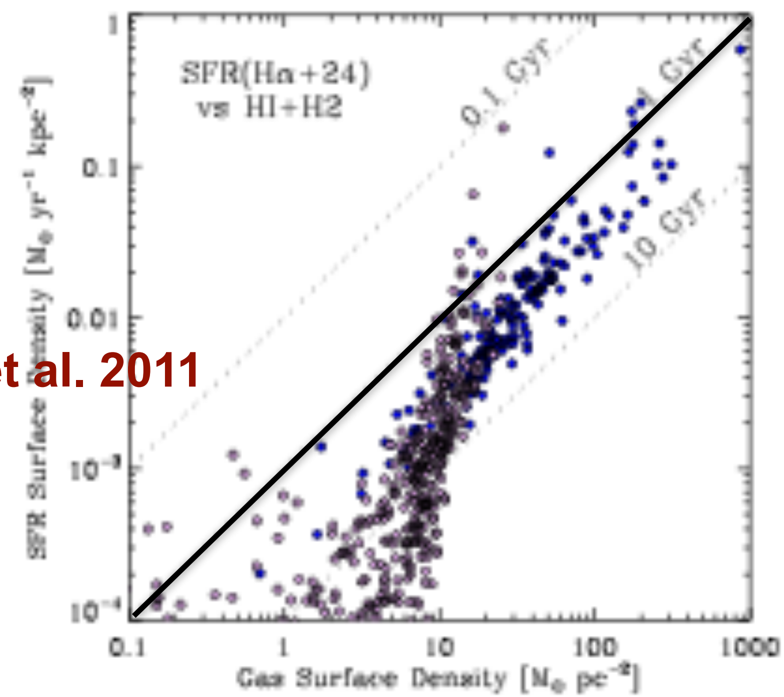
SFR vs. total gas



SFR vs. molecular gas





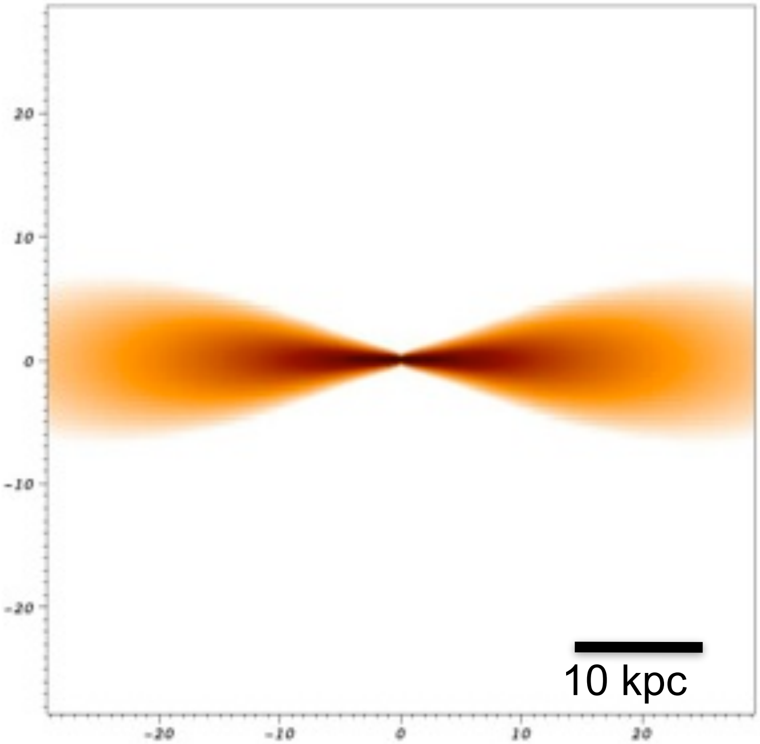


Schruba et al. 2011

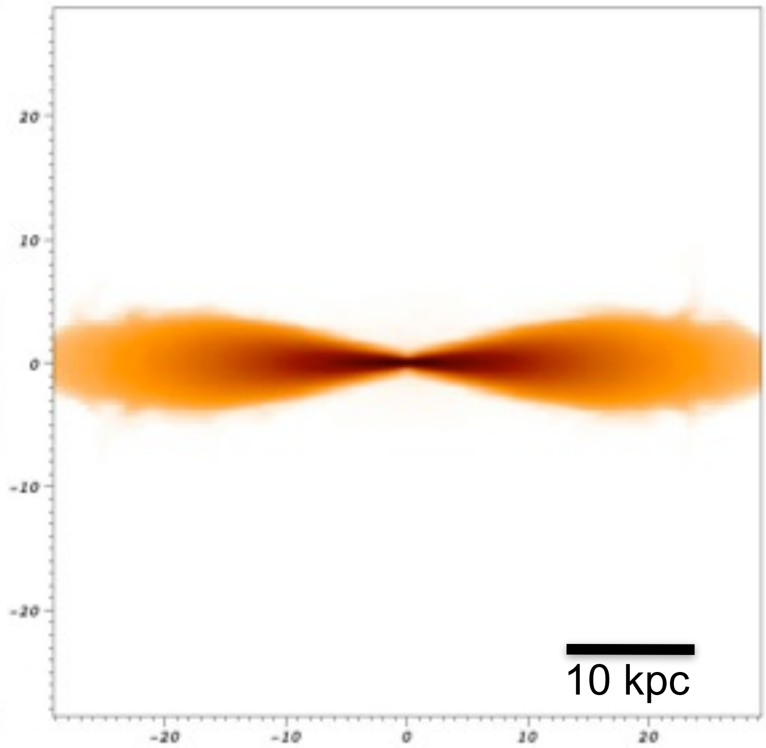
Numerical Simulations: Nyx (Almgren et al. 2012)

- cosmology code developed at LBNL (Berkeley)
- C++ / fortran, MPI + OpenMP parallelized
- block-structured AMR
- unsplit PPM hydro scheme
- particles & PM gravity
- turbulent SGS model (Schmidt & Federrath 2011)
- star particles with feedback
- multiphase ISM model

Isolated Disk Galaxy: adiabatic



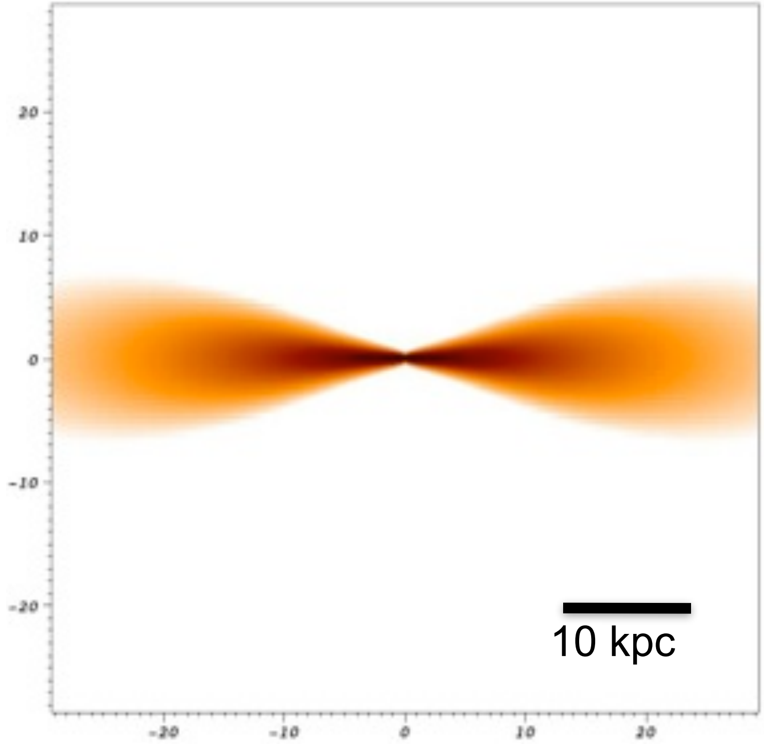
density slice at initialization



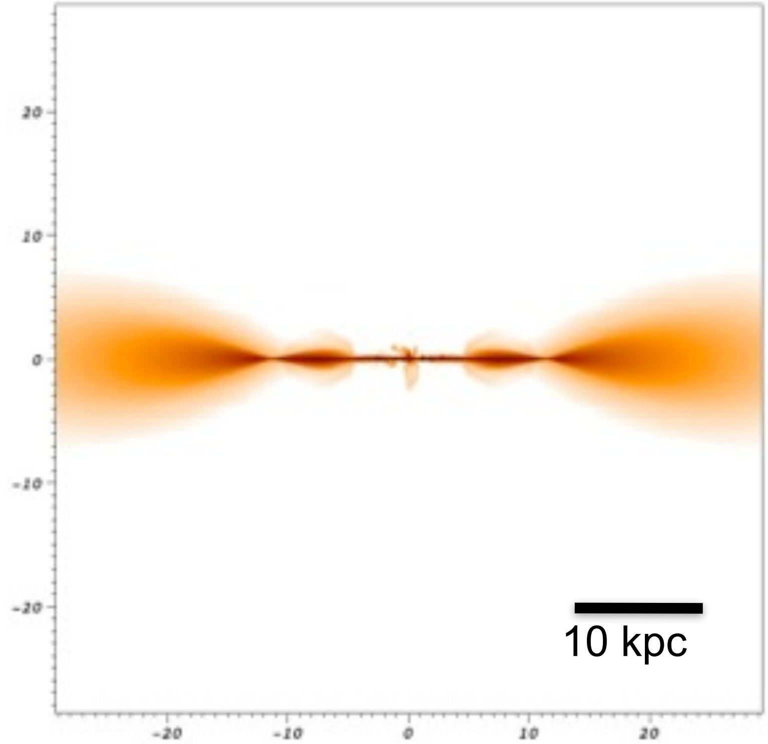
density slice after ~ 1 Gyr

- stable isothermal disk setup (Wang et. al. 2010) at $T = 4{\times}10^4$ K
- $10^{10} M_{sun}$ baryons; $\sim 10^{11} M_{sun}$ DM static NFW-halo; no stars
- 1 Mpc box; 8 refinement levels; 30 pc resolution at finest level

Isolated Disk Galaxy: full model

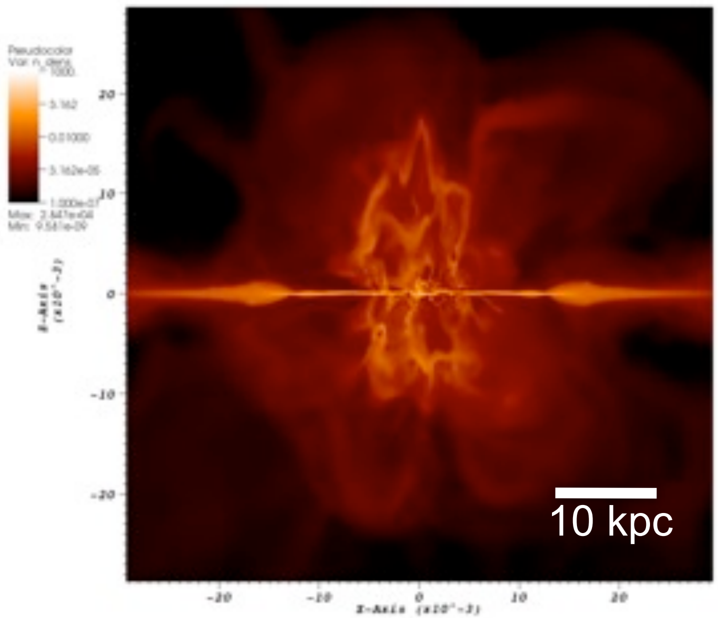


density at initialization

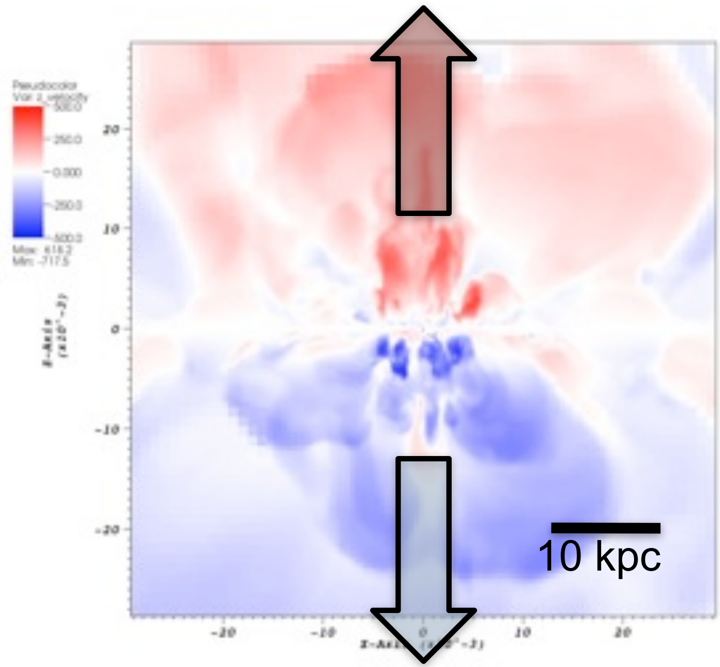


density after ~ 100 Myr

Outflows (300 Myr)

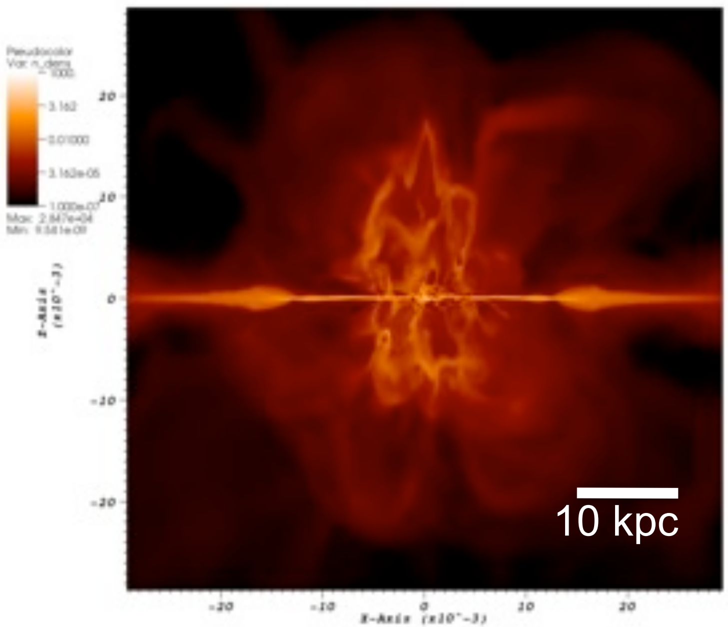


density slice

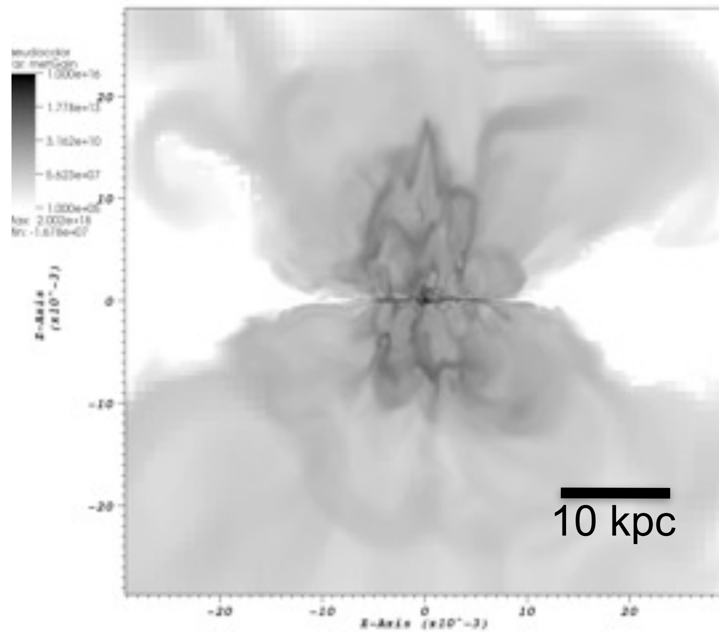


z-velocity slice

Metal enrichement (300 Myr)

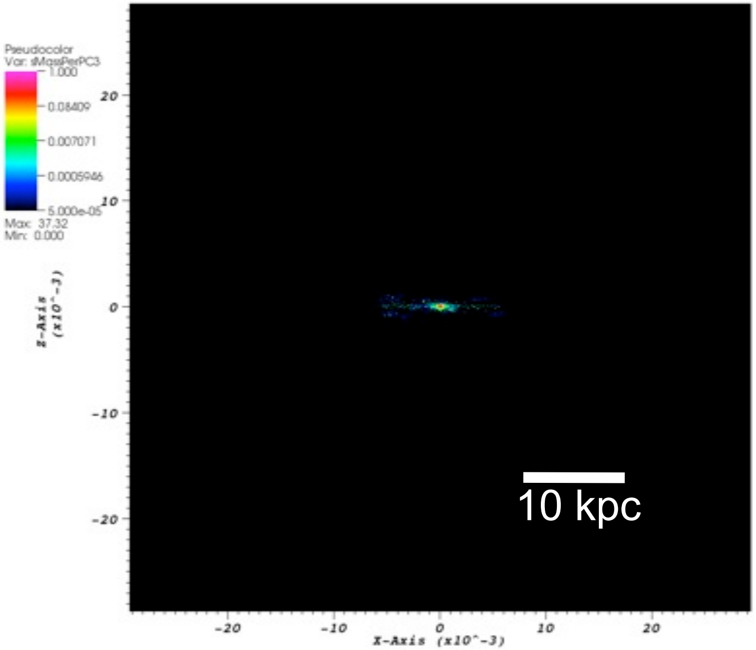


density slice

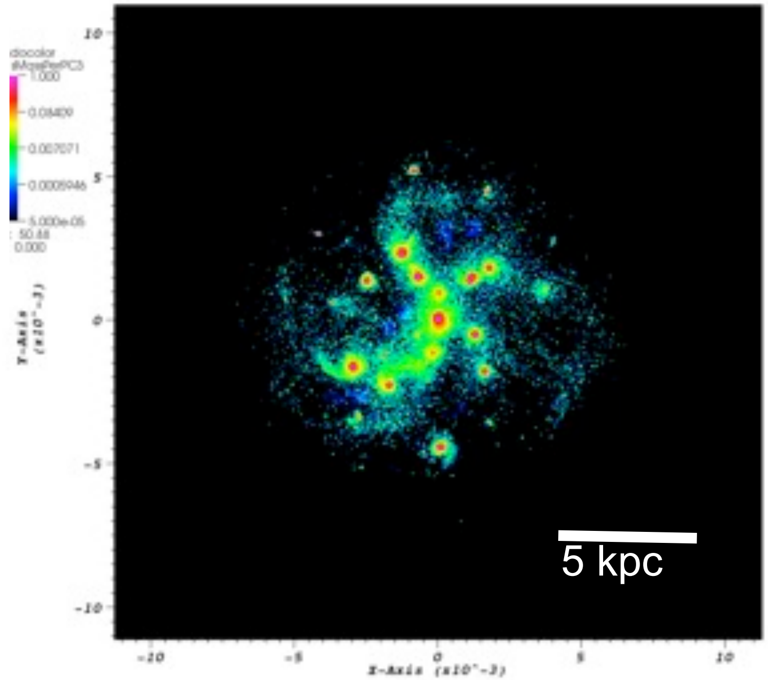


metal enrichment slice

Stellar disk (300 Myr)



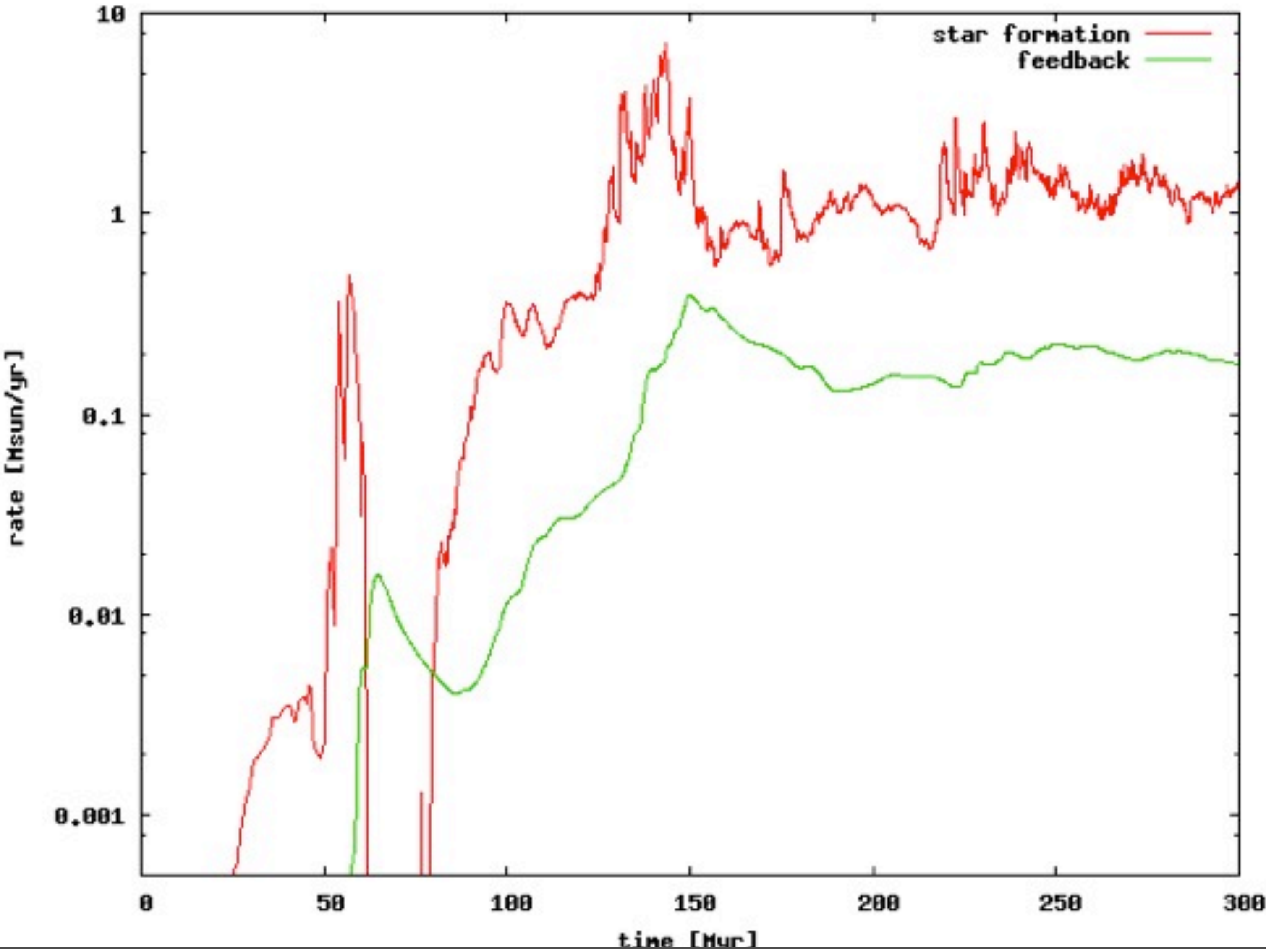
stellar density slices



Low-met ISM 2012 Göttingen:

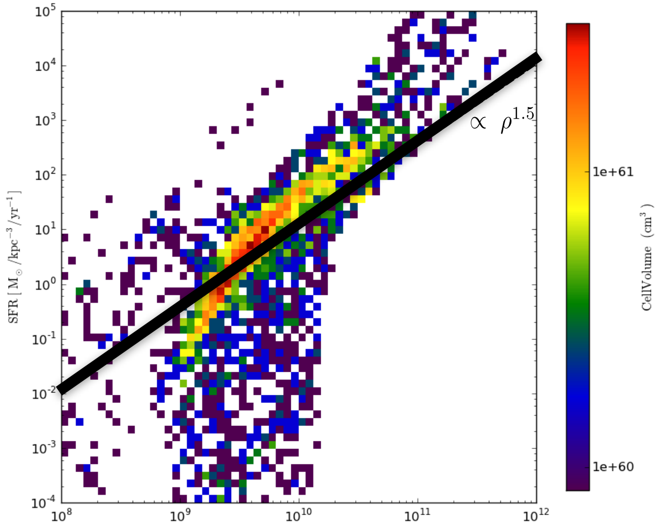
Simulations of an Isolated Disk Galaxy

Evolution of global star formation rate and stellar feedback

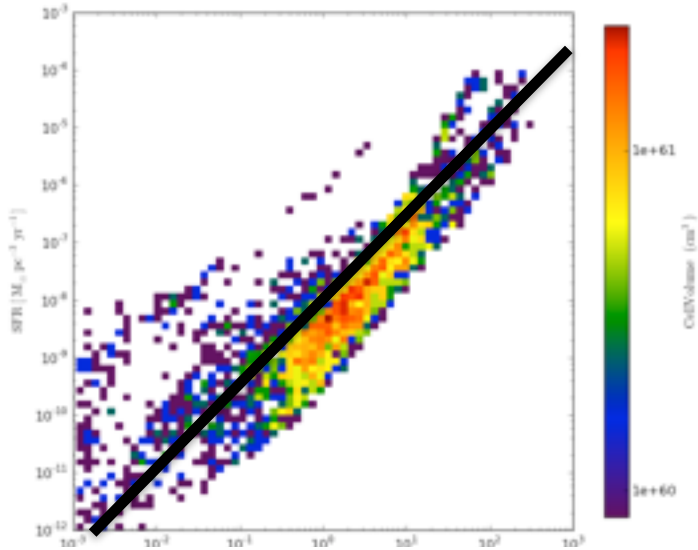


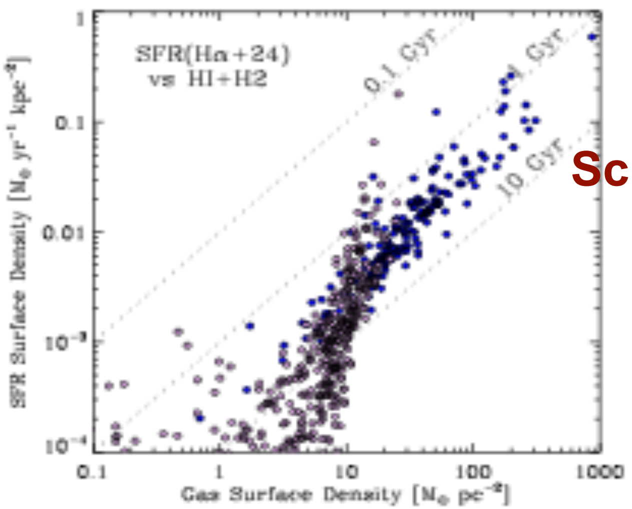
SFR from simulation and observations

SFR vs. total gas

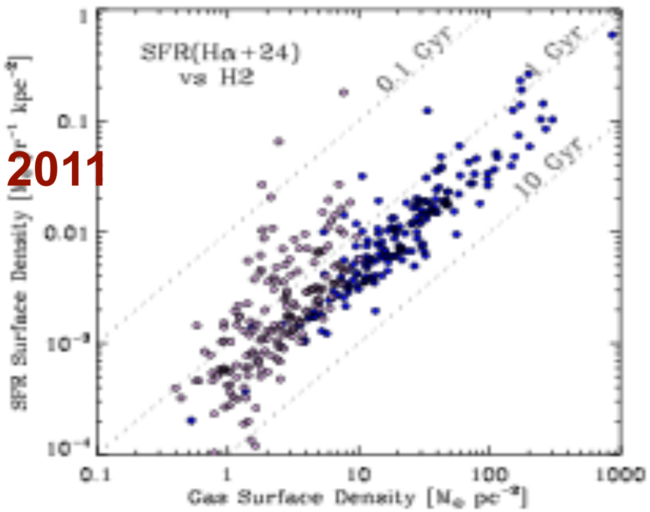


SFR vs. molecular gas





Schruba et al. 2011



Outlook

- Additional degree of freedom:
  kinetic/turbulent subgrid scale energy
  – important for (self–) regulation of star formation
  – important for support of disk against gravity

- 1–2 Gyr run
- Explore effects of turbulence production efficiencies
- Explore effects of different SFR – models
- Analysis: H_2 –, HI distributions, surface density relations, radial and height dependencies, star formation histories, turbulence statistics, SF regulation, gravitational support...