Positive and negative feedback by AGN jets

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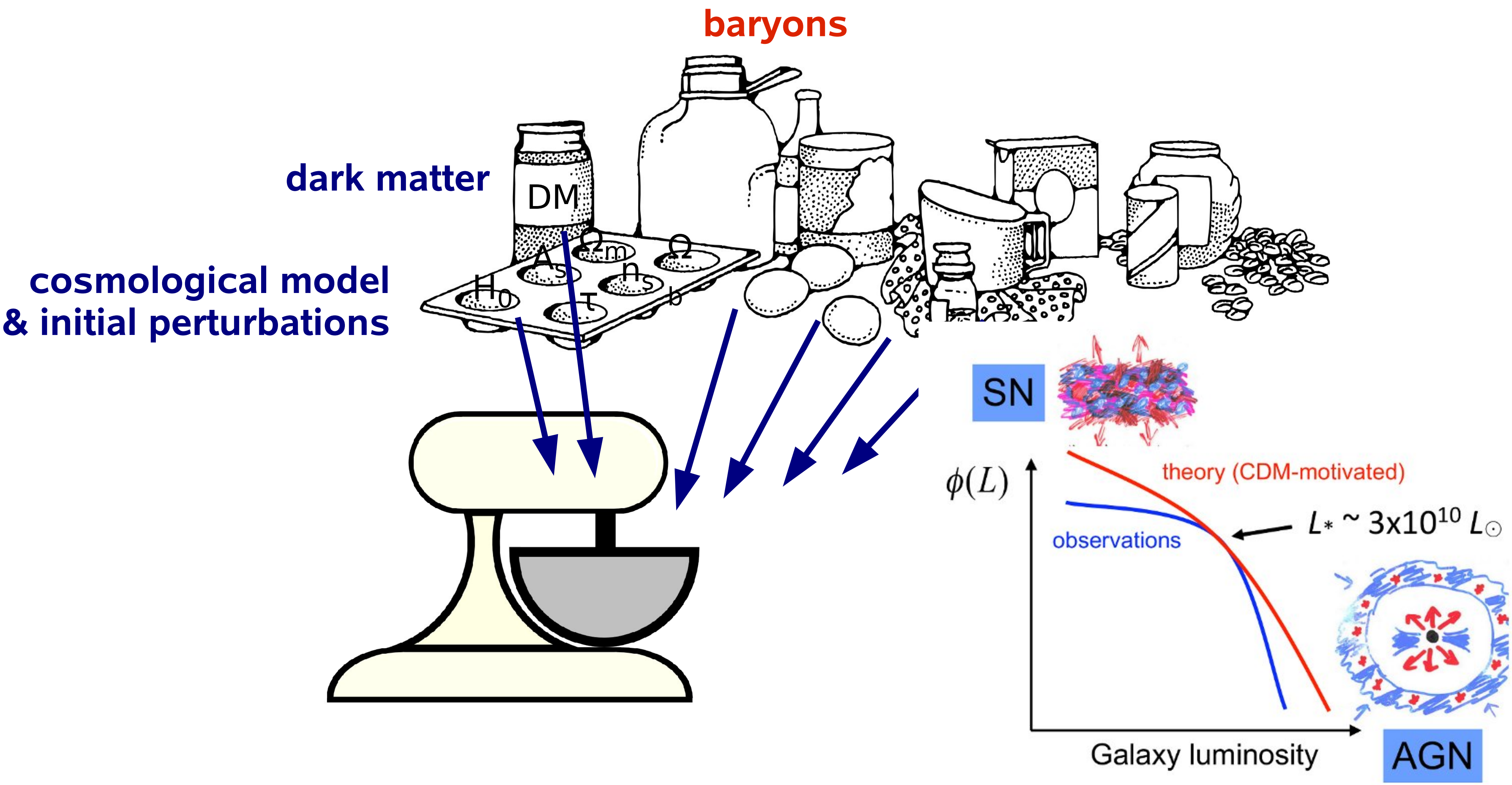
SPP 1177

Baking a galaxy...

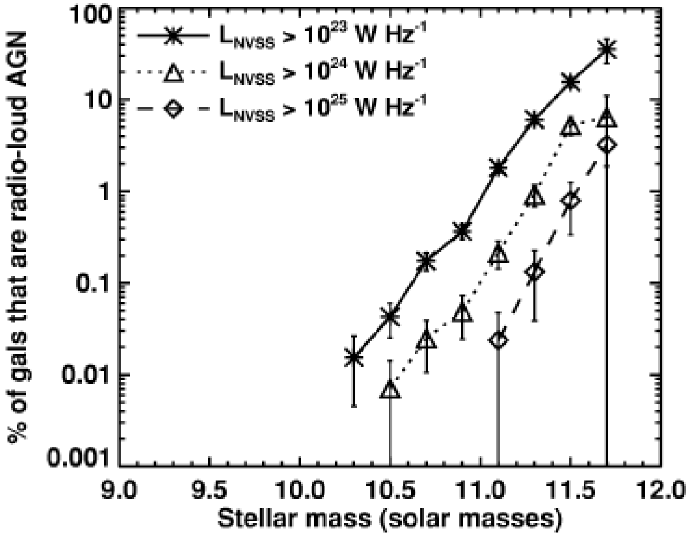


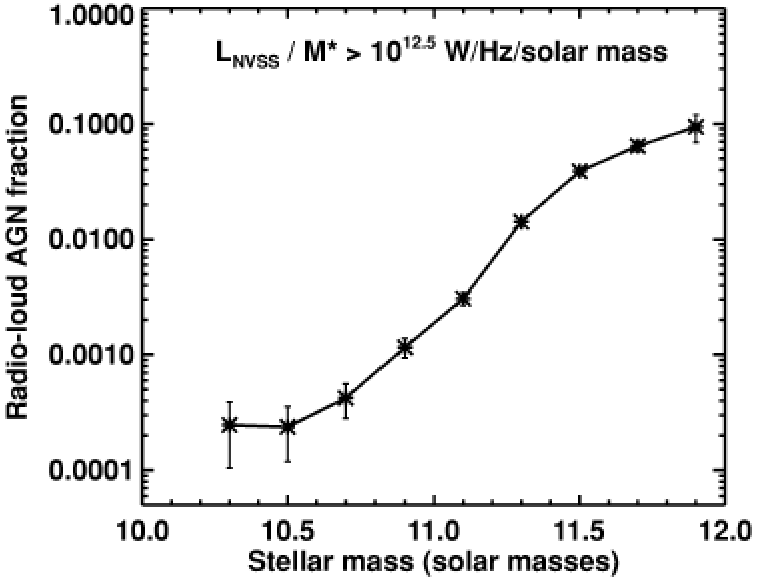
Silk & Mamon 2012

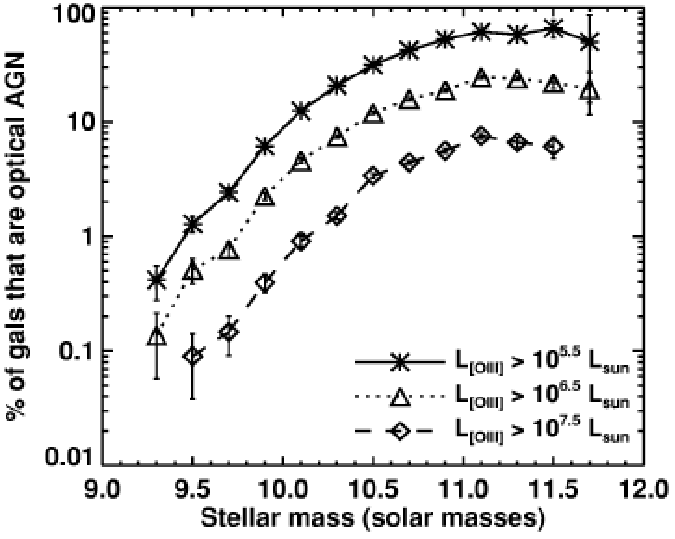
The baryon nuisance

- AGN / jet activity in massive galaxies is quite common
  (> 30% for high-mass bin, Best+ 2005)

  → natural suspect additional processes
  (SN too weak)







The baryon nuisance

- **Idea:**
  energy input from black hole activity quenches
  star formation (cold gas heated, disrupted, expelled, ...)
  → negative feedback

- reasonable model, though somewhat ad-hoc

- 100 kpc scales in galaxy clusters:
  AGN jets can probably regulate the cooling flows,
  negative feedback works there

Rafferty+ 2008,
Birzan+ 2012
Zanni+ 2005,
Gaibler+ 2009

- Works well in semi-analytic models and cosmological hydro simulations – now a common ingredient

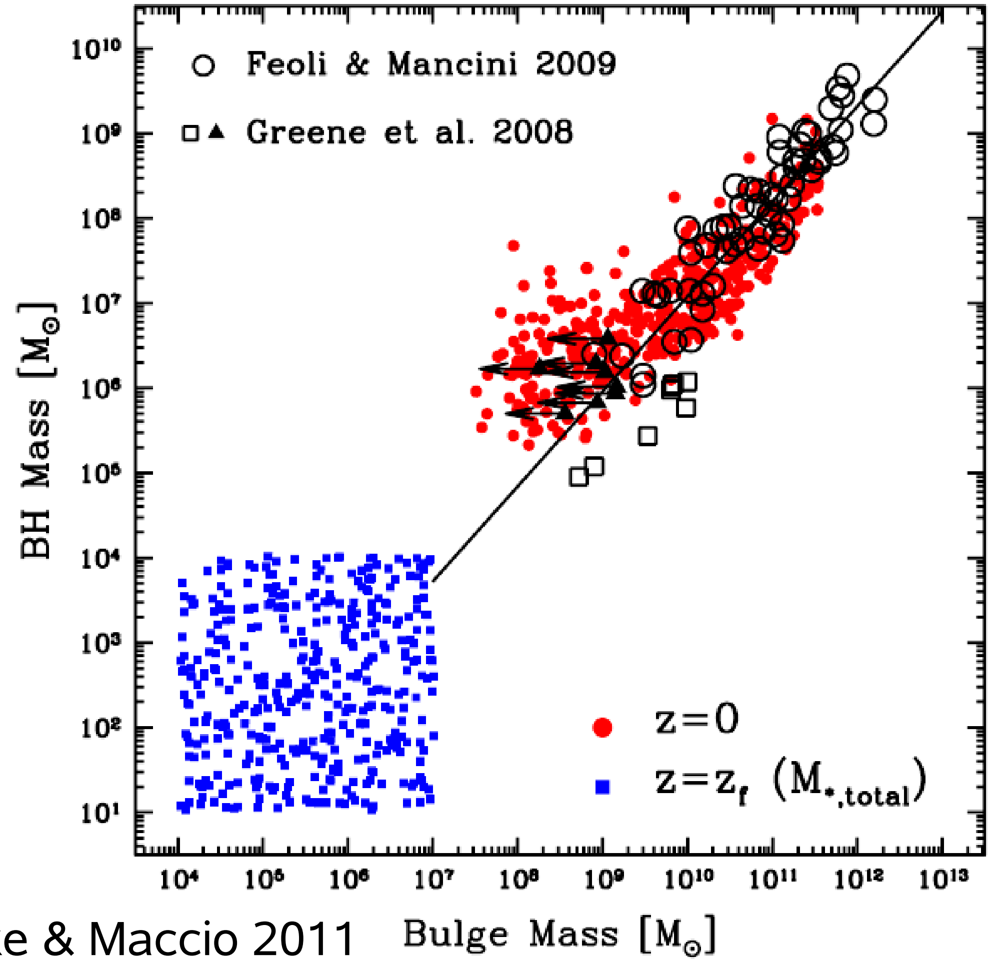
e.g. Croton+ 2006; Di Matteo+ 2005, Sijacki+ 2007, McCarthy+ 2010, Dubois+ 2013

M_{BH} – sigma and M_{BH} - M

- Observed: link between black hole and spheroid mass or velocity dispersion

- → Coevolution of black hole and the spheroid stellar component
→ AGN feedback?

- Maybe, but might be also just statistics....
Jahnke & Maccio 2011



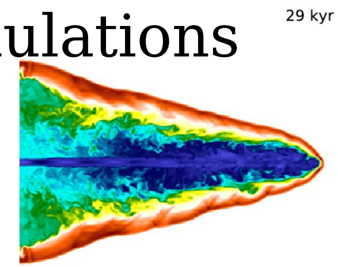
Jahnke & Maccio 2011

Positive feedback

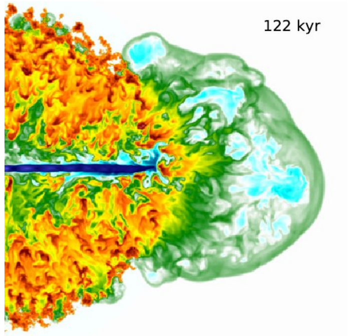
- However, AGN feedback could also lead to increased star formation via compression of gas
→ positive feedback

Silk 2005

- Interstellar medium: multi-phase medium densities, temperatures, clumpy and filamentary (unlike intra-cluster medium)
→ cannot be sufficiently described in large-scale simulations
→ wishful thinking???

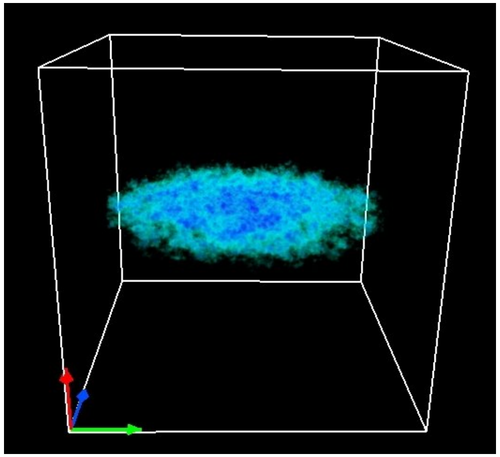


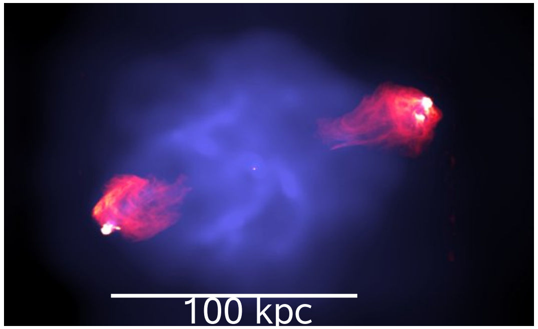
→ back one step and explore how this interaction actually occurs in detail (theory & observations)!



Sutherland & Bicknell 2007, Wagner & Bicknell 2011

Simulating jet feedback





Cyg A
Wilson+,
Perley+

galaxy:
- massive and gas-rich galaxy at z ~ 2-3, 10^{11} solar masses both stars & gas, ~ 150 M_s/yr (e.g. Genzel+ 2010)
- explicitly including *star formation*
- clumpy disk structure, thick disk
- optically thin cooling
- minimum temperature 10^4 K
- RAMSES, adaptive mesh refinement
- 128 kpc box, 62 pc resolution

jet:
- powerful jet (5 x 10^{45} erg/s)
- mildly relativistic (0.8 c)

→ resolved jet beam
→ tiny time steps

details:
VG, Krause, Khochfar, Silk 2012

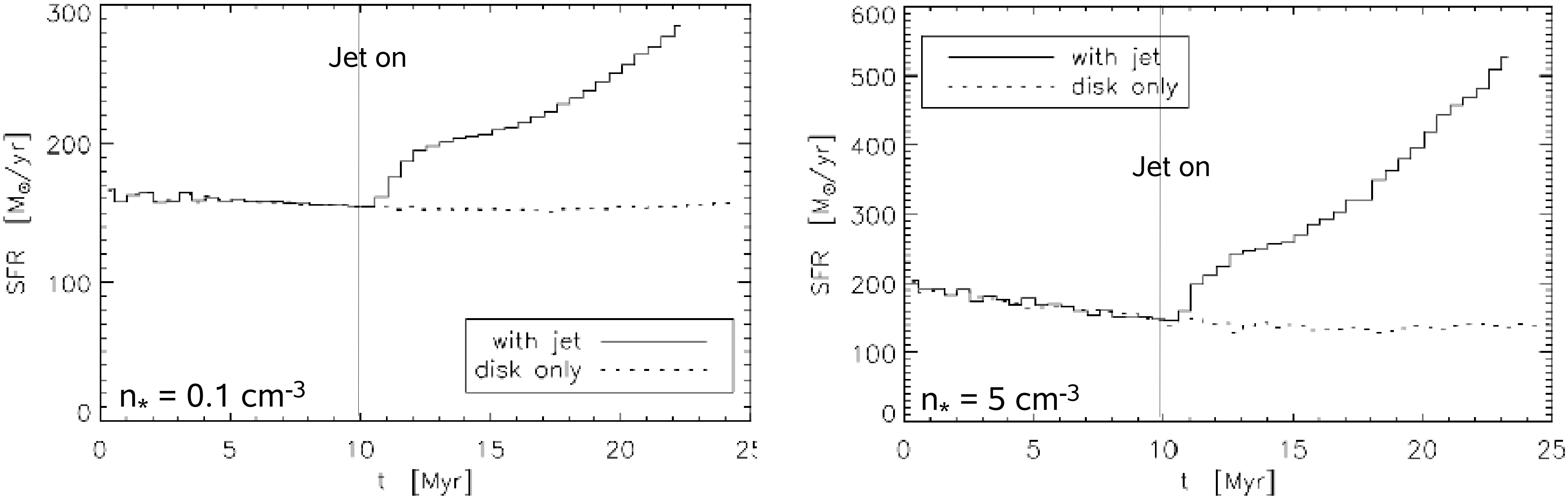
Disk evolution rendering

movies:

jet – disk interaction:
http://www.ita.uni-heidelberg.de/~vgaibler/jet-disk/

jet – disk interaction including star formation:
http://www.ita.uni-heidelberg.de/~vgaibler/jet-disk-sf/

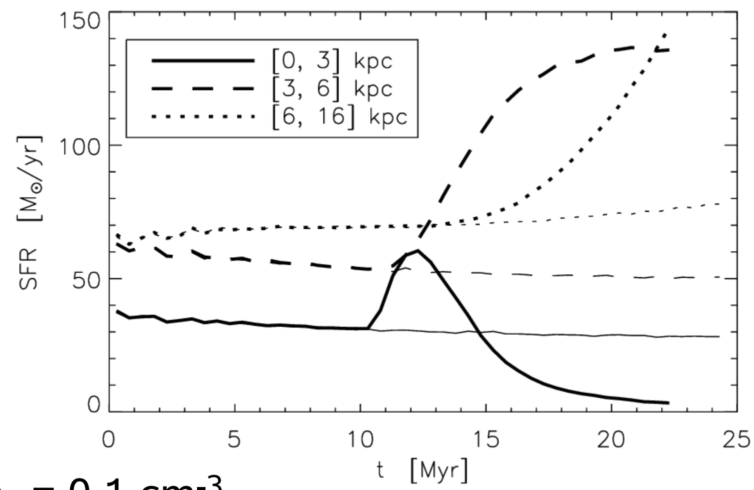
Star formation



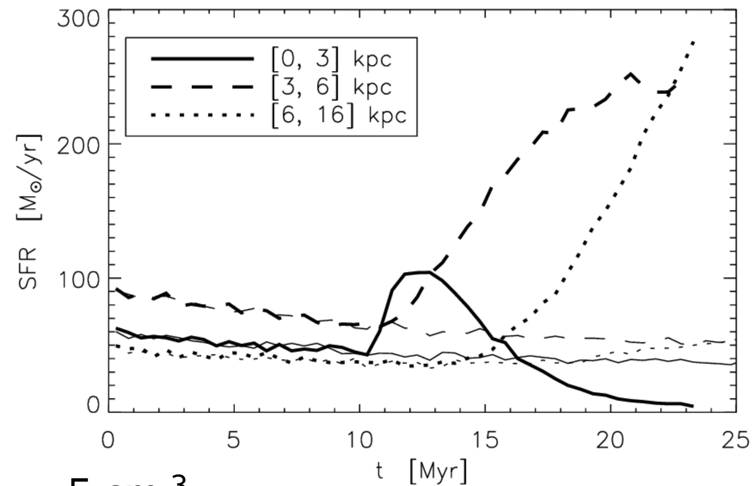
- strong increase in star formation rate: positive feedback
- filling factor of dense gas increases
- cloud survival/destruction:
  - Mellema+ 2002: shocked coulds break up but survive, Jeans-unstable → collapse
  - cloud crushing time and Kelvin-Helmholtz growth time ok

The "3 Faces" of Feedback

- Three aspects of feedback found:
  - Negative in central cavity region
    (gas removal)
    mass drops to ~ 50 %
    (remainder is in dense filaments)
  - Positive in cavity rim
    (ring-like shock/compression region)
    Mellema+ 2002
  - Positive at large scales
    (disk embedded in an
    overpressured cocoon,
    thermal and backflow ram pressure)
    - despite ablation!

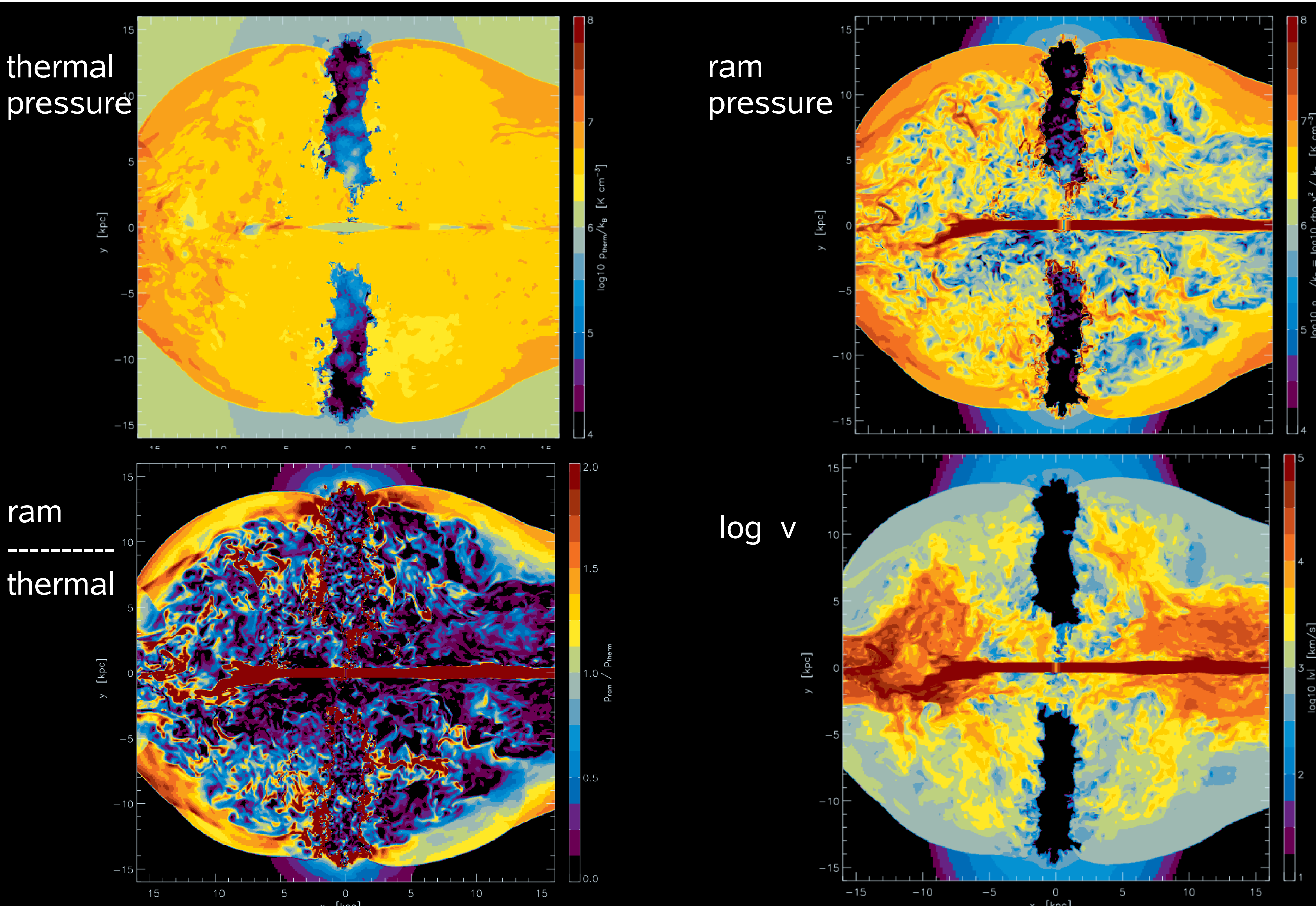


$n_* = 0.1\ cm^{-3}$

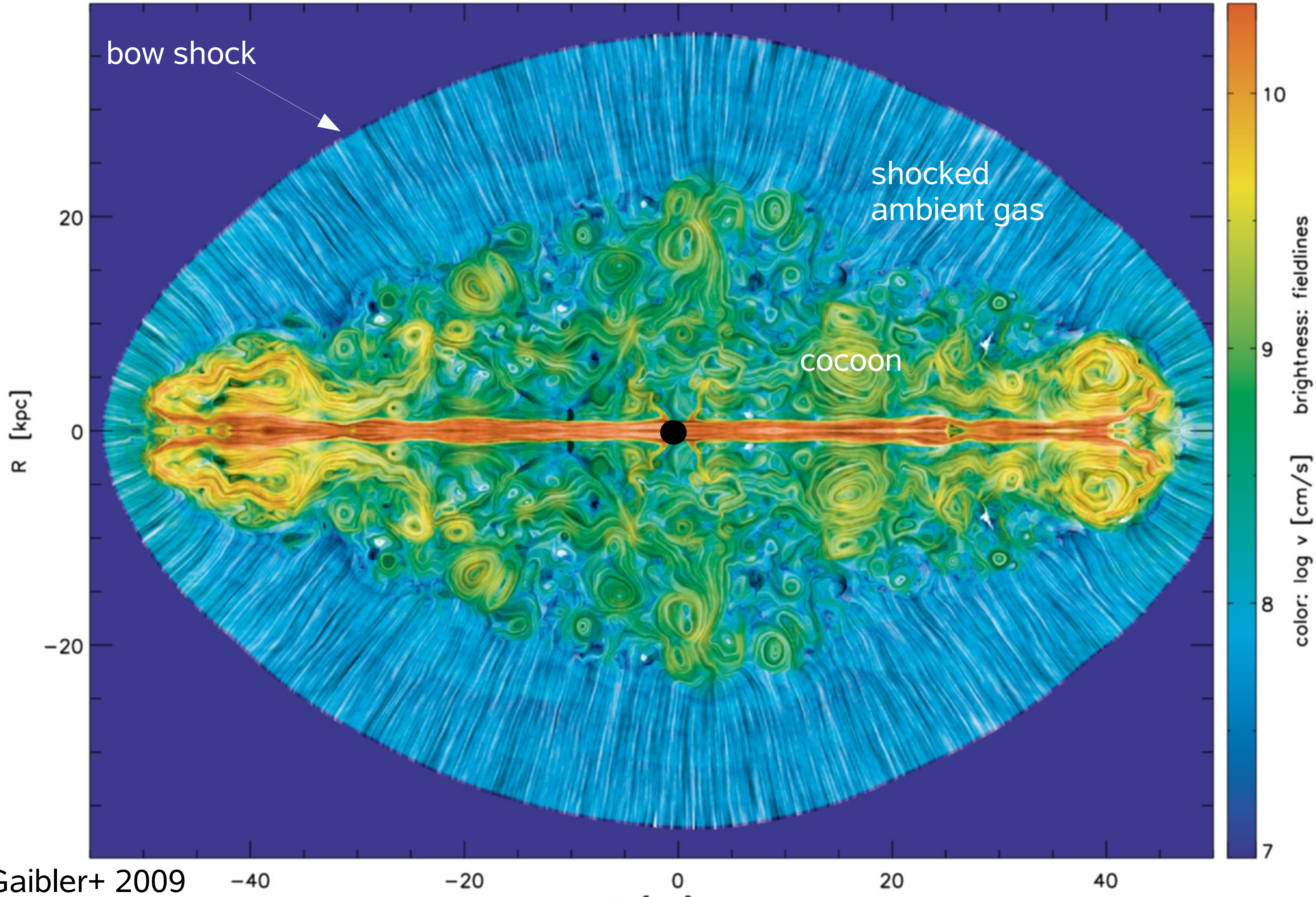


$n_* = 5\ cm^{-3}$

Cocoon dynamics



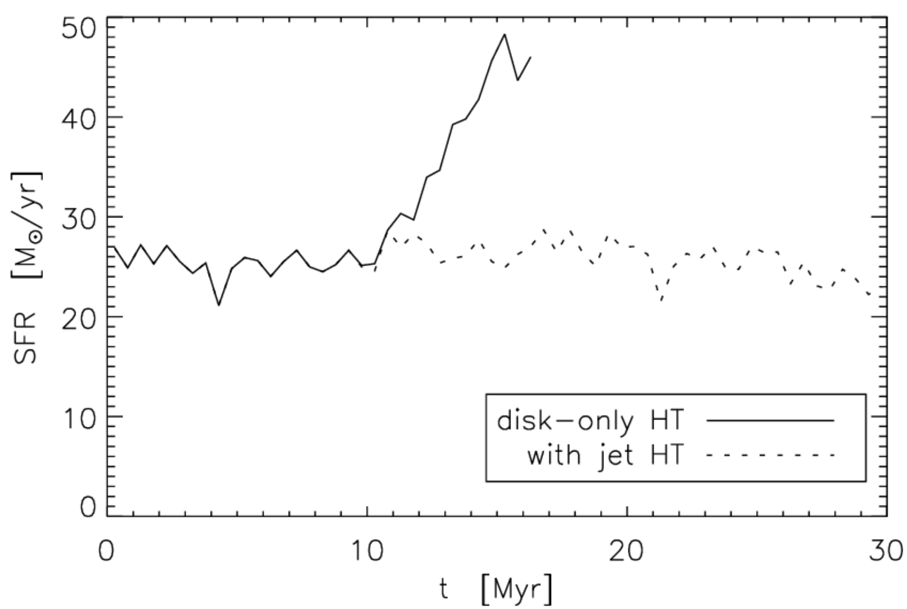
Cocoon dynamics



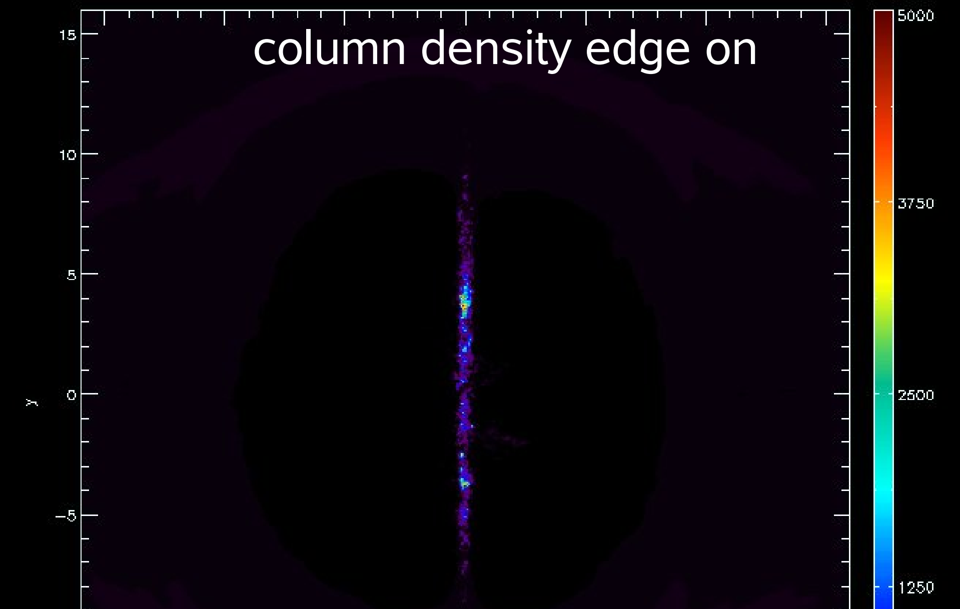
Gaibler+ 2009

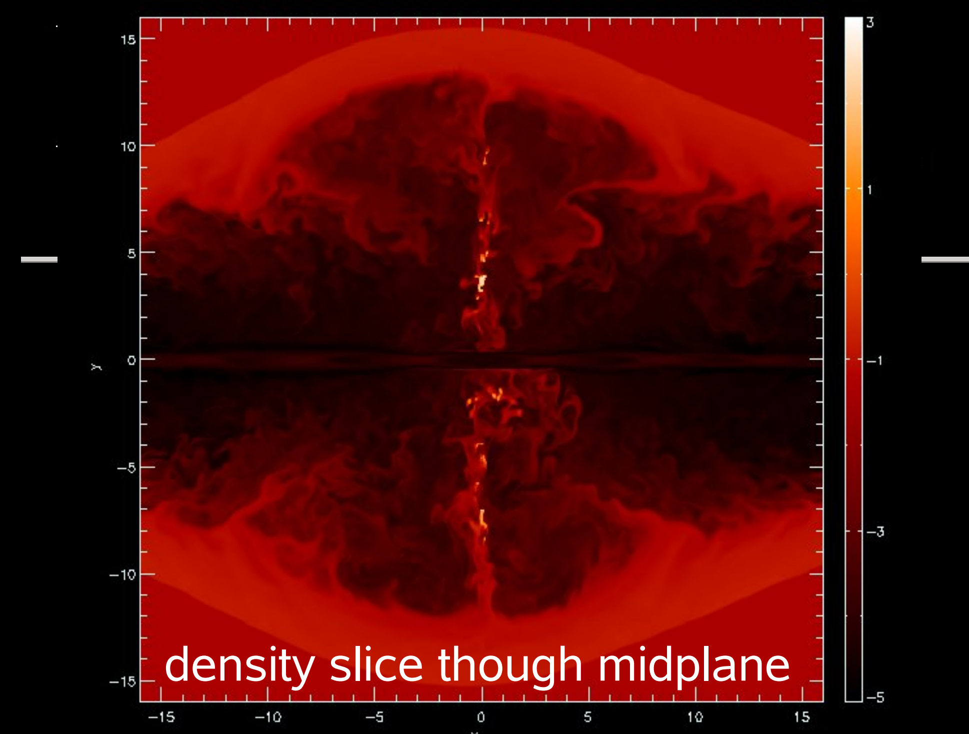
Lower gas mass, thinner disk

much thinner disk (300 pc)
smaller filling factor
gas mass is 20 x smaller



--- preliminary ---





Observational results / 1

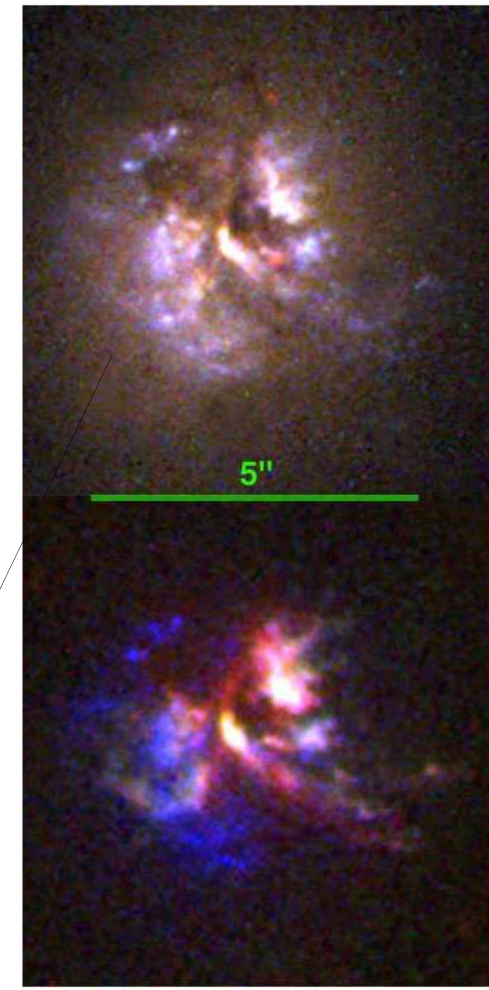
- Low redshift:
  only few, due to low gas masses?

  Minkowski's object (Croft+ 2006),
  Cen A (Mould+ 2000, Morganti 2010)
  Cygnus A: ring of young stars
  (Jackson, Tadhunter, Sparks 1998)

- Higher redshift:

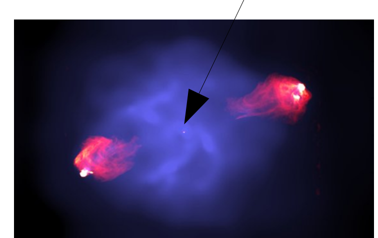
  PKS2250-41 (Inskip+ 2008, z = 0.3),
  4C 41.17 (Dey+ 1997, Bicknell 2000, z = 3.8)

Blue: B, green: F622W, red: F814W



Blue: B, green: [OIII], red: Hα
Cyg A, R. Fosbury

radio+X-ray



Observational results / 2

- recent SF in >75% of compact radio sources (Dicken+ 2012, $0.05 < z < 0.7$, < 15 kpc)
- young stellar populations in $z < 0.7$ radio galaxies (Tadhunter+ 2002, Wills+ 2002, Baldi & Capetti 2008, Tadhunter+ 2011,
  in central regions: Aretxaga+ 2001)
- Holt+2007: ~30 % of local radio galaxies have YSP detected
  find considerable UV excess due to
  YSP, not only nuclear activity,
  50 % have ages < 0.1 Gyr,
  make 1-35 % of mass

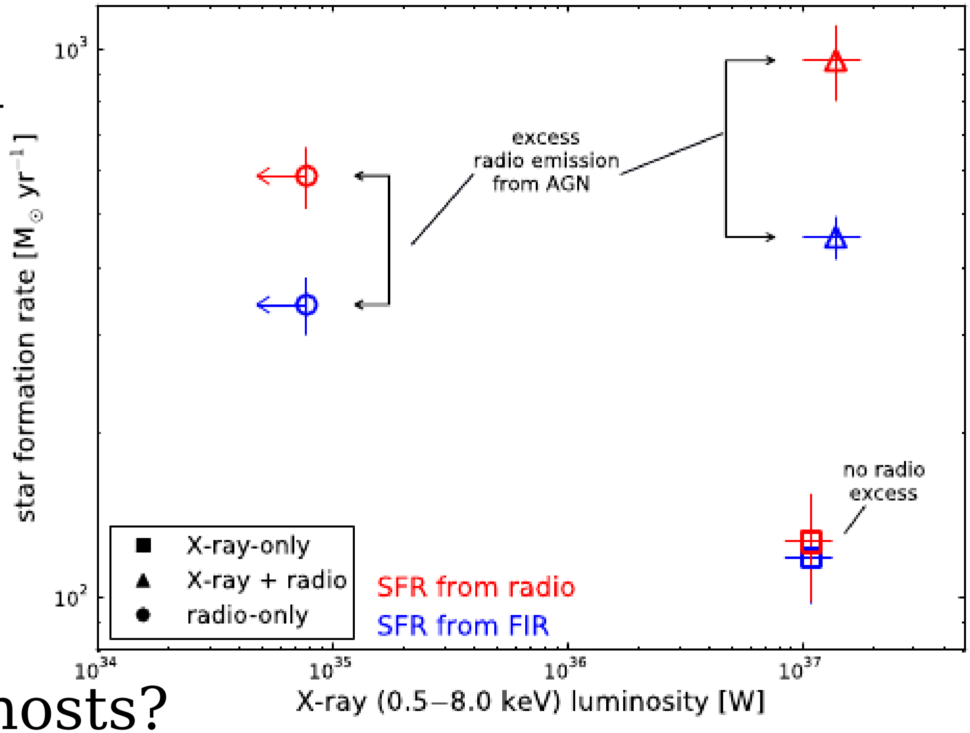
Observational results / 3

- Rovilos+ 2012:
  star formation correlates with
  AGN activity (z = 0.5 … 4)

- Zinn+ 2013:
  >200 radio/X-ray AGN stacked,
  redshifts z = 0 … 4 (avg. 2)

  star formation rates from FIR
  with Herschel
  not contaminated by AGN

  → radio power makes the
  difference in SFR, not X-ray

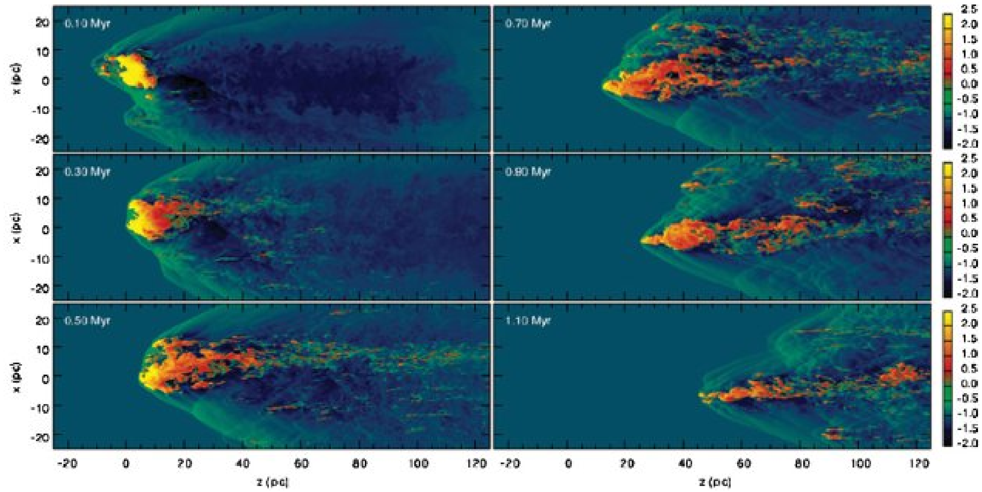


- increase in SFR,
  what about sSFR?
  Systematicaly more massive hosts?

Stability of the star-forming clouds

- Mellema et al. 2002:
  shocked cloud breaks up, small and dense fragment survive long due to strong cooling, Jeans-unstable, SF induced

- Cooper et al. 2009:
  cloud in by starburst-driven galactic wind, cools and fragments to ~pc sized clouds



Cooper+ 2009

- *Estimates from our sims,*
  100 pc cloud radius,
  100 m_p/cm^3 fiducial:

- cloud crushing time:
  $t_{crush} = R_c / v_{sh} > 10^8$ yr

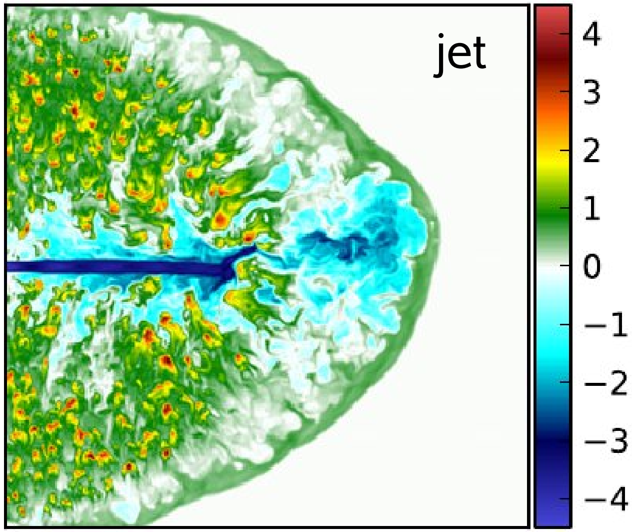
- KH growth time in our sim:
  $t_{KH} \sim 10^5 - 10^6$ yr

self-gravity stabilizes,

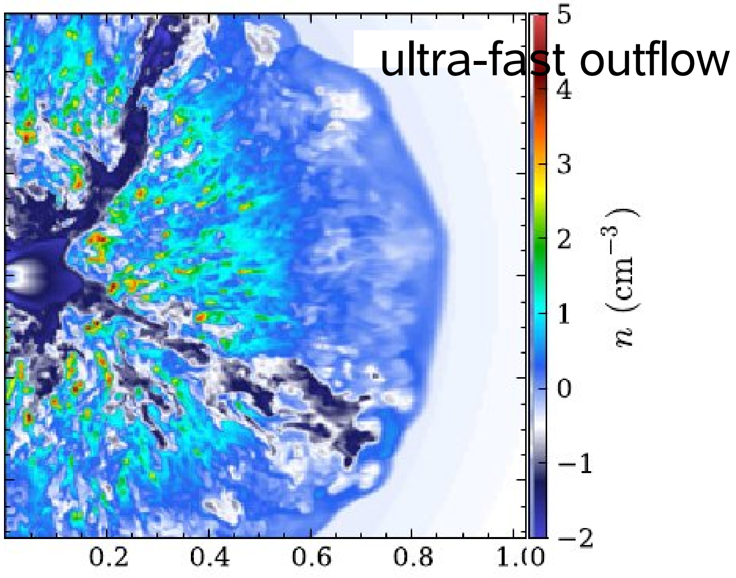
KH time increased by magnetic fields, less ablation?

Quasar feedback

- So far: jet feedback (collimated beam as driver, mechanical) high-power FR II vs. low-power FR I (more common)
- Quasar
  - radiation feedback (ionization, heating)
  - mechanical feedback via radiation-driven winds, BAL quasars, ultra-fast outflows (see Alex' talk)



Wagner & Bicknell 2011



Wagner et al. 2013

Quasar feedback

- Only jet feedback simulated so far –
  quasar feedback might be negative, but beware:
  - significant fraction might go into heating
    → blastwave → similar result as for jets
  - presence of dusty torus limits the opening angle considerably, not easy to affect much of the gaseous disk (misalignment vs solid angle affected)

Summary

- Clumpy multi-phase structure of ISM is important:
  Complex interaction of the jet with the clouds
  Need more physical models for jet feedback!
- Negative feedback not so easy at galaxy scales
- Positive feedback is efficient via blastwave formation
  increasing observational evidence
- Impact for galaxy evolution so far uncertain
  - long-term effects?
  - interaction / survival of self-gravitating clumps
  - more physical models necessary