The manifold nature of AGN feedback

from 3D simulations

Salvo Cielo - IAP, Paris

J. Silk (IAP)
M. Volonteri (IAP)
A. Babul (UVIC)
V. Antonuccio-Delogu (INAF)

R. Bieri (MPA)
A. Wagner (CSS, IAP)
Y. Dubois (IAP)

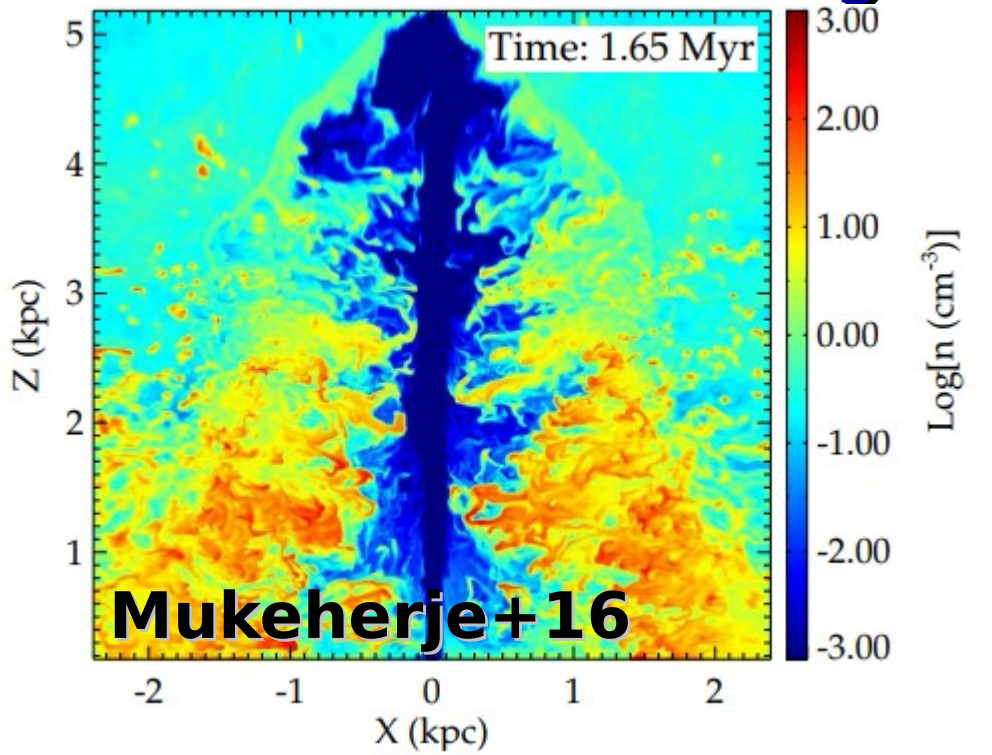
AGN Feedback

Radio mode:
mechanical VS hot gas

Chandra's Perseus cluster (e.g. Fabian12)

Radio Galaxy Cyg A (nasa.gov)

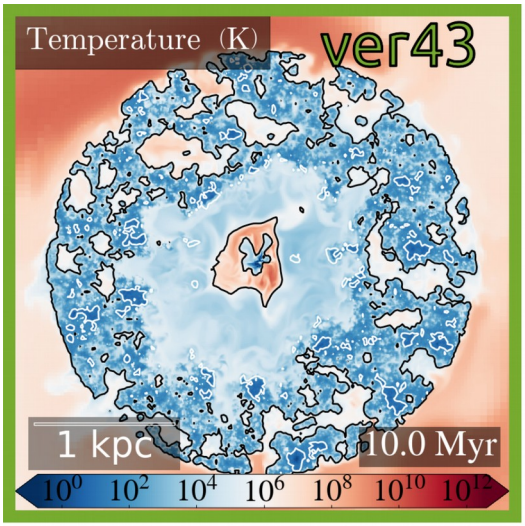
Quasar mode:
mech/rad VS cold gas

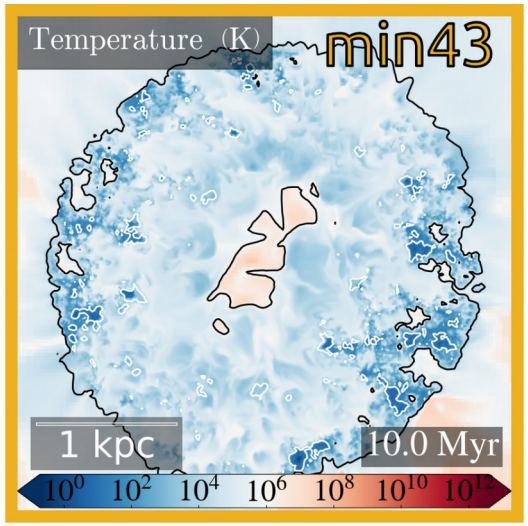


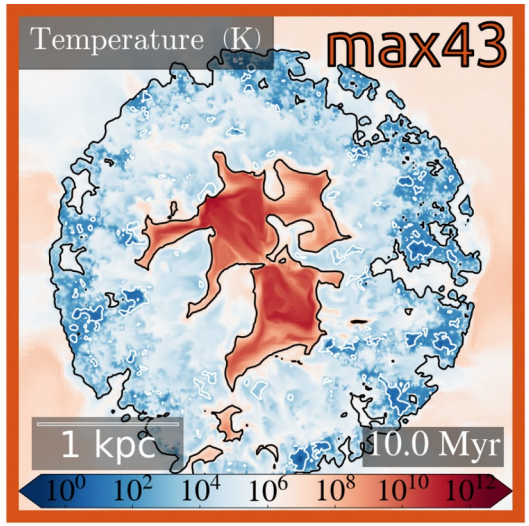
Mukeherje+16

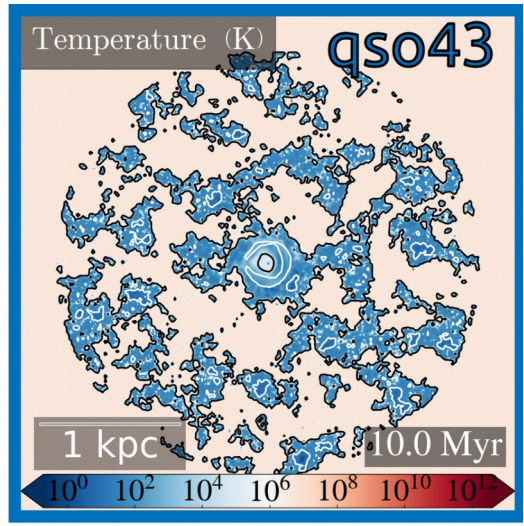
Artist's view of a QSO like APM 08279+5255 (nasa.gov)

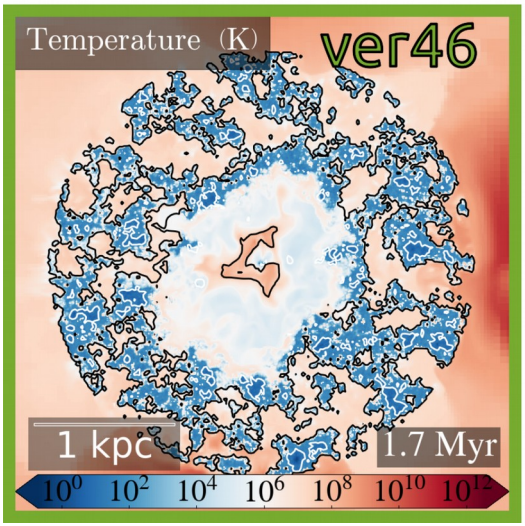
Quasar mode AGN in disc galaxy

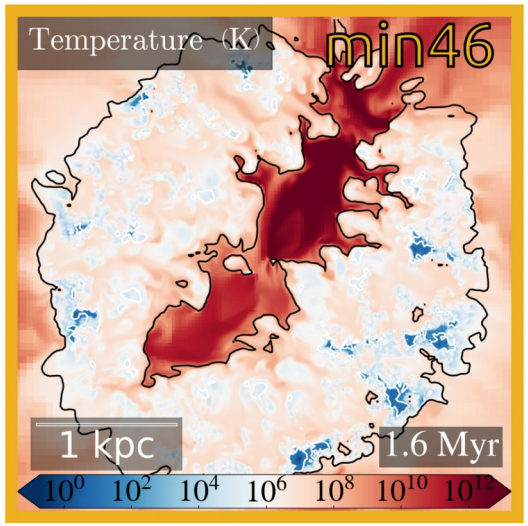


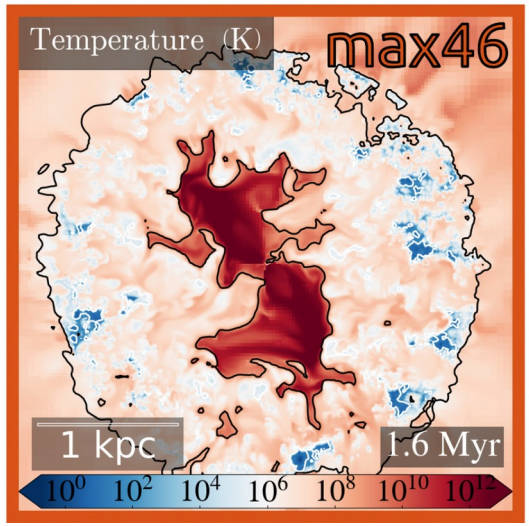


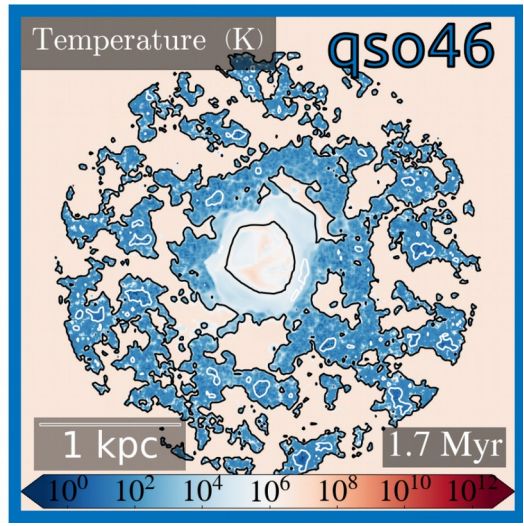












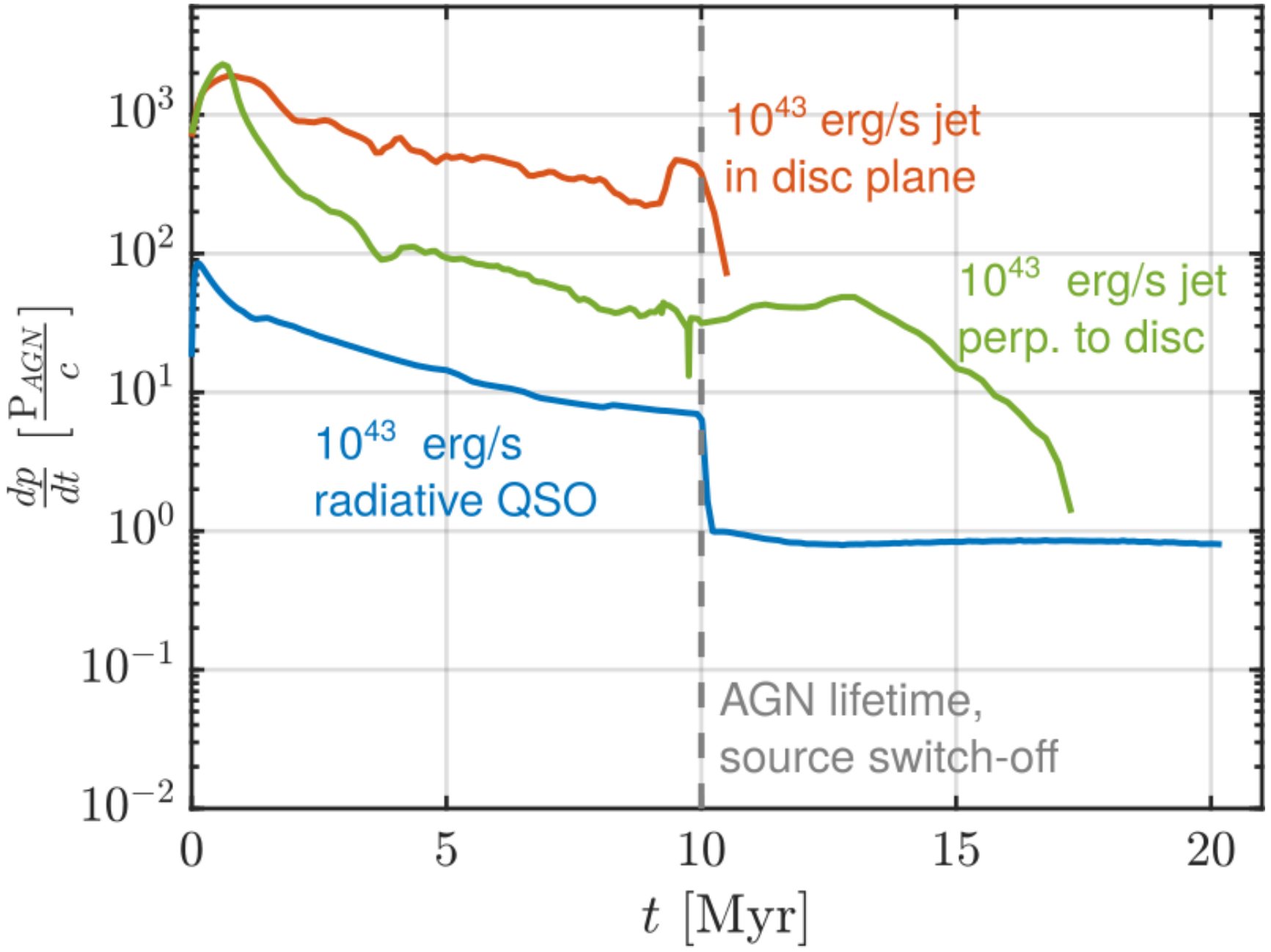
Jet along z-axis

Jet in z=0 min inertia

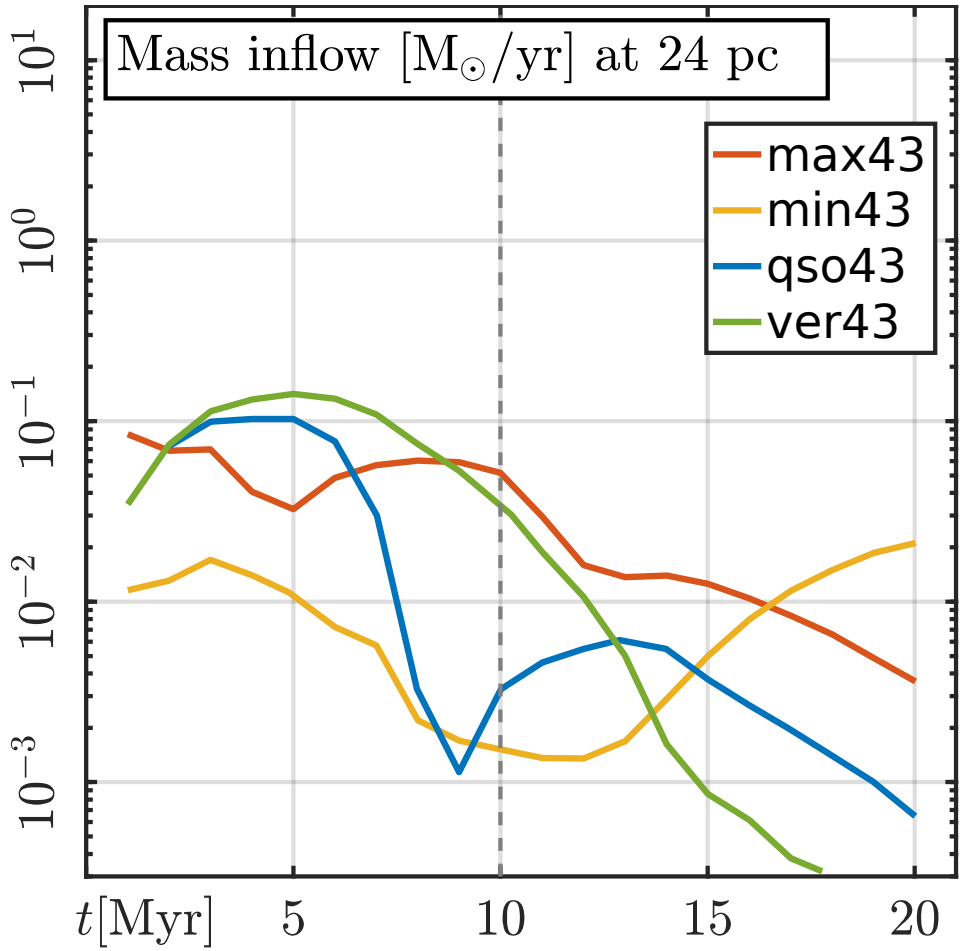
Jet in z=0 max inertia

Quasar, radiative

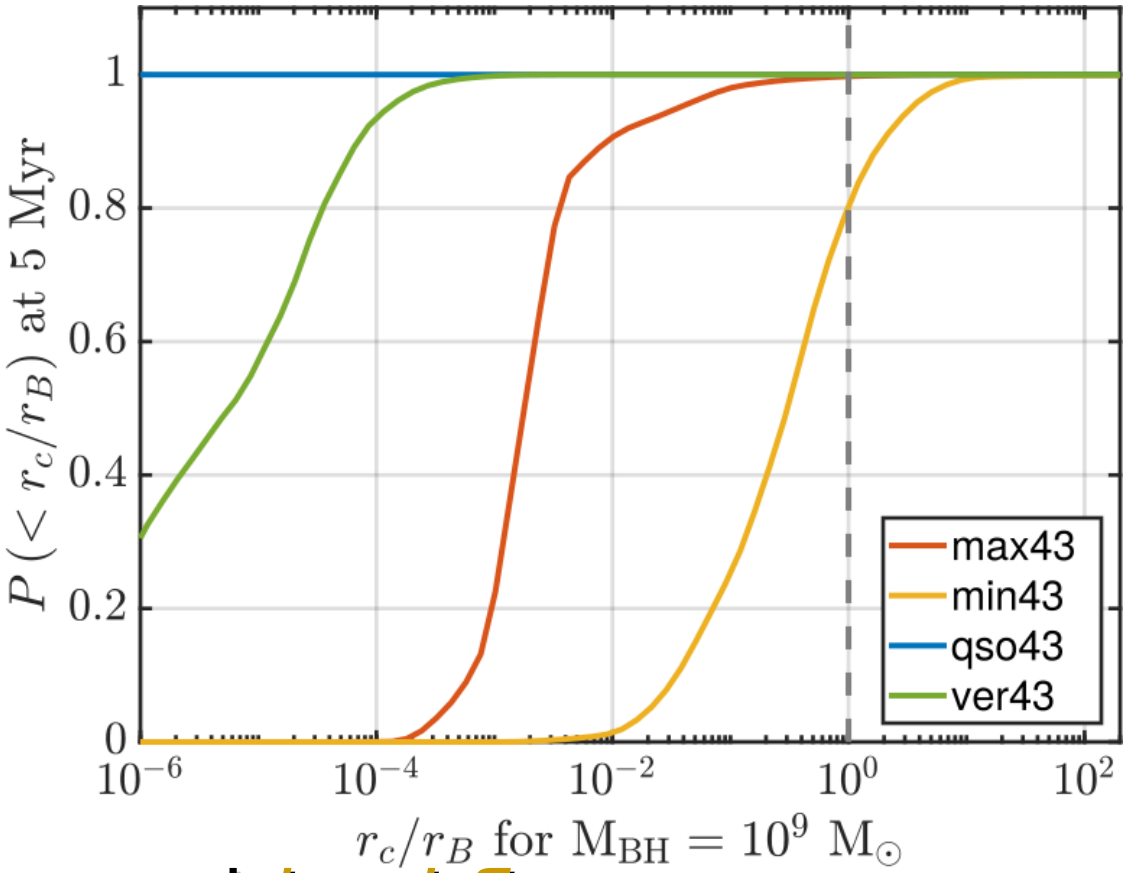
Quasar mode: outflow acceleration



Quasar mode: inflow/self-feeding



Well within BH Bondi radius



Inflows by reverse shocks and *backflows*

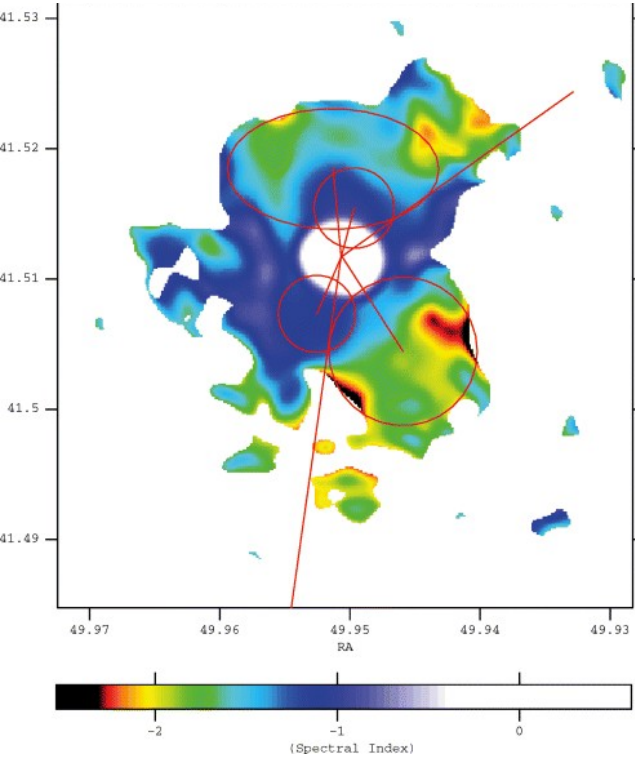
For 0.01 M_{sun}/yr → P_{AGN} ~ 0.1 dM/dt c^2 ~6x10^{43} erg/s

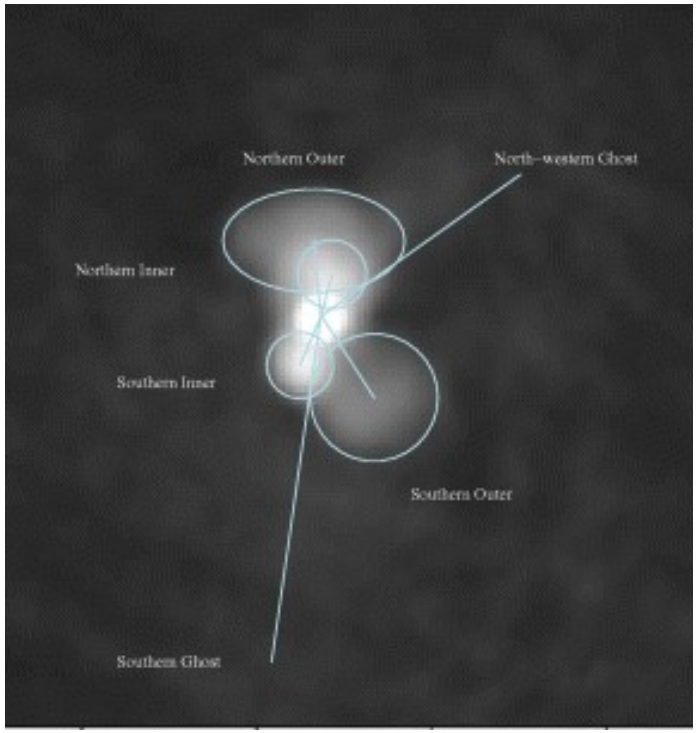
Conclusions - I

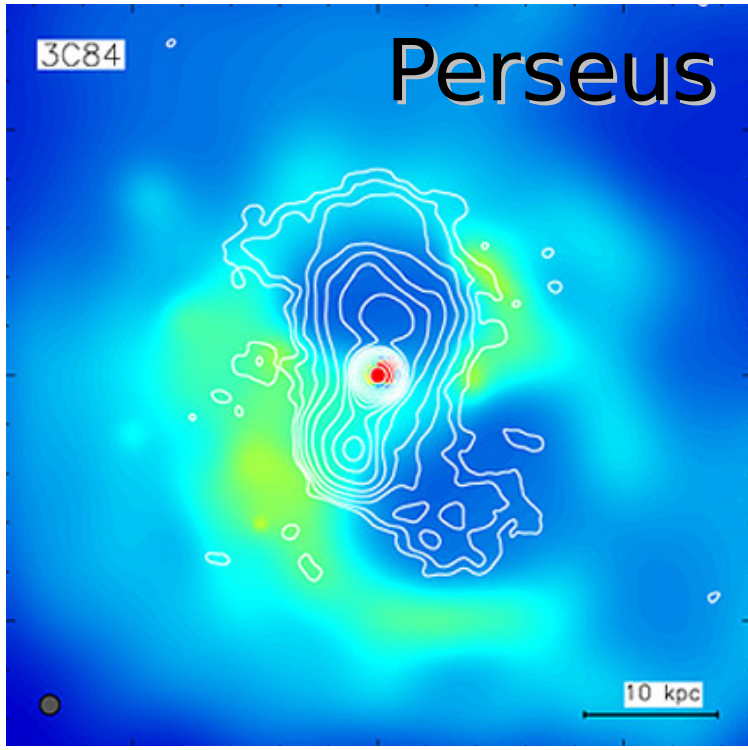
Quasar-mode AGN Feedback

- power fast outflows, especially jets
- Inflows significant for AGN self-regulation

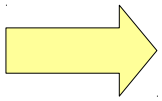
Radio mode AGN: cool-core clusters







Cooling ↔ feedback
is shaping **X-ray** gas

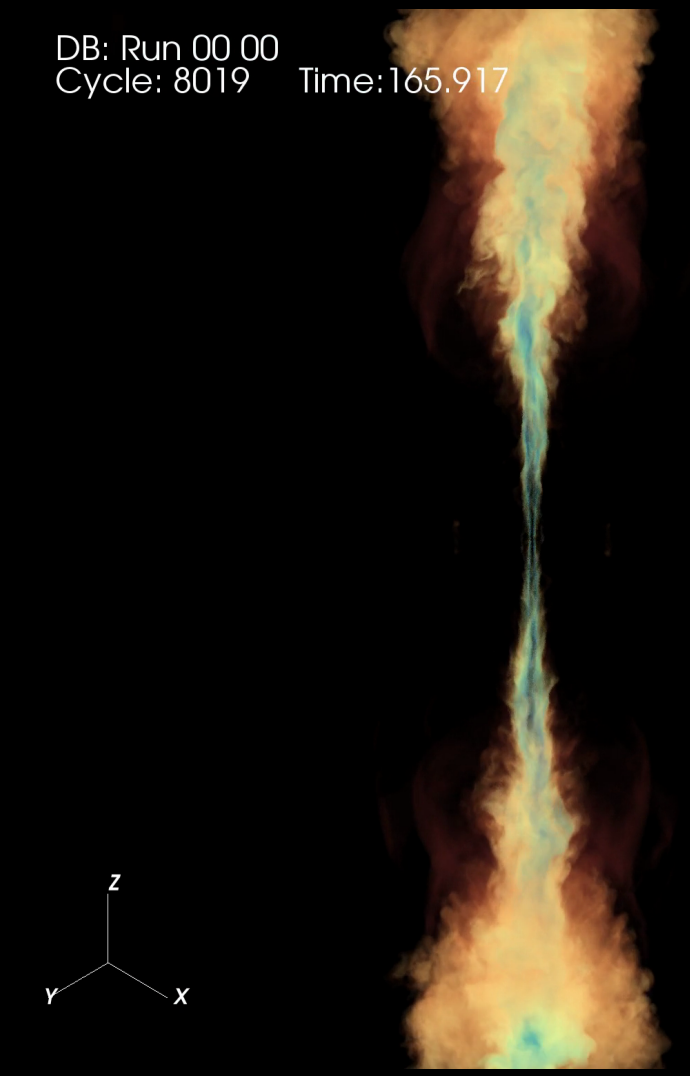


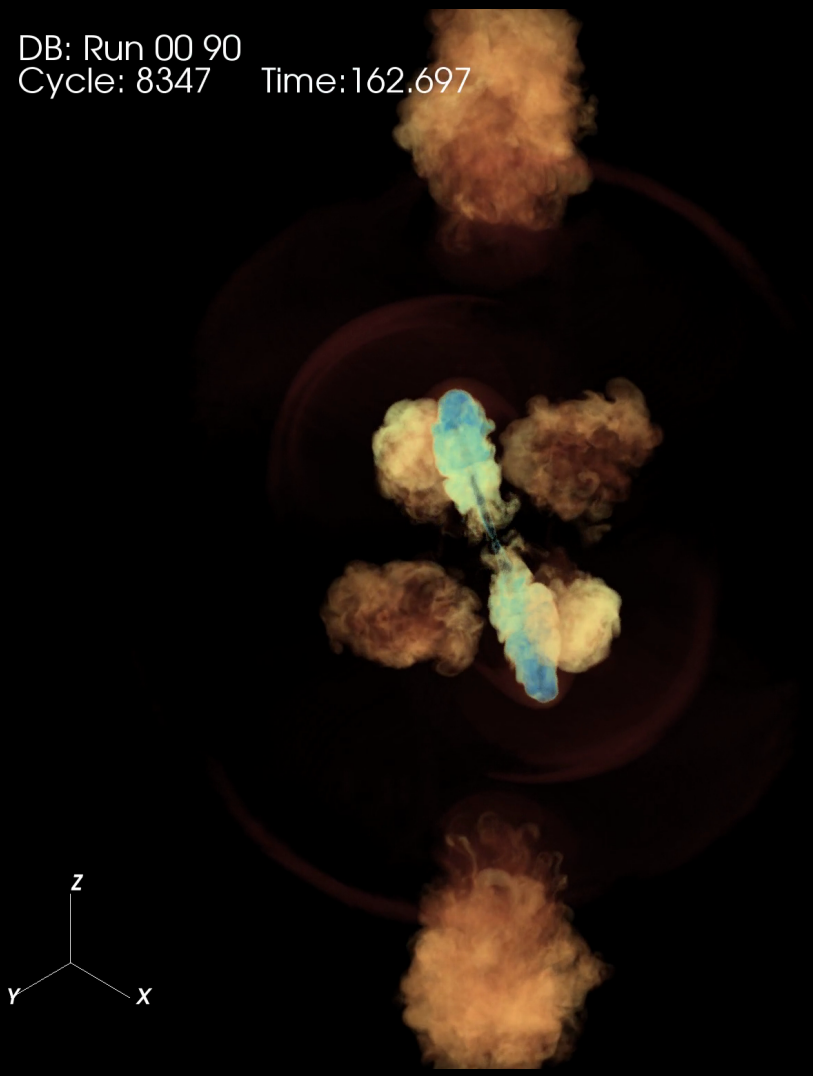
$t^0_{cool} \sim 3x10^8$ y →
~~SFR > 100 M_{sun}/y~~

Models show isotropy problems...
e.g. Vernaleo&Reynolds 2007

...but jets change direction in time!

Hydro sim. of re-orienting jets





Virgo-mass, 10^{45} erg/s, 2 Myr break

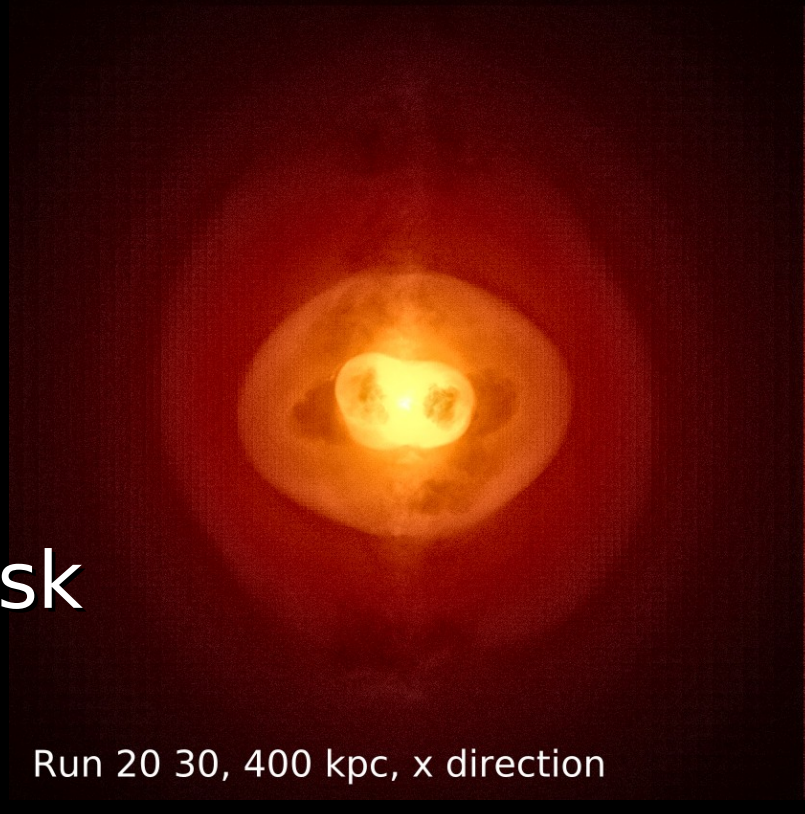
Soft X-ray cavities, bow-shocks

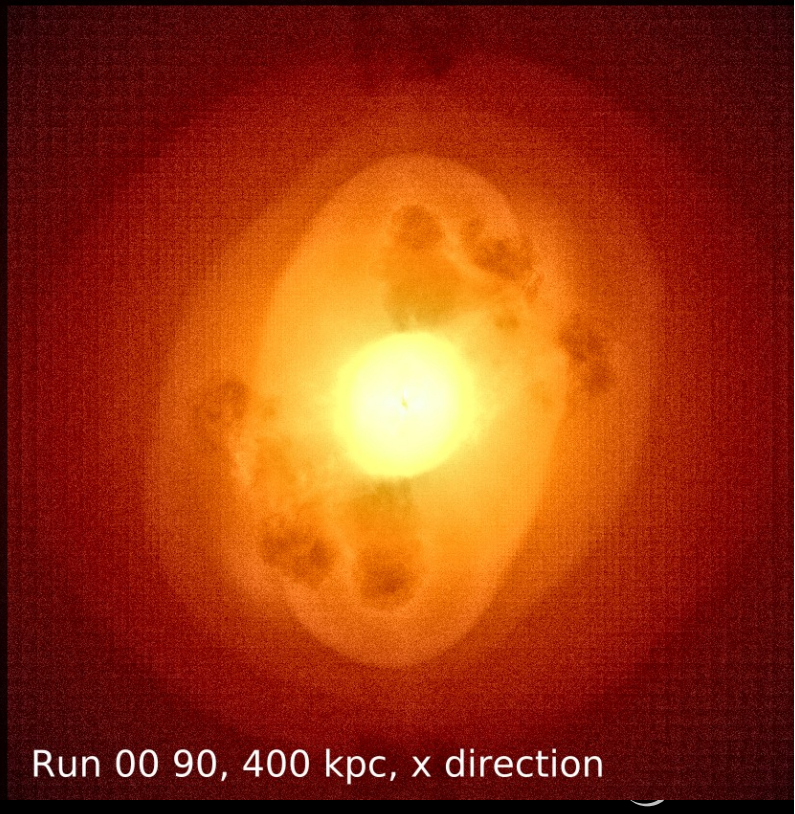
yt/pyXSIM
Biffi+13
Zuhone+14

~1 Ms @ z=0.02

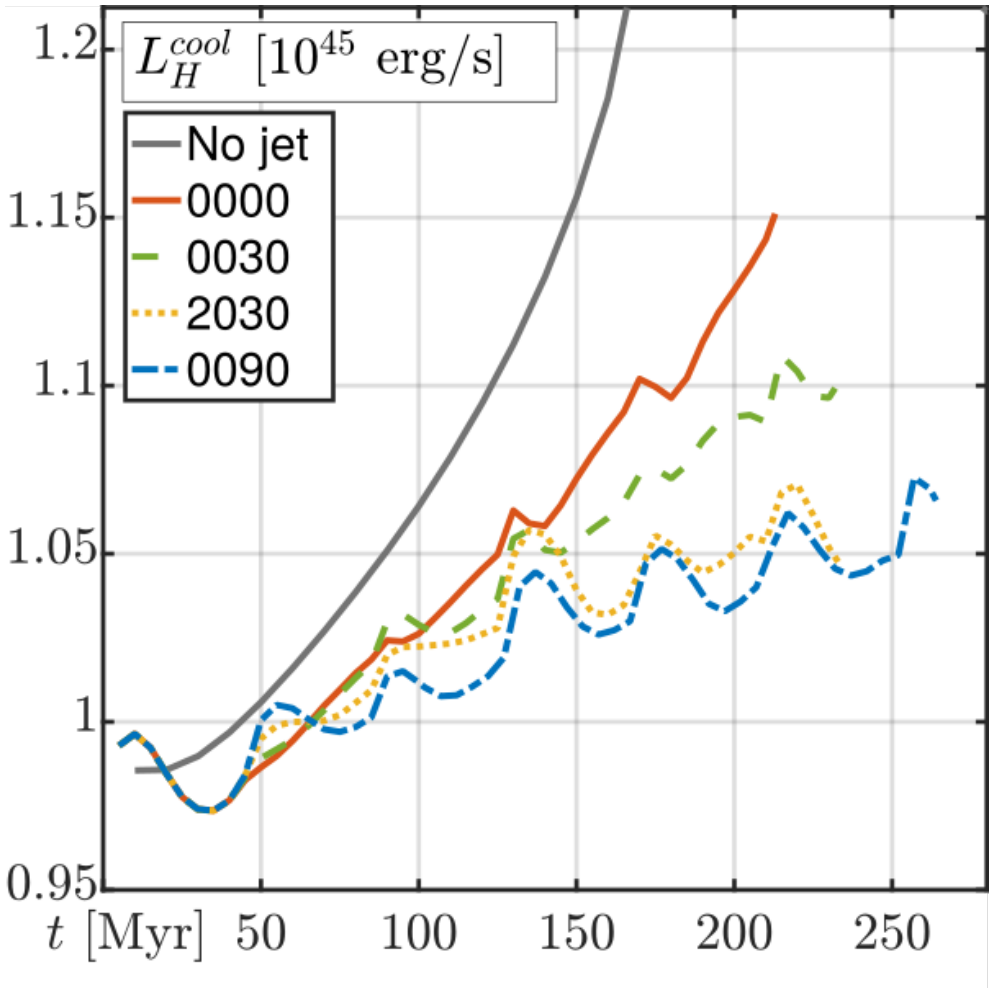
Chandra's ACIS-I

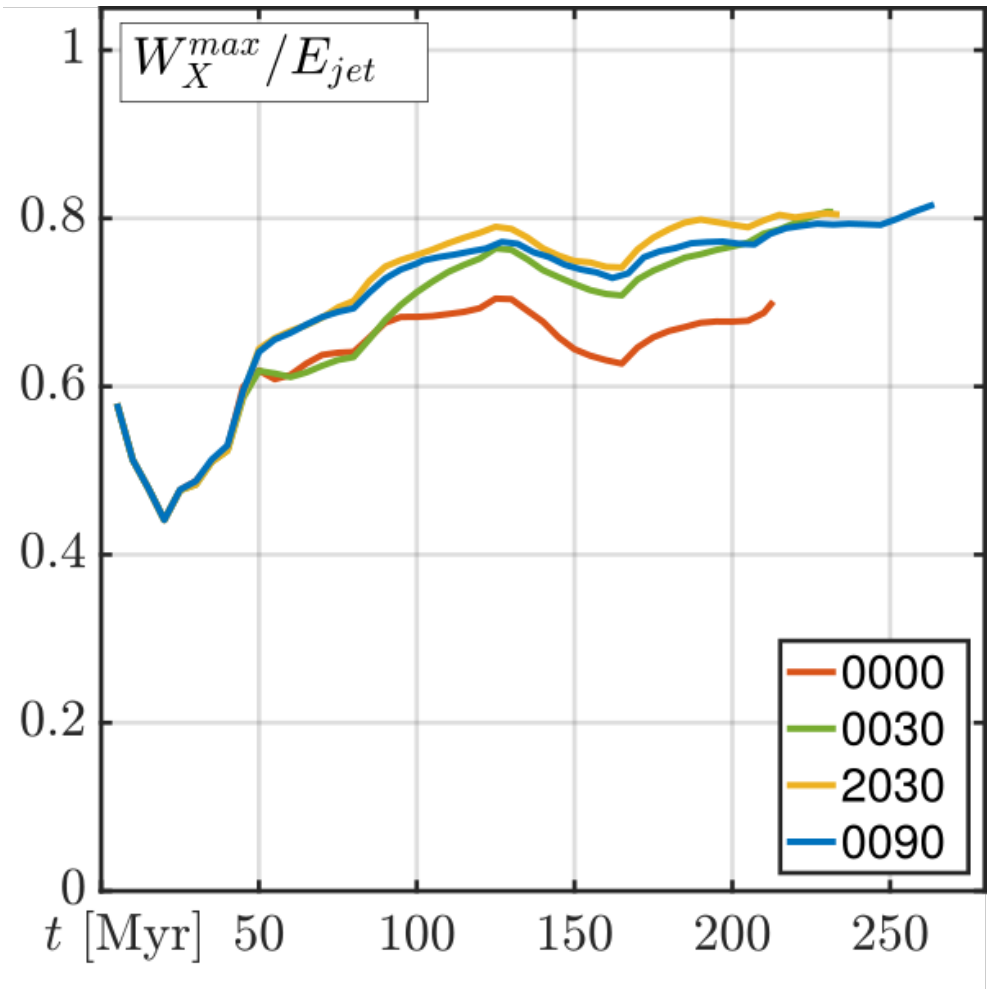
Unsharp-mask filtered





Stability: cooling and heating





Re-orienting jets limit cooling to observed values ...

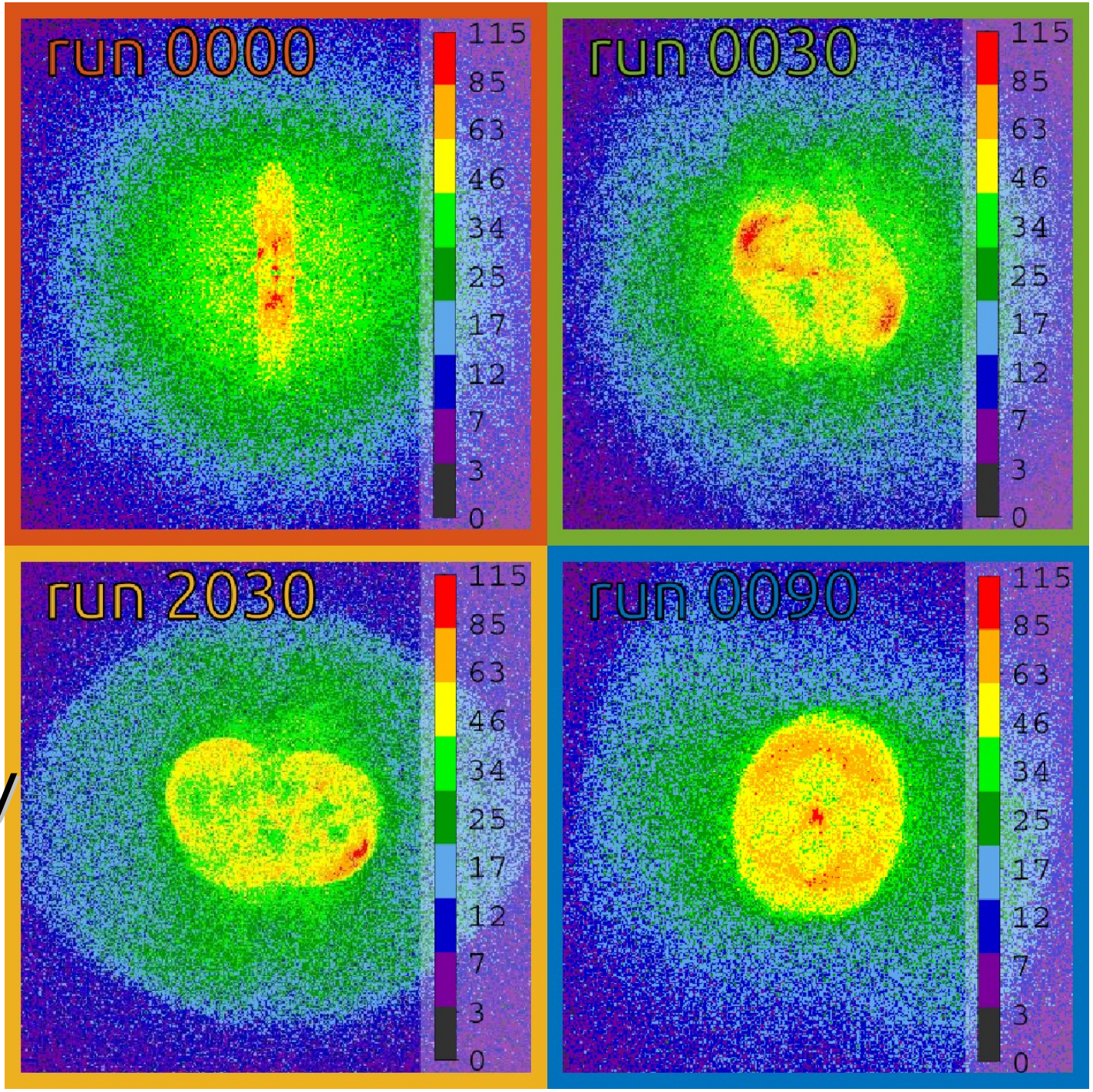
... and transfer more energy to the ICM.

Hard X-ray

200 kpc in
[10, 30] keV
(e.g. NuSTAR)

Hot Spot,
post-shock gas
jet beams

Complementary
view of the
cavities.



Conclusions - II

Quasar-mode AGN Feedback

- power fast outflows, especially jets
- Inflows significant for AGN self-regulation

Radio-Mode AGN Feedback

- Re-orientation of jets produces many realistic cavities features...
- ... and limits core cooling
- Hard X-ray show origin of shocked gas

Thank you!