UNIFYING THE MICRO AND MACRO PROPERTIES OF AGN FEEDING & FEEDBACK

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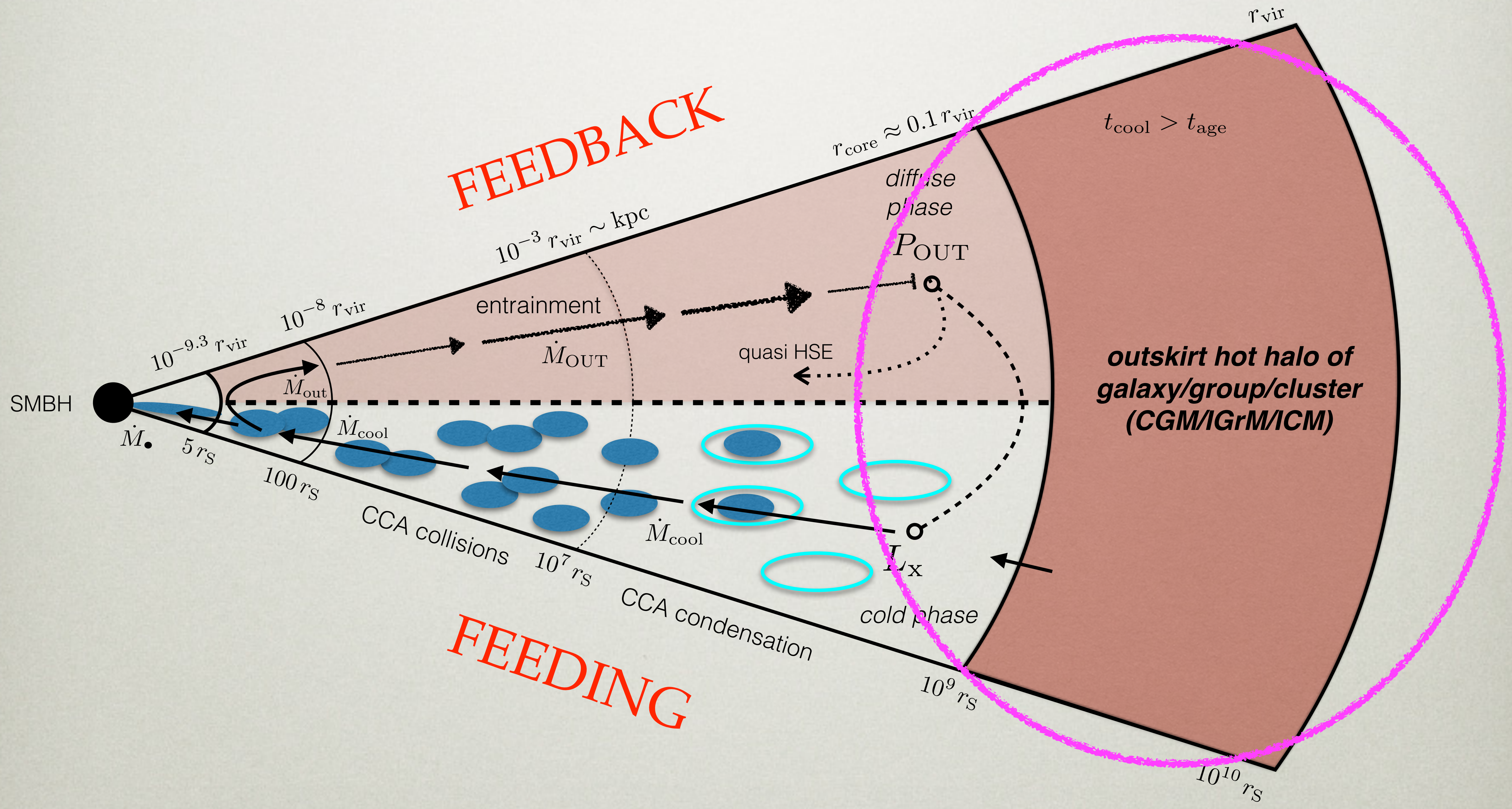
AGN FEEDING AND FEEDBACK UNIFICATION



MG+2011-2017

HOT HALO ASTROPHYSICS - MACRO

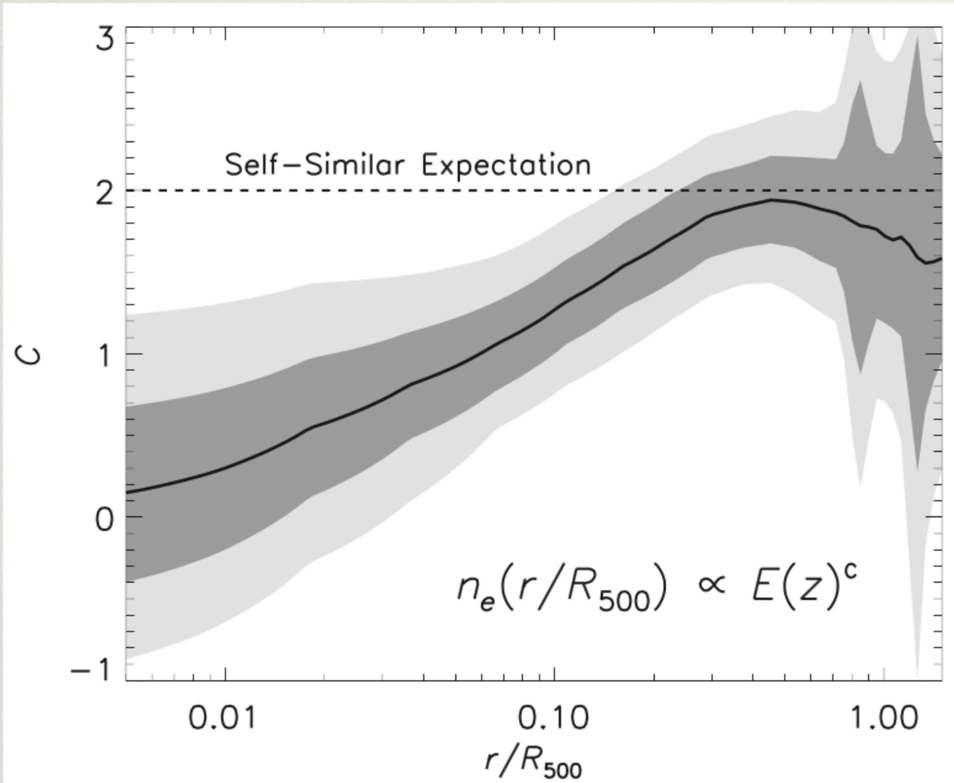
cool cores, conduction, turbulence, metals, thermodynamics

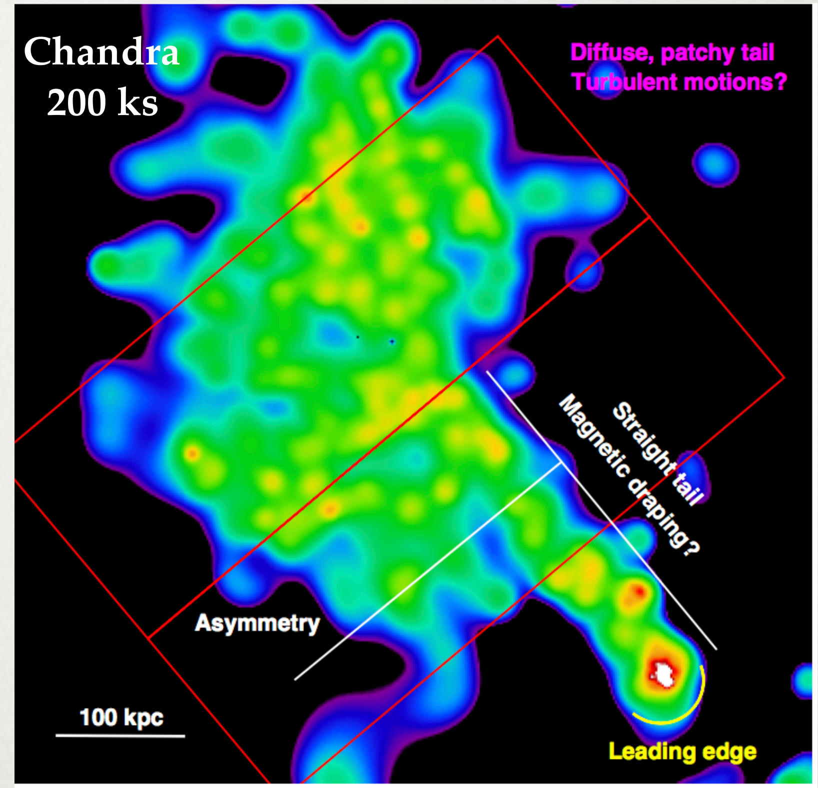
X-ray observations

McDonald et al. 2017

49 clusters - *Chandra*/SPT clusters

Cool cores are non-evolving since z < 2





Eckert, Gaspari et al. 2017

group falling into a massive cluster A2142

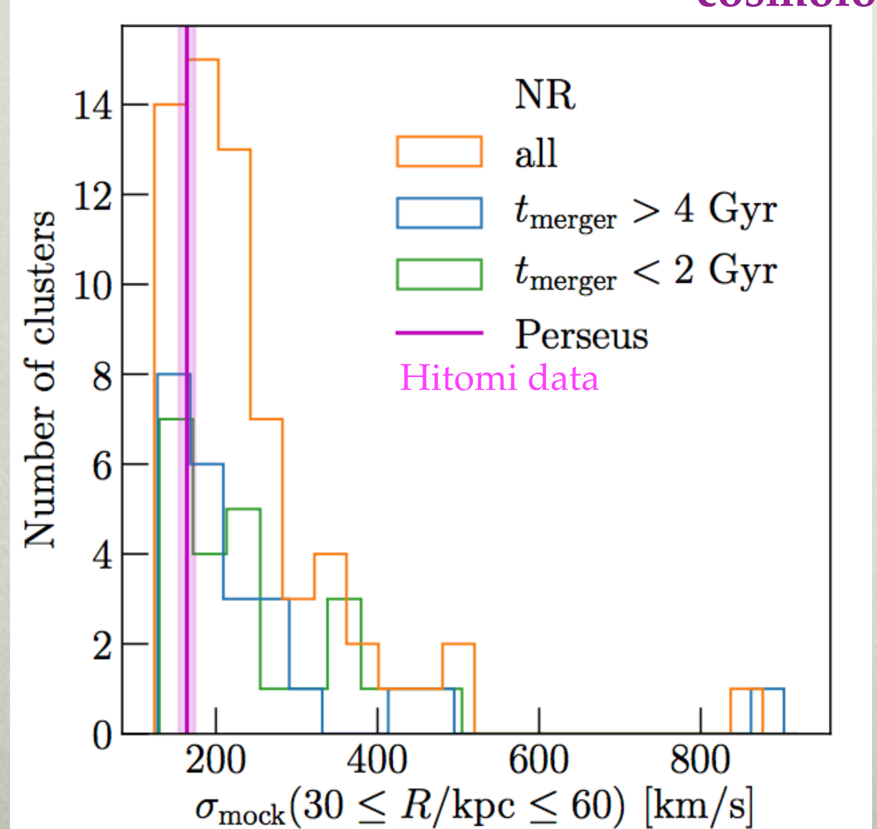
first power spectrum in a tail => conduction strongly suppressed

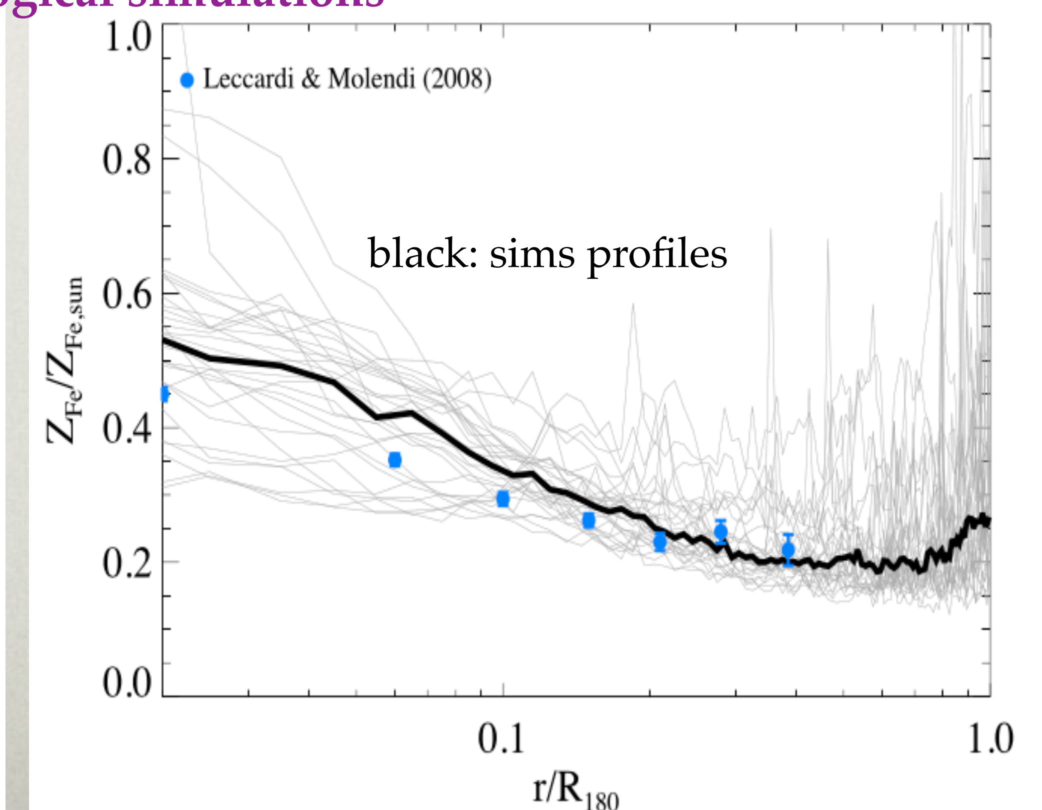
cosmological simulations

Lau, Gaspari et al. 2017

turbulence generated via mergers and cosmological flows

mock Hitomi analysis



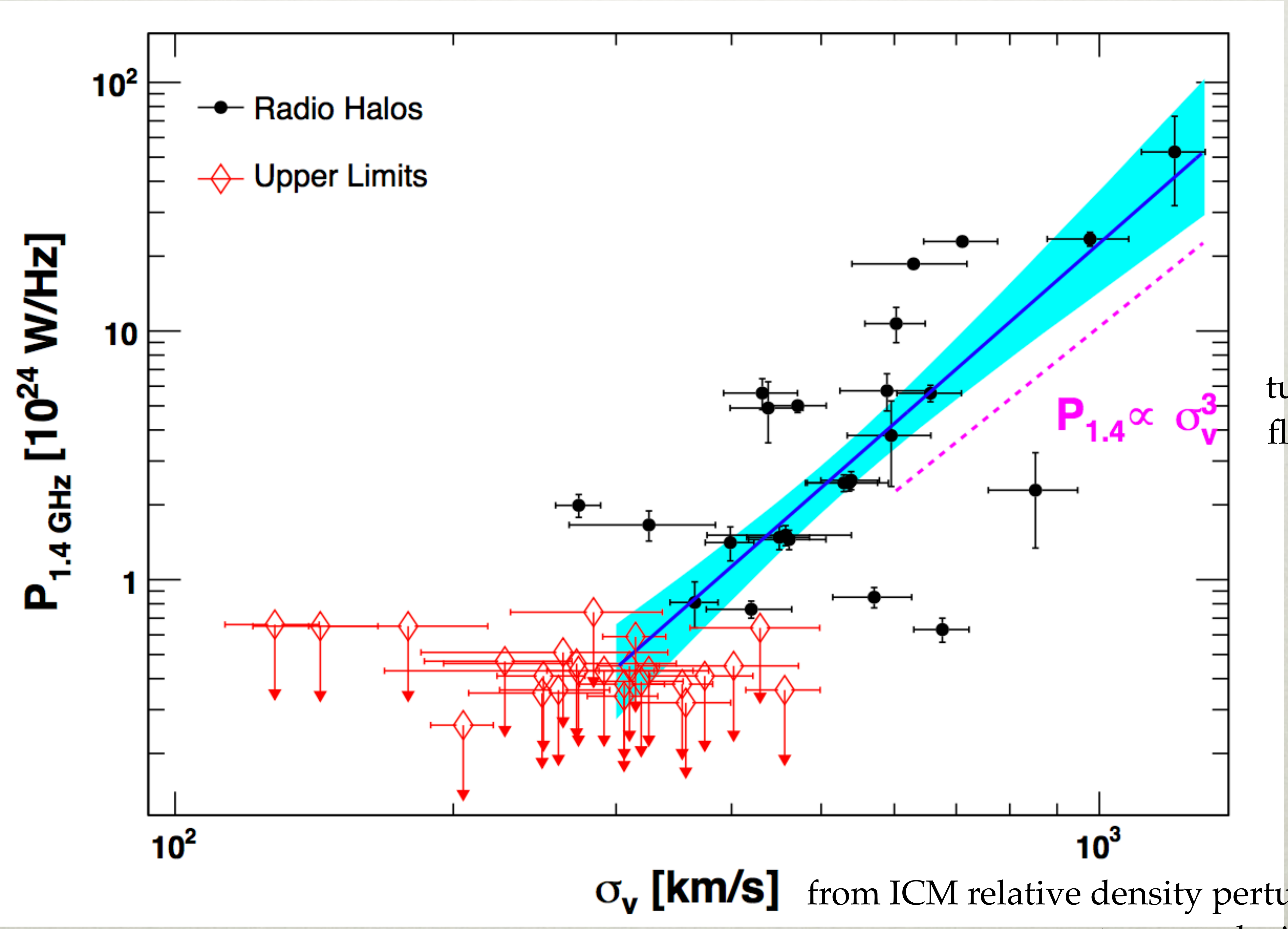


Biffi et al. 2017

chemical enrichment history of ICM

ICM TURBULENCE - RADIO POWER

emission power
of radio halos
(several 100 kpc)
in galaxy clusters

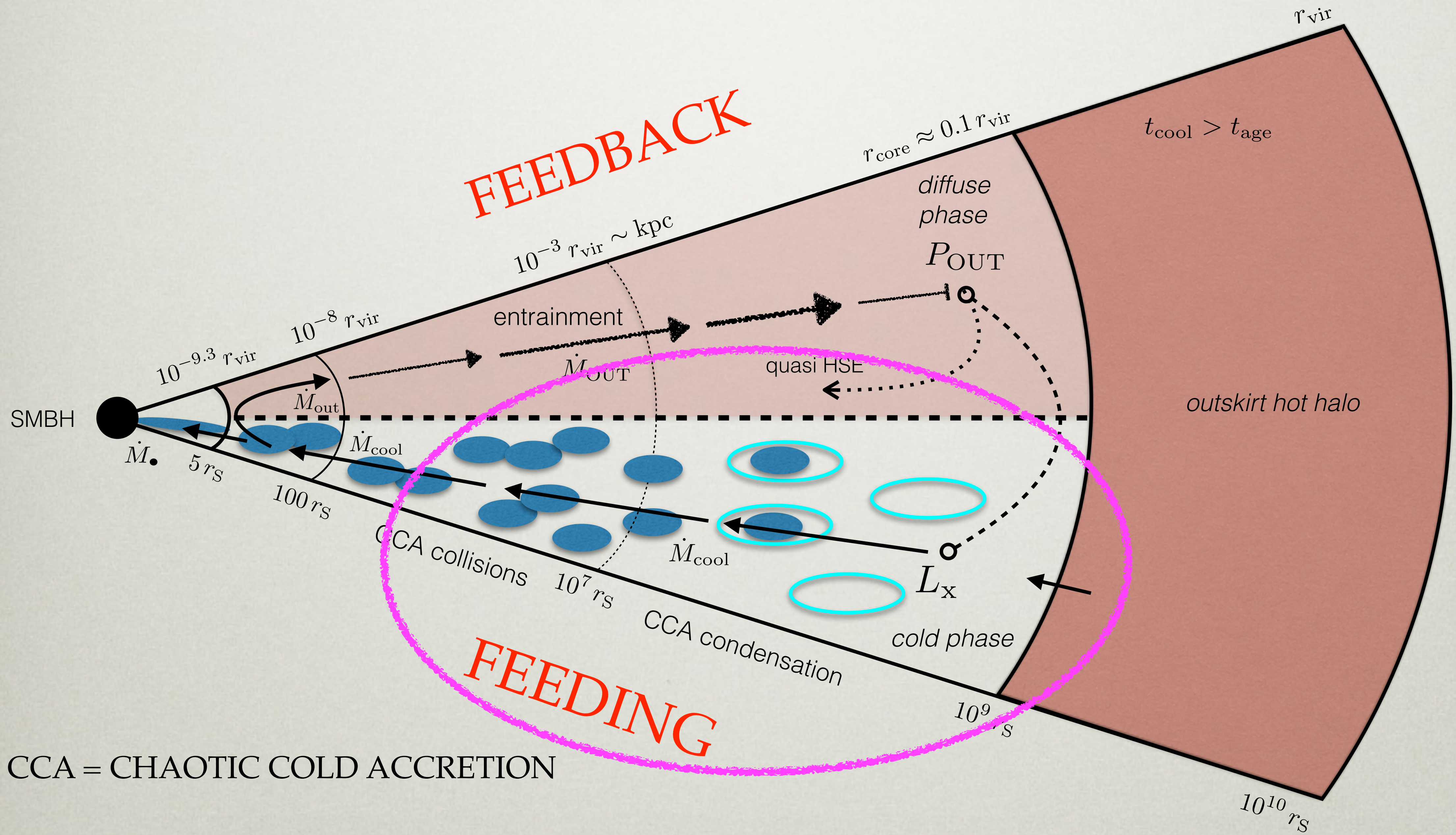


turbulent energy
flux rate scaling!

from ICM relative density perturbations
power spectrum analysis

Eckert, Gaspari, et al. 2017
(ApJL)

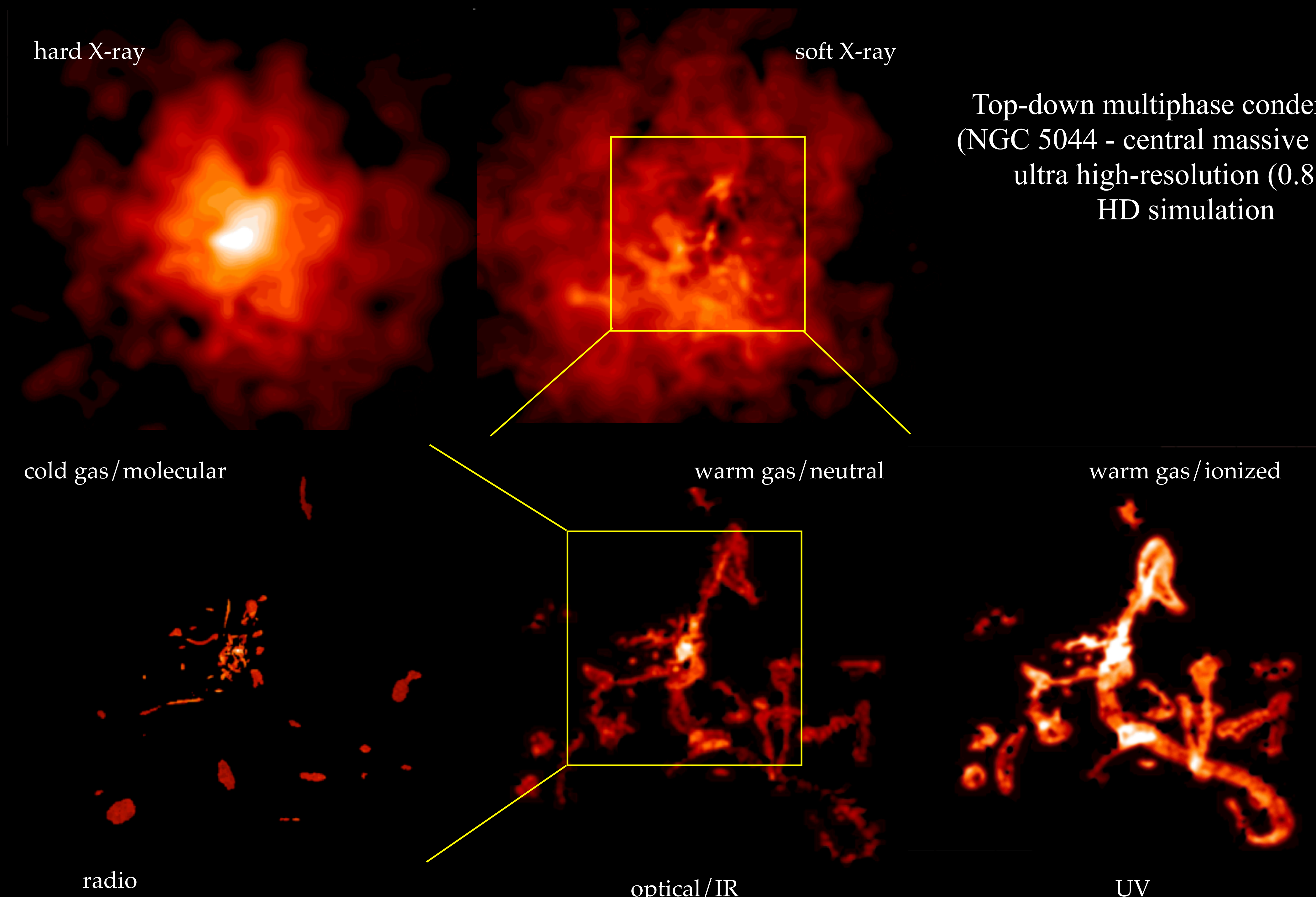
AGN FEEDING AND FEEDBACK UNIFICATION



CCA = CHAOTIC COLD ACCRETION

multiphase condensation cascade ("raining")

MG+2011-2017



Top-down multiphase condensation
(NGC 5044 - central massive galaxy):
ultra high-resolution (0.8 pc)
HD simulation

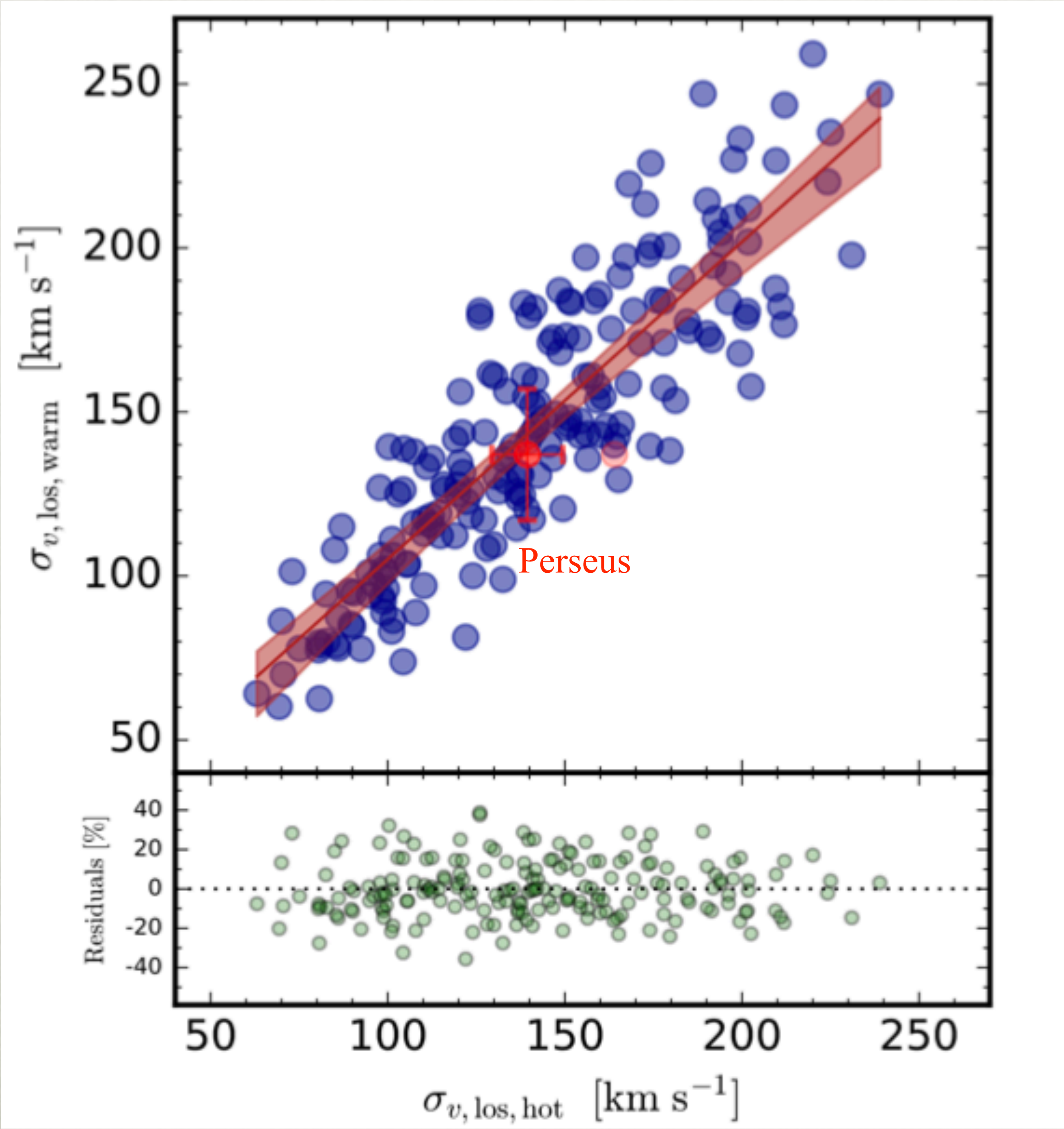
Gaspari et al. 2017a -
Chaotic Cold Accretion

KINEMATIC TRACERS OF THE MULTIPHASE CONDENSATION CASCADE

"shaken snow globes"

Gaspari et al. 2017b

ENSEMBLE beam
(R < 45 kpc)



long-term (several Gyr)
self-regulated AGN
outflow feedback run

warm-hot phase
tight turbulence kinematics

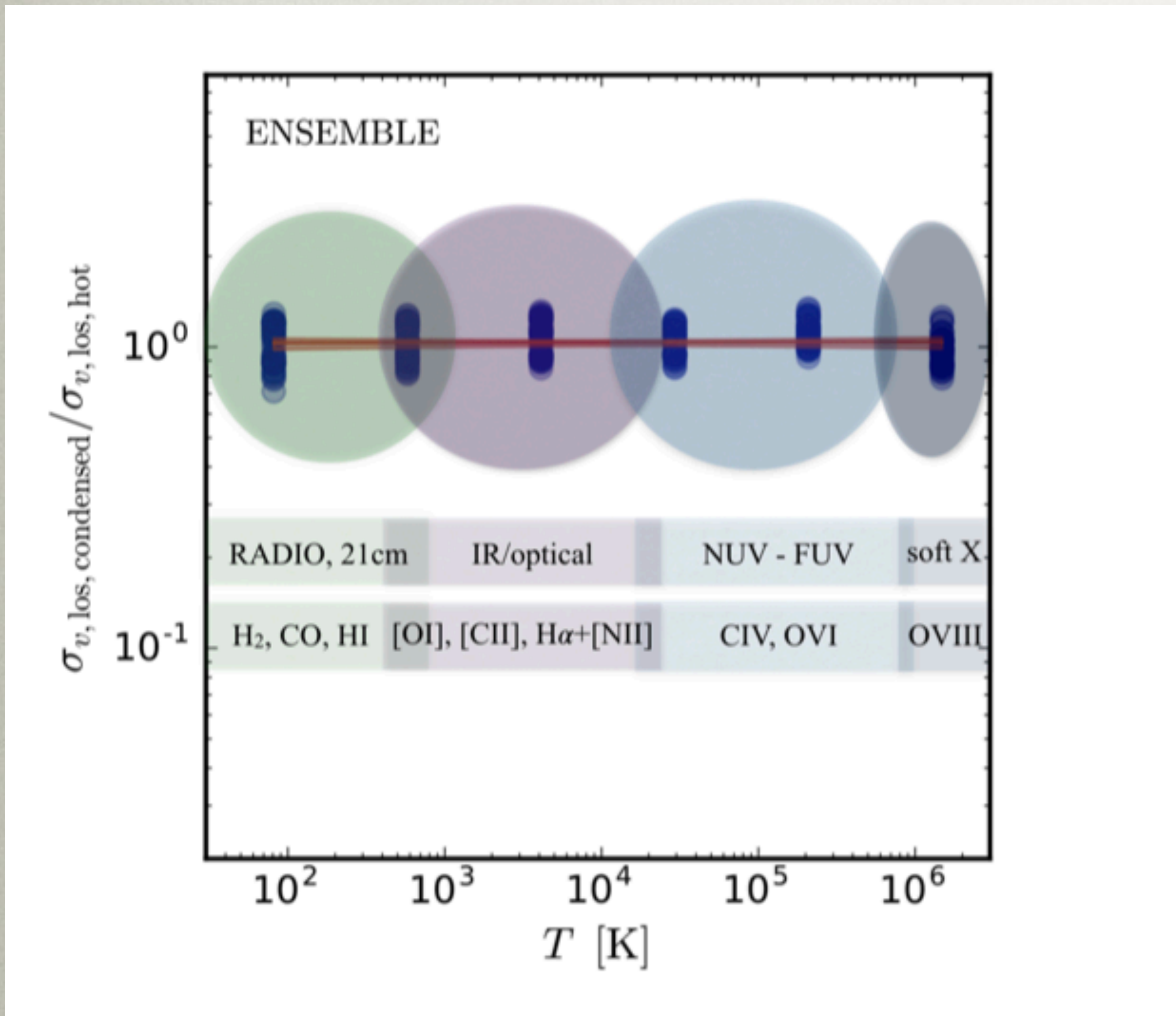
novel method to constrain turbulence in the warm phase
(X-ray spectroscopy very expensive and often unresolved)

KINEMATIC TRACERS:

Velocity dispersion in different phases compared with the turbulence driven in the hot plasma

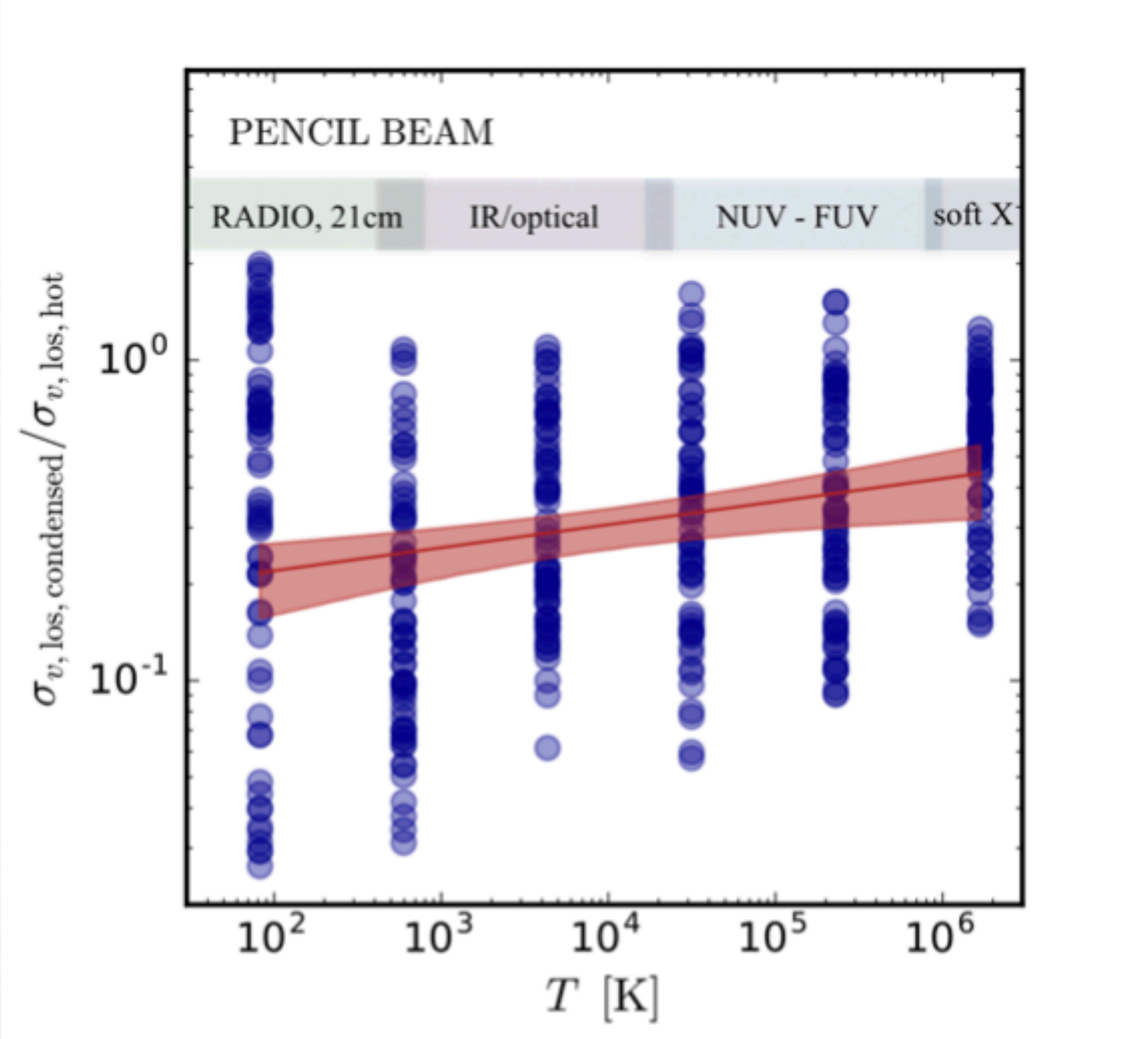
short-term (100 Myr): ultra high-resolution (0.8 pc) CCA runs

Gaspari et al. 2017b



wide-aperture (R < 15 kpc)

- small scatter: tracing large-scale volume-filling turbulence
- again tight correlation among all phases during CCA



small-aperture (R < 25 pc)

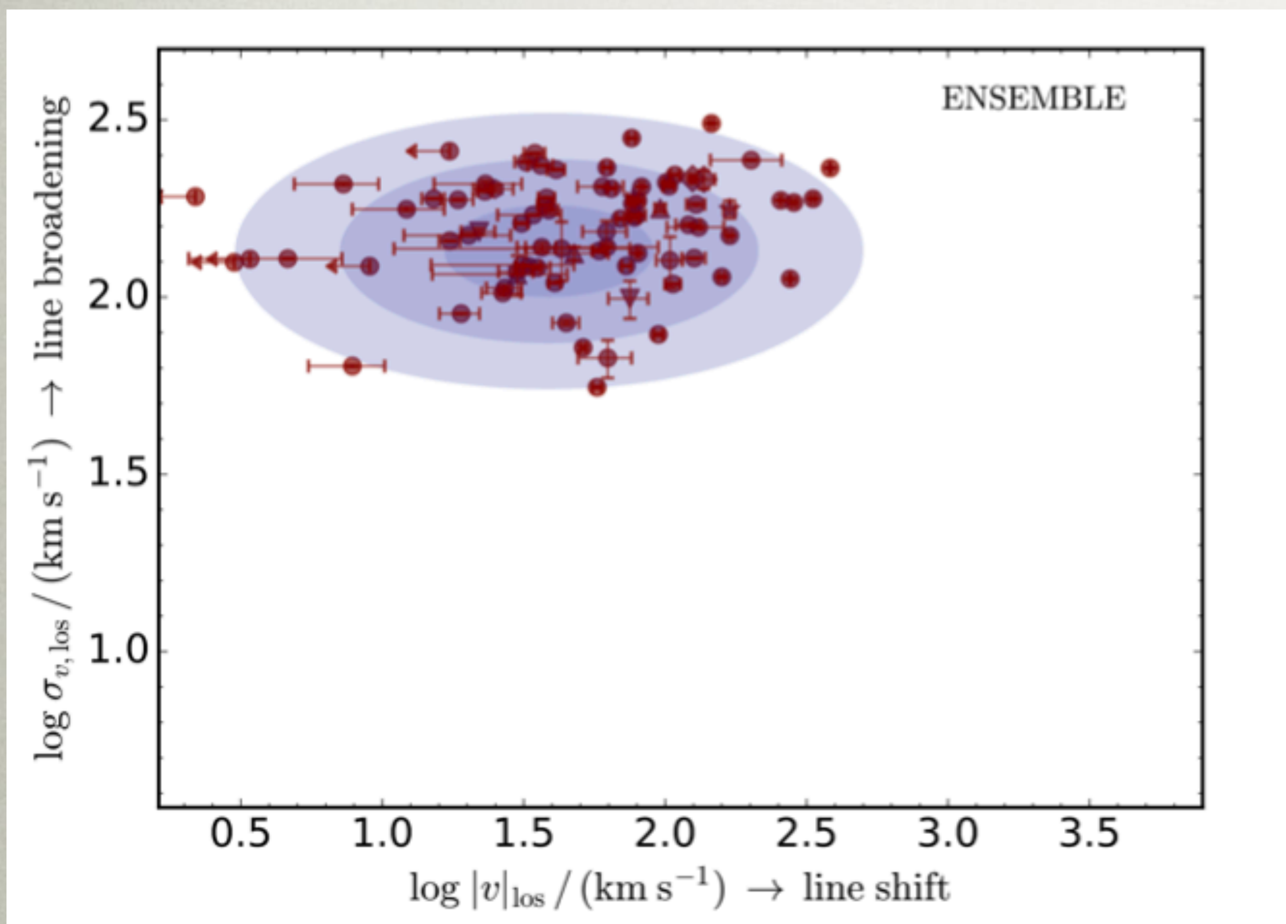
- large scatter: tracing the small scale clouds, infalling onto the SMBH or drifting at large radii
- following the turbulent eddy Kolmogorov cascade

KINEMATIC TRACERS:

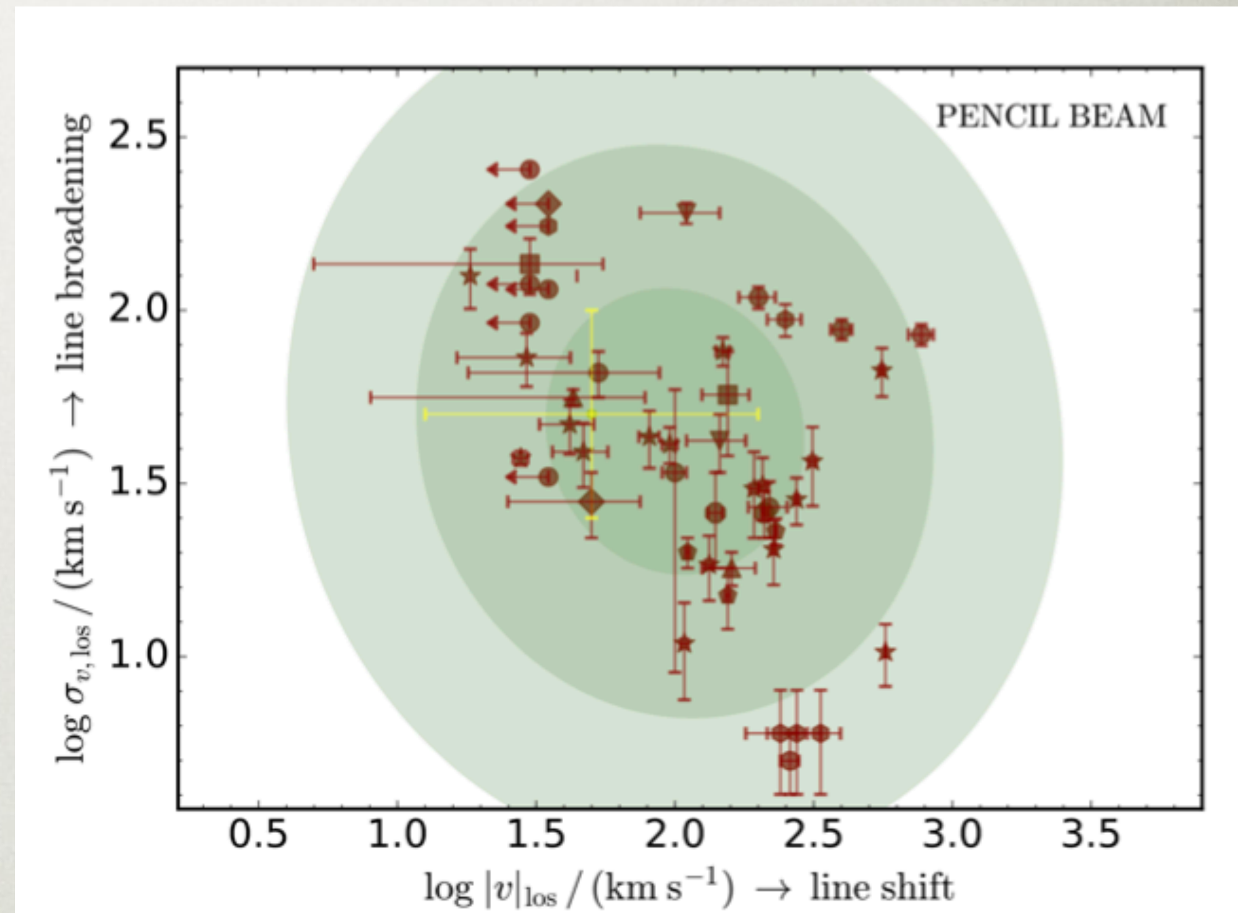
observational tests

(massive galaxies in groups and clusters)

spectral line **broadening** = turbulent motions vs. line **shift** = bulk motions



substantial line broadening and small scatter



large line shifts and narrow broadening: accreting clouds

red points: ~80 systems (Hα+[NII], HI, CO, [CII] lines) — contours: simulation lognormal distributions

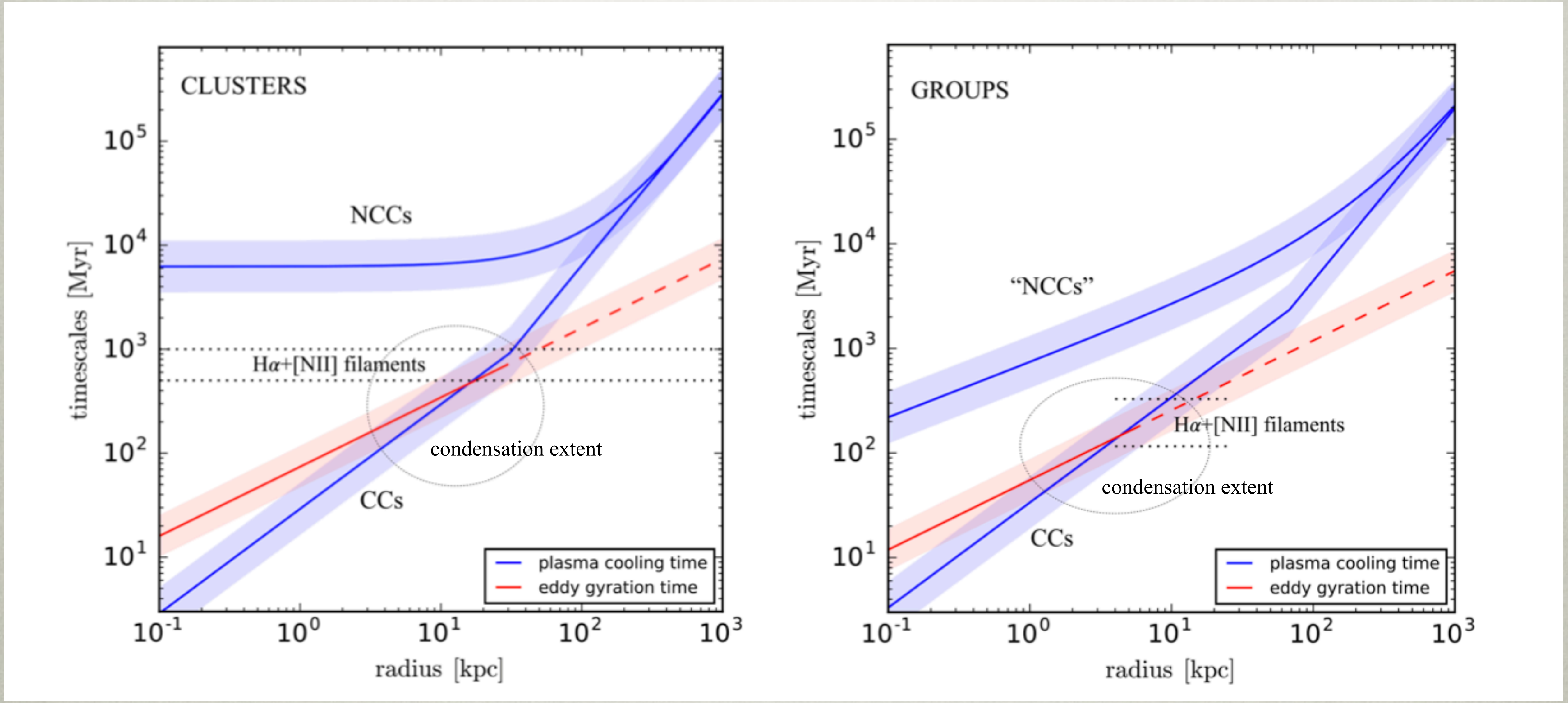
Gaspari et al. 2017b

KINEMATIC TRACERS:

key physically-motivated condensation criterium

$$C \equiv t_{\rm cool}/t_{\rm eddy} \approx 1$$

Gaspari et al. 2017b



plasma cooling time

$$t_{\rm cool} = \frac{3k_{\rm b}T}{n_{\rm e}\Lambda}$$

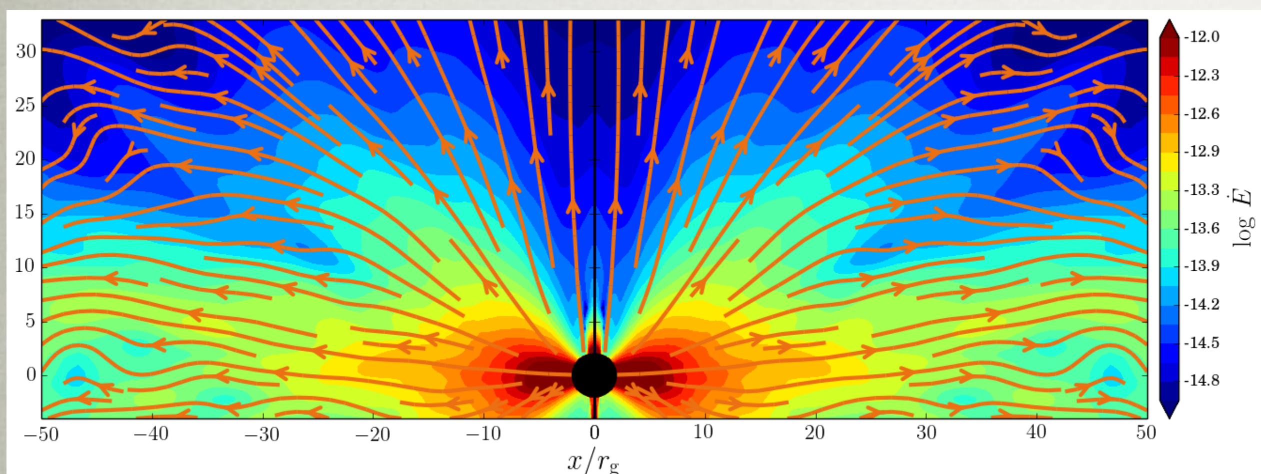
versus

eddy gyration time

$$t_{\rm eddy} = 2\pi \, \frac{r^{2/3}L^{1/3}}{\sigma_{v,L}}$$

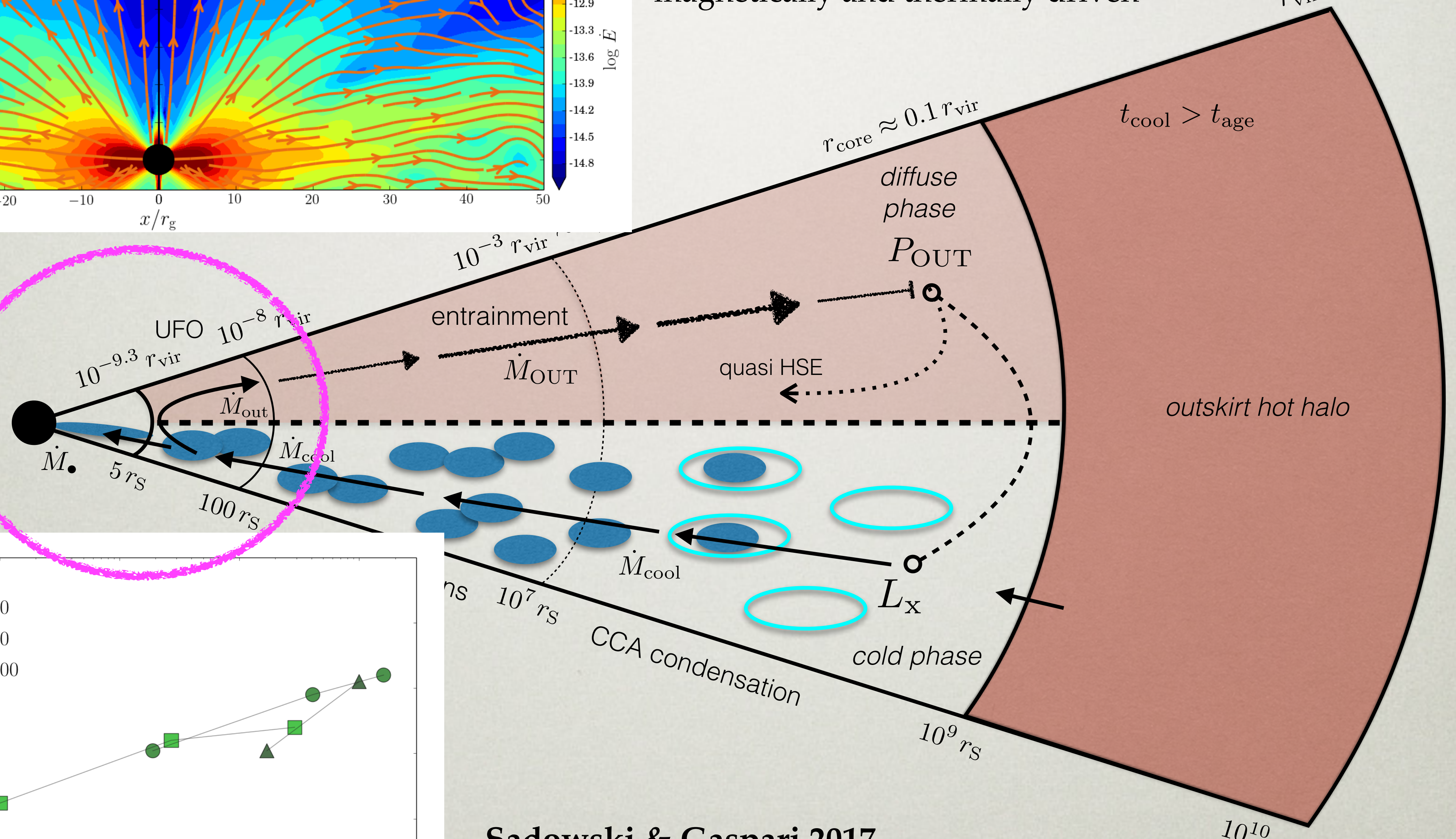
free-fall time is secondary

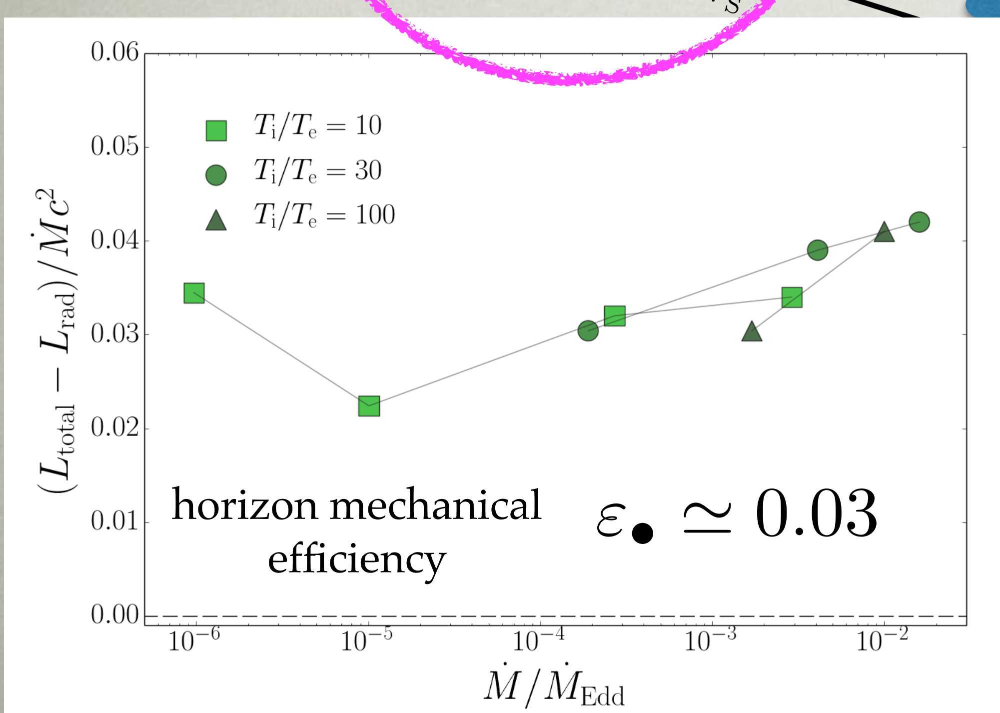
AGN FEEDBACK: MICRO SCALE - GR-RMHD SIMS



UFO = Ultra-Fast Outflows

magnetically and thermally driven





Sadowski & Gaspari 2017

General relativistic, radiative, MHD sims

thick accretion flow and nearly null BH spin (due to chaotic accretion)

UNIFYING THE MICRO AND MACRO EFFICIENCY

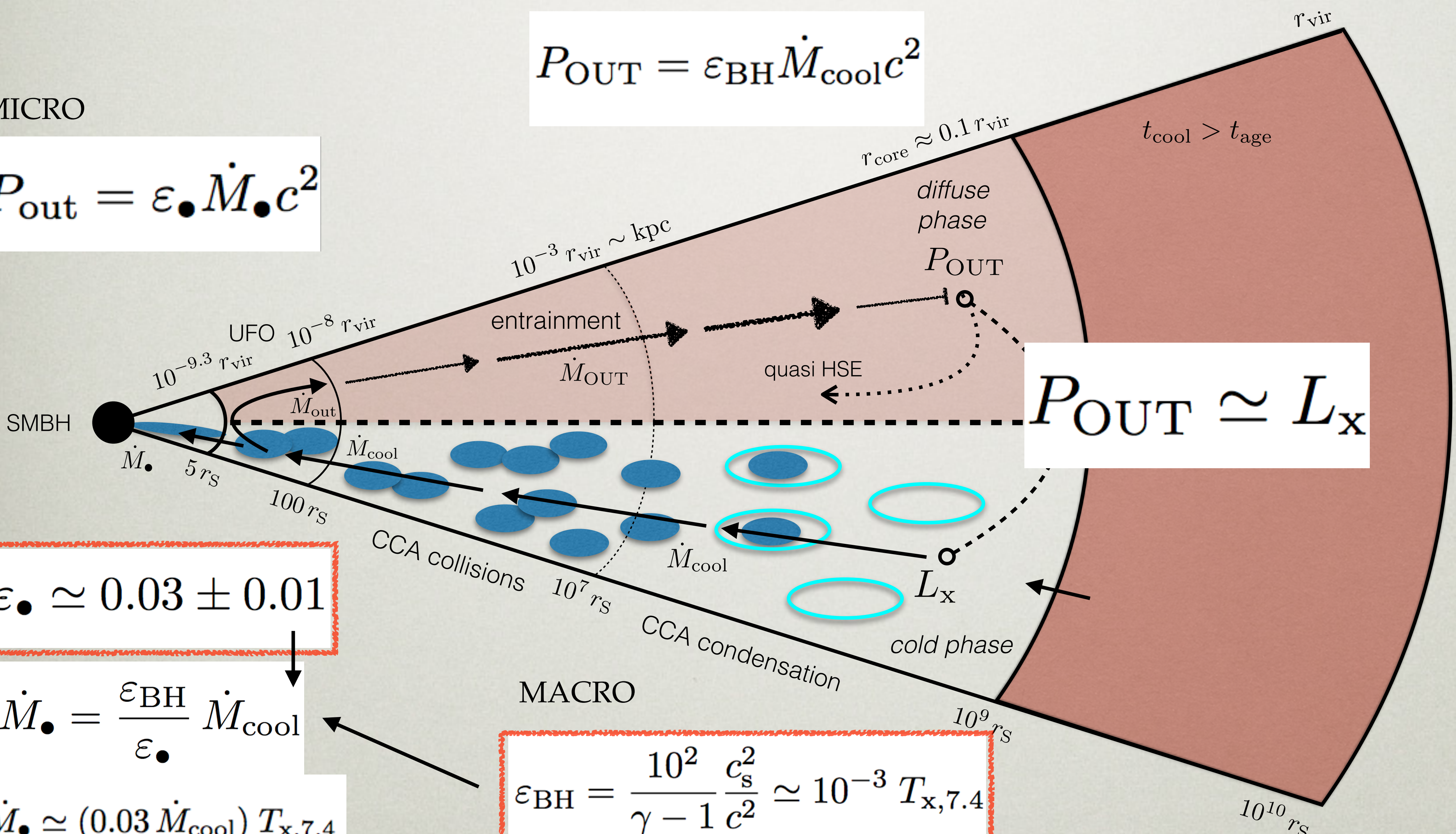
Gaspari & Sadowski 2017

MACRO

$$P_{\rm OUT} = \varepsilon_{\rm BH} \dot{M}_{\rm cool} c^2$$

MICRO

$$P_{\rm out} = \varepsilon_{\bullet} \dot{M}_{\bullet} c^2$$



$$P_{\rm OUT} \simeq L_{\rm x}$$

cycle has frequency $t_{\rm cool}^{-1}$

$$\varepsilon_{\bullet} \simeq 0.03 \pm 0.01$$

$$\dot{M}_{\bullet} = \frac{\varepsilon_{\rm BH}}{\varepsilon_{\bullet}} \dot{M}_{\rm cool}$$

$$\dot{M}_{\bullet} \simeq (0.03\, \dot{M}_{\rm cool})\, T_{\rm x,7.4}$$

most of the mass ejected

MICRO

MACRO

$$\varepsilon_{\rm BH} = \frac{10^2}{\gamma - 1} \frac{c_{\rm s}^2}{c^2} \simeq 10^{-3}\, T_{\rm x,7.4}$$

$$\dot{M}_{\rm cool} \simeq 10^{-2}\, \dot{M}_{\rm CF} \simeq 6.7 \times 10^{-3} \frac{L_{\rm x}}{c_{\rm s,x}^2}$$

CCA X-ray spectrum

quenched cooling flow scaling relation

$$L_{\rm x} \simeq 6 \times 10^{43}\, (T_{\rm x}/2.2\,{\rm keV})^3\ {\rm erg\, s^{-1}}$$

halo scaling relation

UNIFYING THE MICRO AND MACRO OUTFLOWS

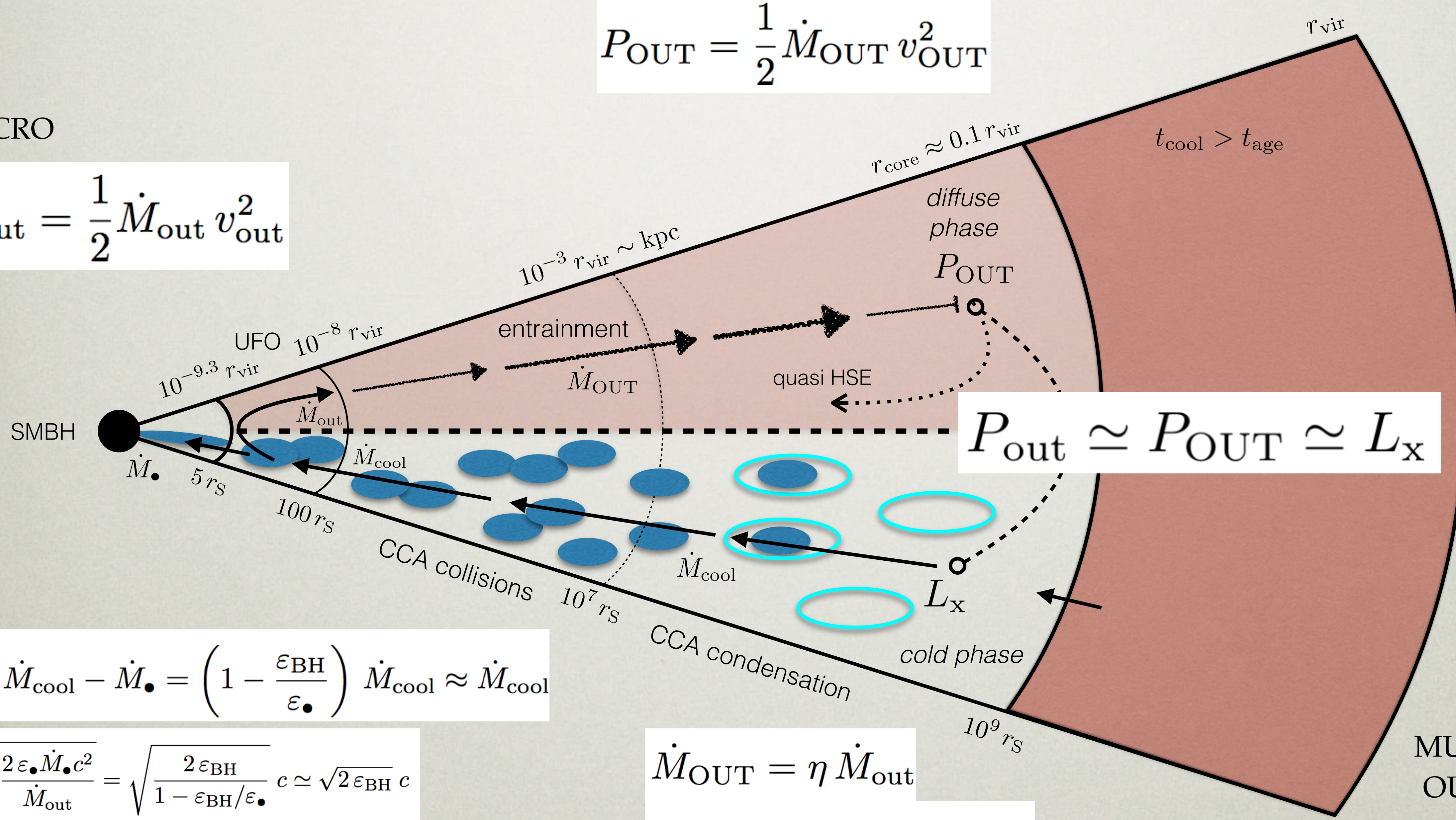
Gaspari & Sadowski 2017

MACRO

$$P_{\rm OUT} = \frac{1}{2}\dot{M}_{\rm OUT}\, v_{\rm OUT}^2$$

MICRO

$$P_{\rm out} = \frac{1}{2}\dot{M}_{\rm out}\, v_{\rm out}^2$$



$$\dot{M}_{\rm out} = \dot{M}_{\rm cool} - \dot{M}_\bullet = \left(1 - \frac{\varepsilon_{\rm BH}}{\varepsilon_\bullet}\right)\dot{M}_{\rm cool} \approx \dot{M}_{\rm cool}$$

$$v_{\rm out} = \sqrt{\frac{2\,\varepsilon_\bullet \dot{M}_\bullet c^2}{\dot{M}_{\rm out}}} = \sqrt{\frac{2\,\varepsilon_{\rm BH}}{1-\varepsilon_{\rm BH}/\varepsilon_\bullet}}\, c \simeq \sqrt{2\,\varepsilon_{\rm BH}}\, c$$

$$\simeq (1.4\times10^4\ {\rm km\,s^{-1}})\, T_{\rm x,7.4}^{1/2}$$

MICRO

conservation of mass and energy

MACRO

$$\dot{M}_{\rm OUT} = \eta\, \dot{M}_{\rm out}$$

$$\dot{M}_{\rm OUT} = \Omega\, r^2\, \rho(r)\, v_{\rm OUT}(r)$$

$$v_{\rm OUT} = \sqrt{\frac{2P_{\rm OUT}}{\dot{M}_{\rm OUT}}} = \eta^{-1/2}\, v_{\rm out}$$

MULTIPHASE OUTFLOWS:

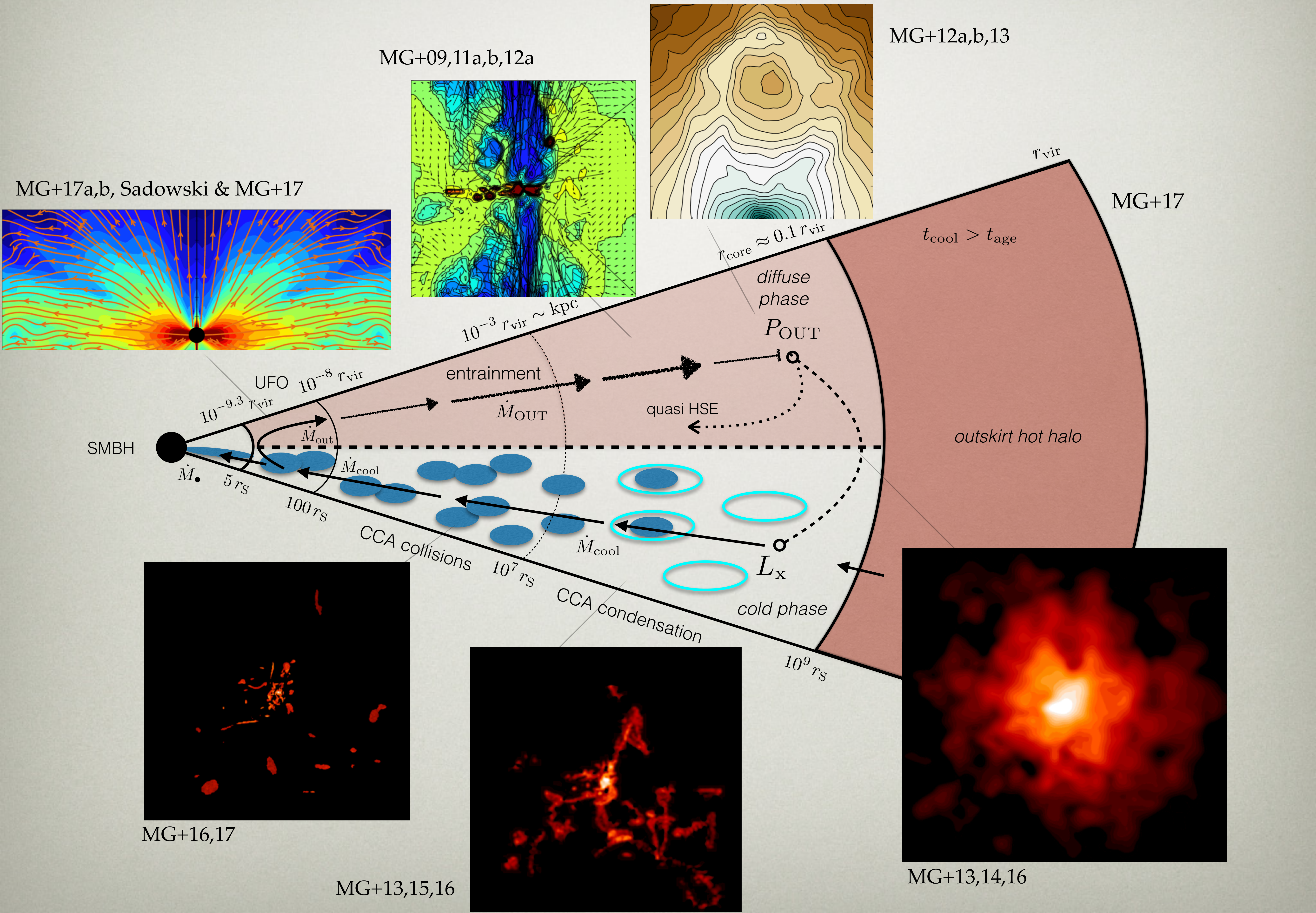
$v_{\rm OUT,ion} \approx$ a few $10^3\ {\rm km\,s^{-1}}$

$v_{\rm OUT,mol} \approx 500\ {\rm km\,s^{-1}}$

$\dot{M}_{\rm OUT,ion} \approx 10{\rm s}\ {\rm M_\odot\,yr^{-1}}$

$\dot{M}_{\rm OUT,mol} \approx$ several $100\ {\rm M_\odot\,yr^{-1}}$

AGN FEEDBACK UNIFICATION



Event

Title:	Multiphase AGN Feeding & Feedback
When:	09.07.2018 - 13.07.2018
Where:	Sexten Primary School - Via Panorama 6, Sexten
Category:	Conferences 2018

Description

http://www.sexten-cfa.eu/conferences/2018/details/100-multiphase-agn-feeding-a-feedback.html