KICC — Epoch of Galaxy Quenching Virtual Meeting

Untangling the Properties & Effects of AGN Feedback in Galaxy Clusters

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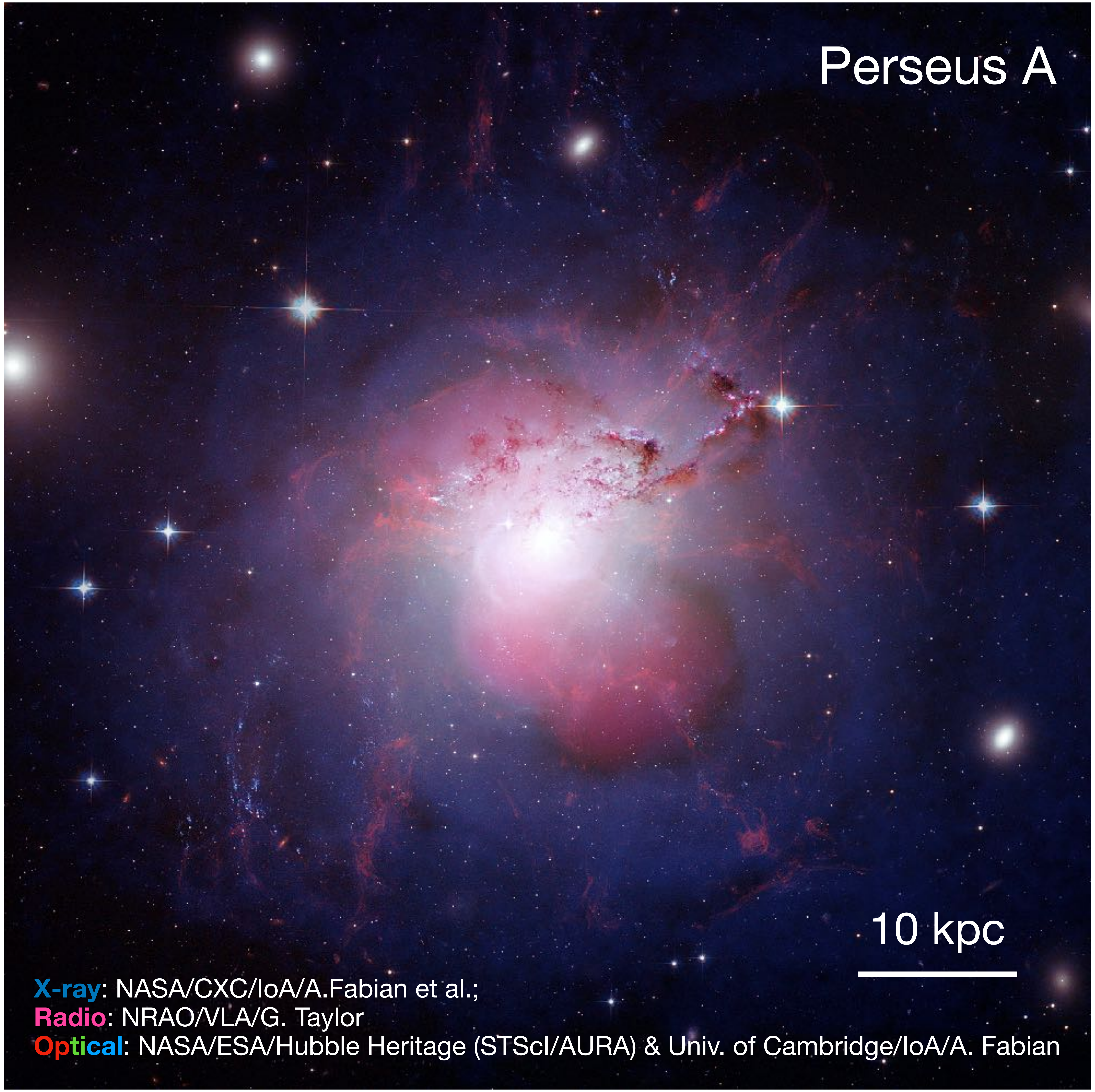
Sept. 10th, 2020

AGN feedback

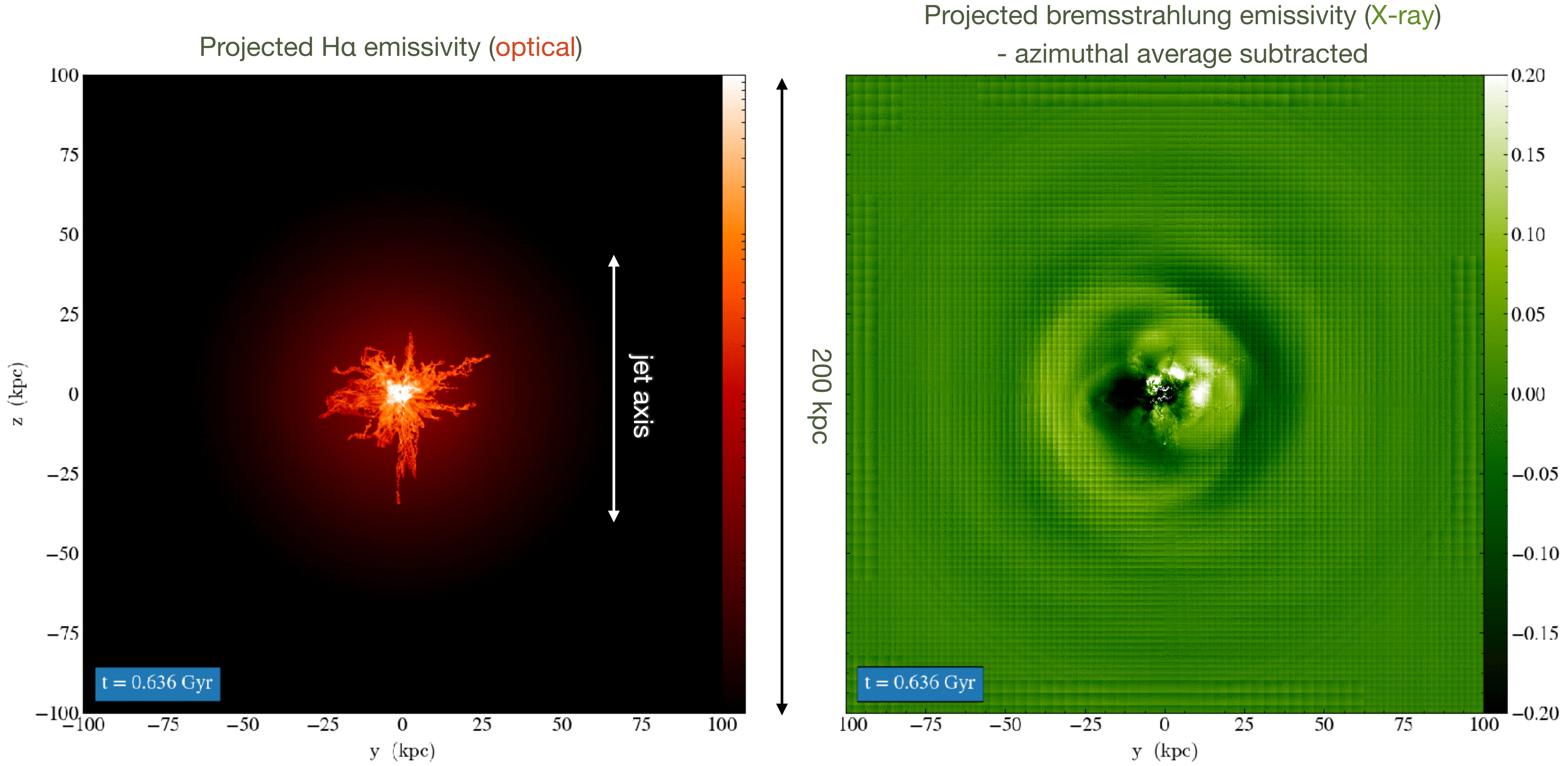
in cool-core clusters

- CCCs: central $t_{\text{cool}} < 1$ Gyr
- Perseus cluster:
  - $L_{\text{AGN,X}} \sim 10^{43\text{-}44}$ erg/s (Fabian et al. 2015)
  - X-ray cavities filled with radio plasma: indicative of relativistic jets
  - Red excess in the form of filaments: Hα line emission associated with $T \sim 10^4$ K gas



Simulation study

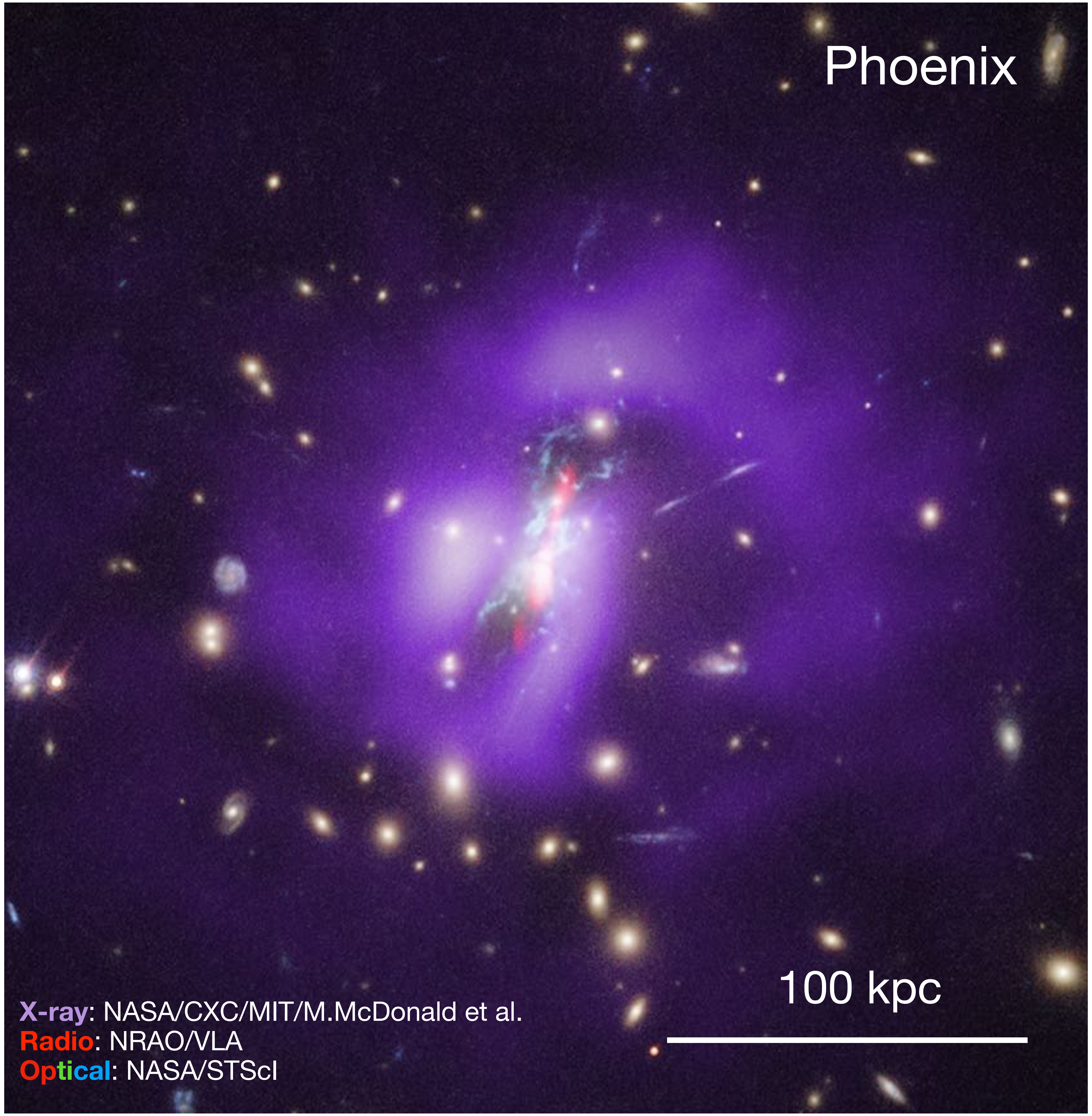
Simultaneously reproduce observational properties in both optical and X-ray (Qiu et al.2019a)



AGN feedback

in Phoenix cluster

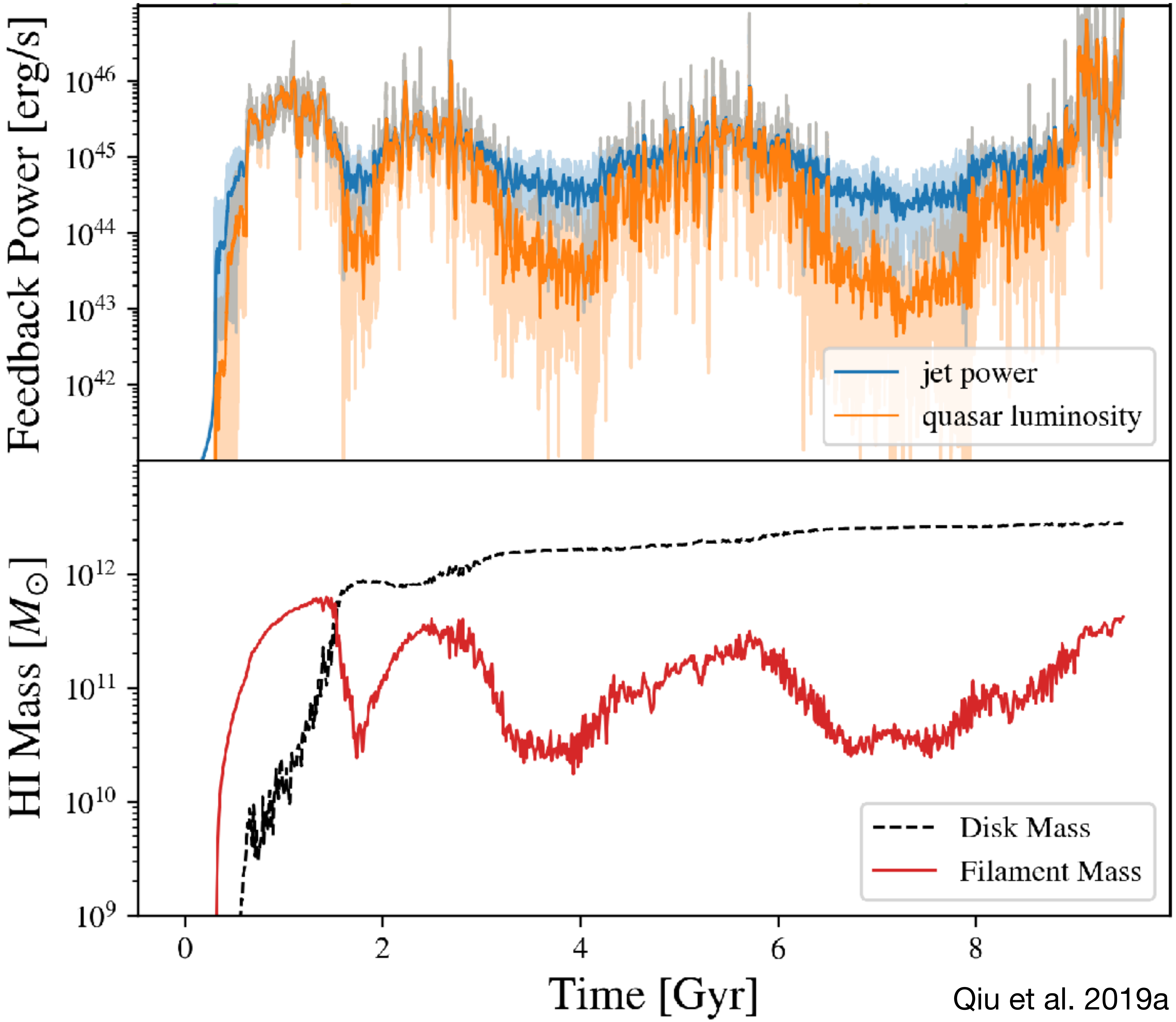
- X-ray cavities, optical filaments, radio jets, similar to Perseus
- $L_{AGN,X} \sim 5.6\times10^{45}$ erg/s (McDonald et al. 2015)
- SFR ~ 500-800 $M_\odot$/yr (McDonald et al. 2012, 2013a; Mittal et al. 2017), an extreme cool core (McDonald 2019)
- May be at the start of an AGN outburst



AGN evolution

over ~10 Gyr

- AGN transitions between radiatively efficient and inefficient states in cycles of 2-4 Gyr.
- Observations find AGNs in BCGs transition from radiatively efficient to inefficient over the past 5 Gyr (Hlavacek-Larrondo et al. 2013)
- *Feedback power correlates positively with filament mass and filament spatial extent (Qiu et al. 2019a,b)

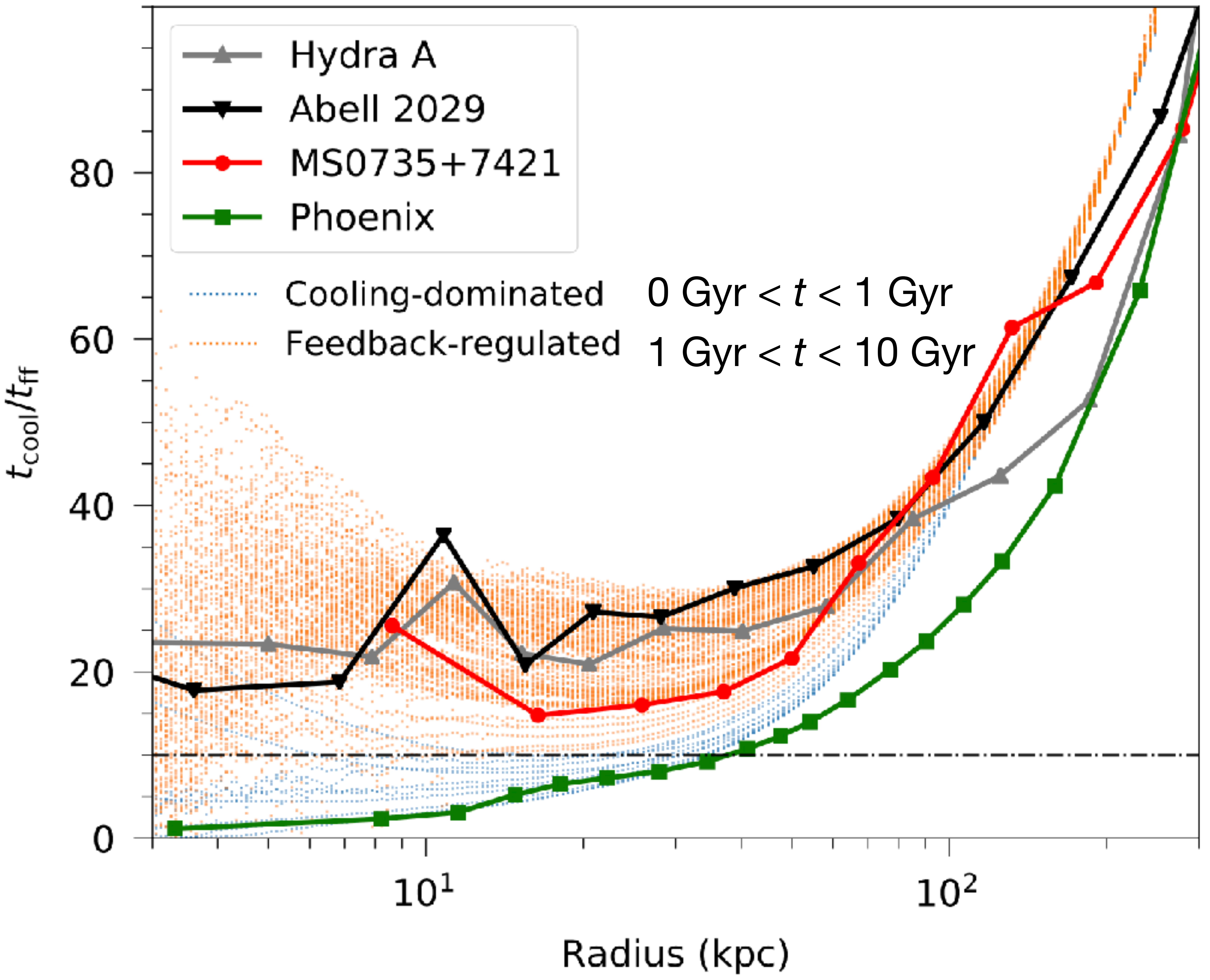


Qiu et al. 2019a

Cluster evolution

radial t_{cool} / t_{ff} profile

- Commonly used to assess thermal stability of the intra-cluster medium (McCourt et al. 2012, Sharma et al. 2012)
- Value < 10 uncommon in observations (exceptions include Phoenix)
- Phoenix corresponds to the cooling-dominated stage of the simulated cluster
- AGN feedback able to regulate cool core structure for billions of years

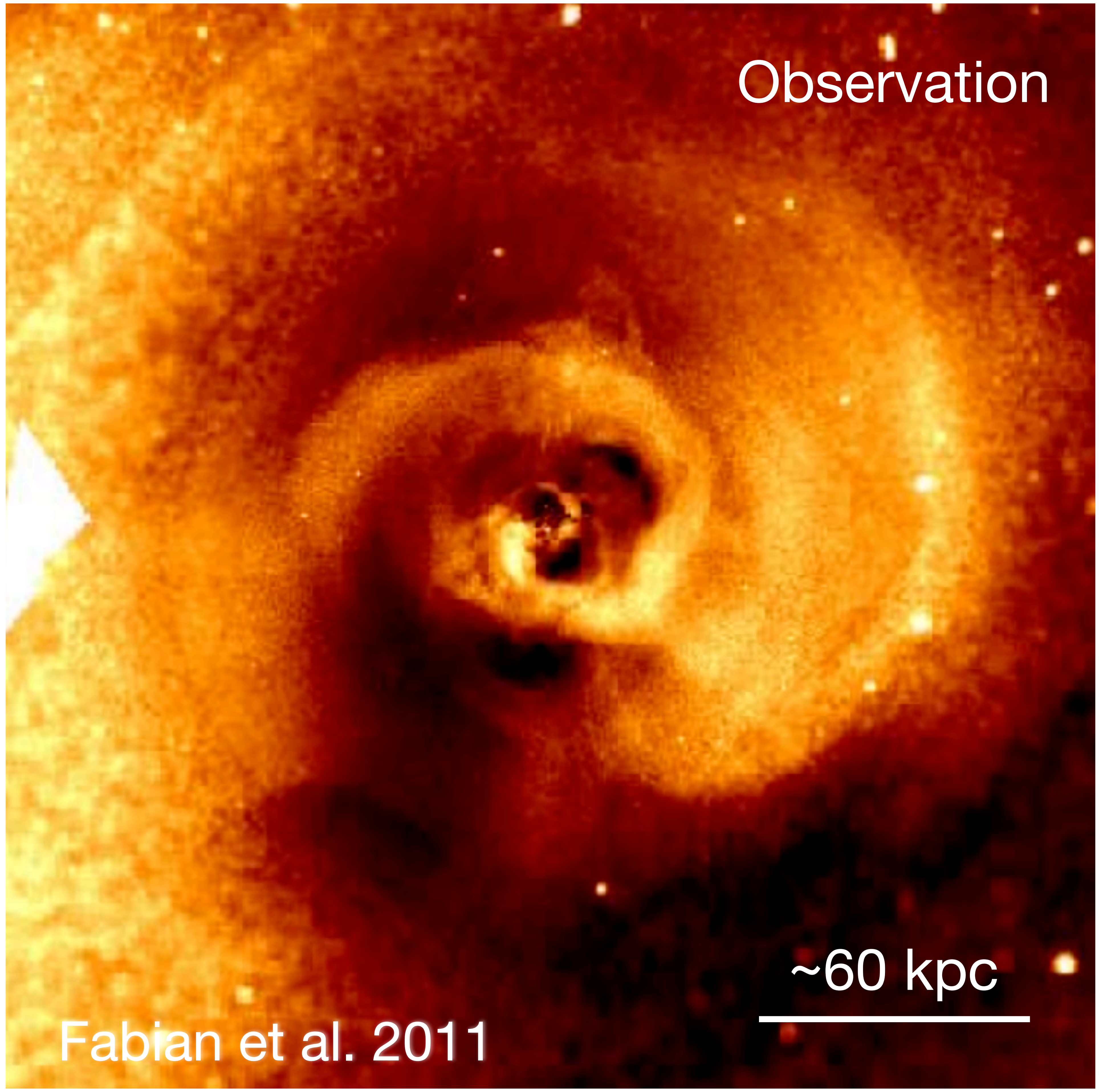


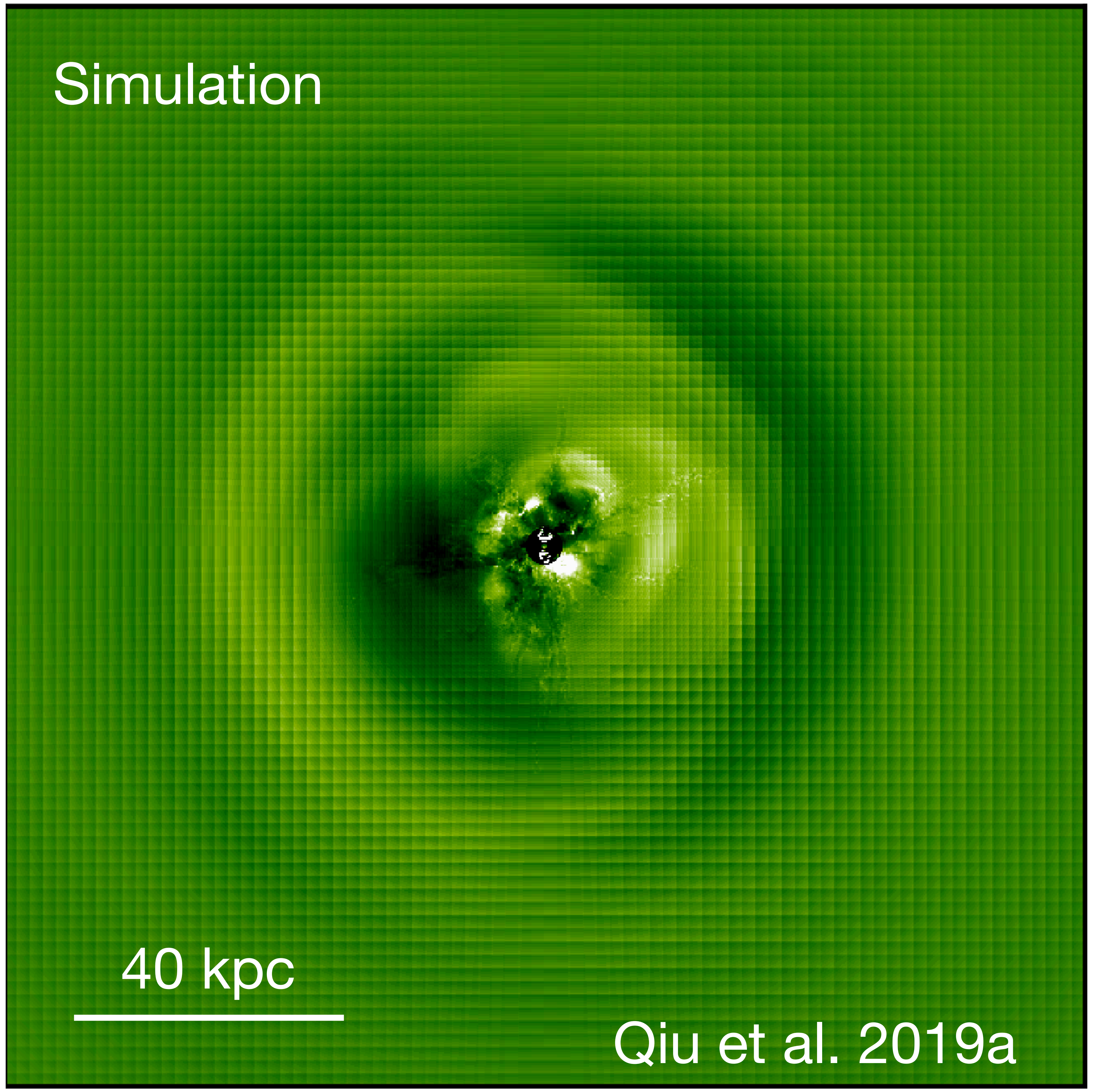
Qiu et al. 2020

Impact of AGN feedback

heat the intra-cluster medium through:

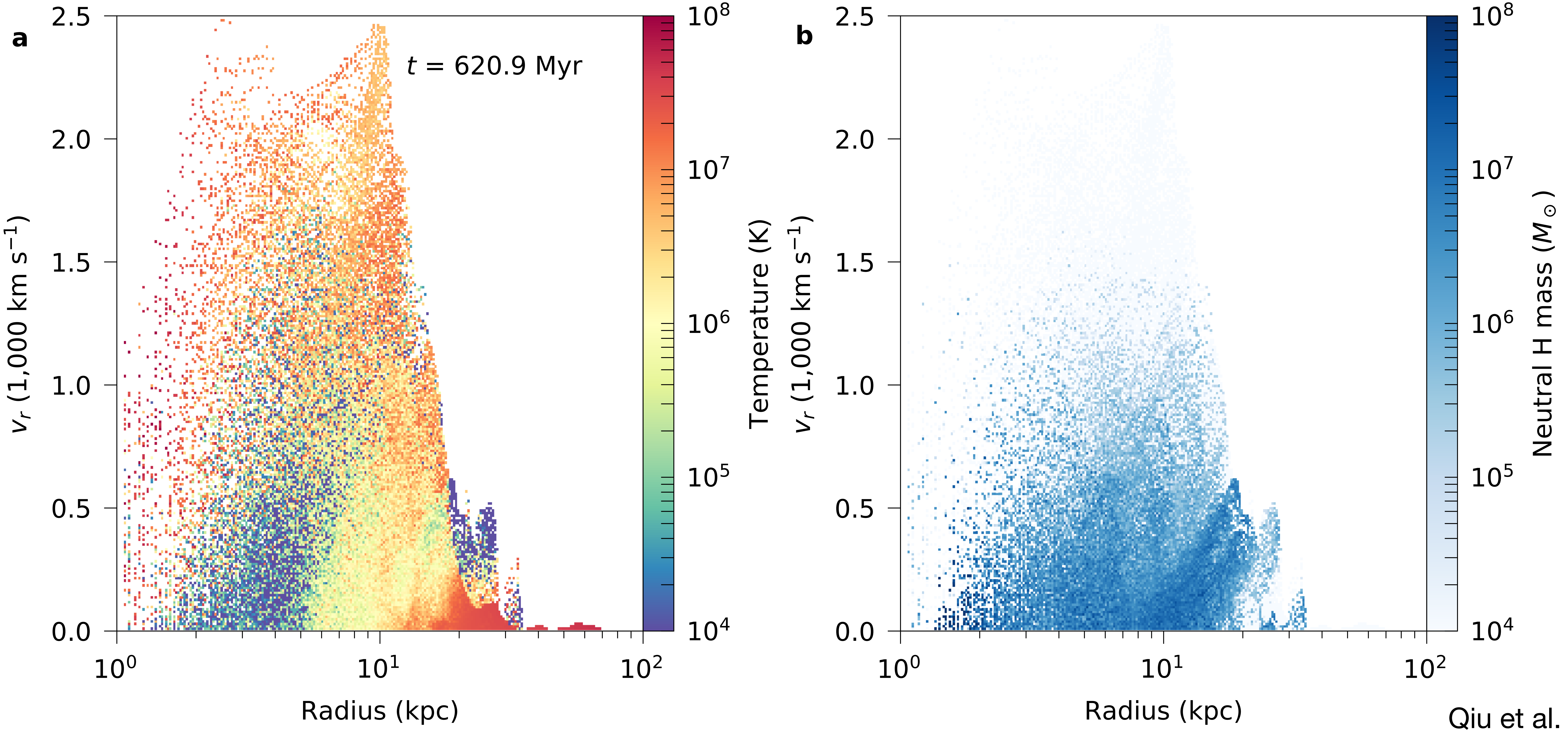
- Sound waves
  (Sanders & Fabian 2007)
- Weak shocks
  (Forman et al. 2007, Li, Ruszkowski & Bryan 2017)
- Turbulence
  (Zhuravleva et al. 2014)
- Internal waves
  (Zhang, Churazov & Schekochihin 2018)





Impact of AGN feedback

radial velocity distribution of multiphase outflows



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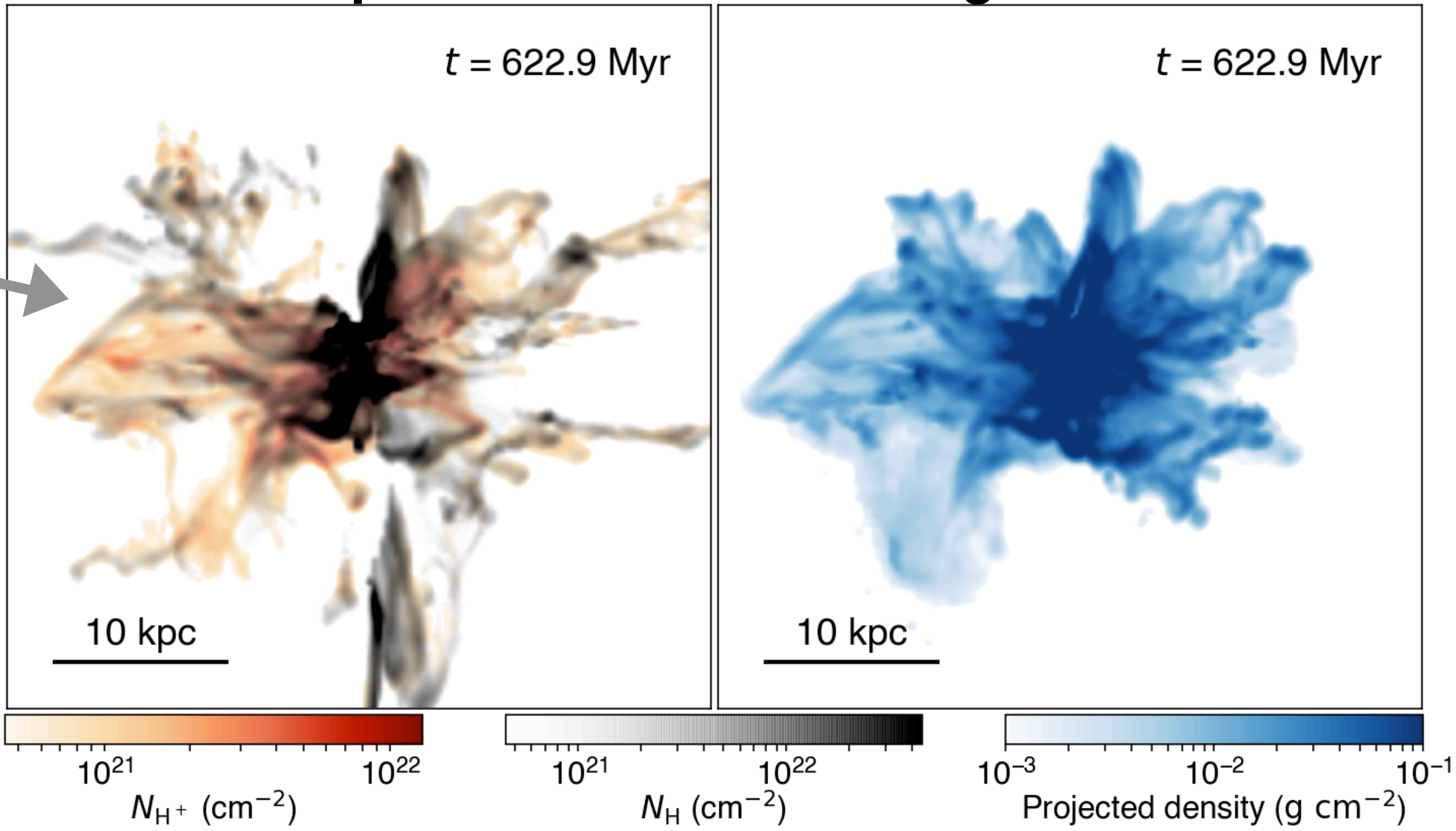
Driving the formation of filaments

from warm ionized plasma to cold neutral gas filaments



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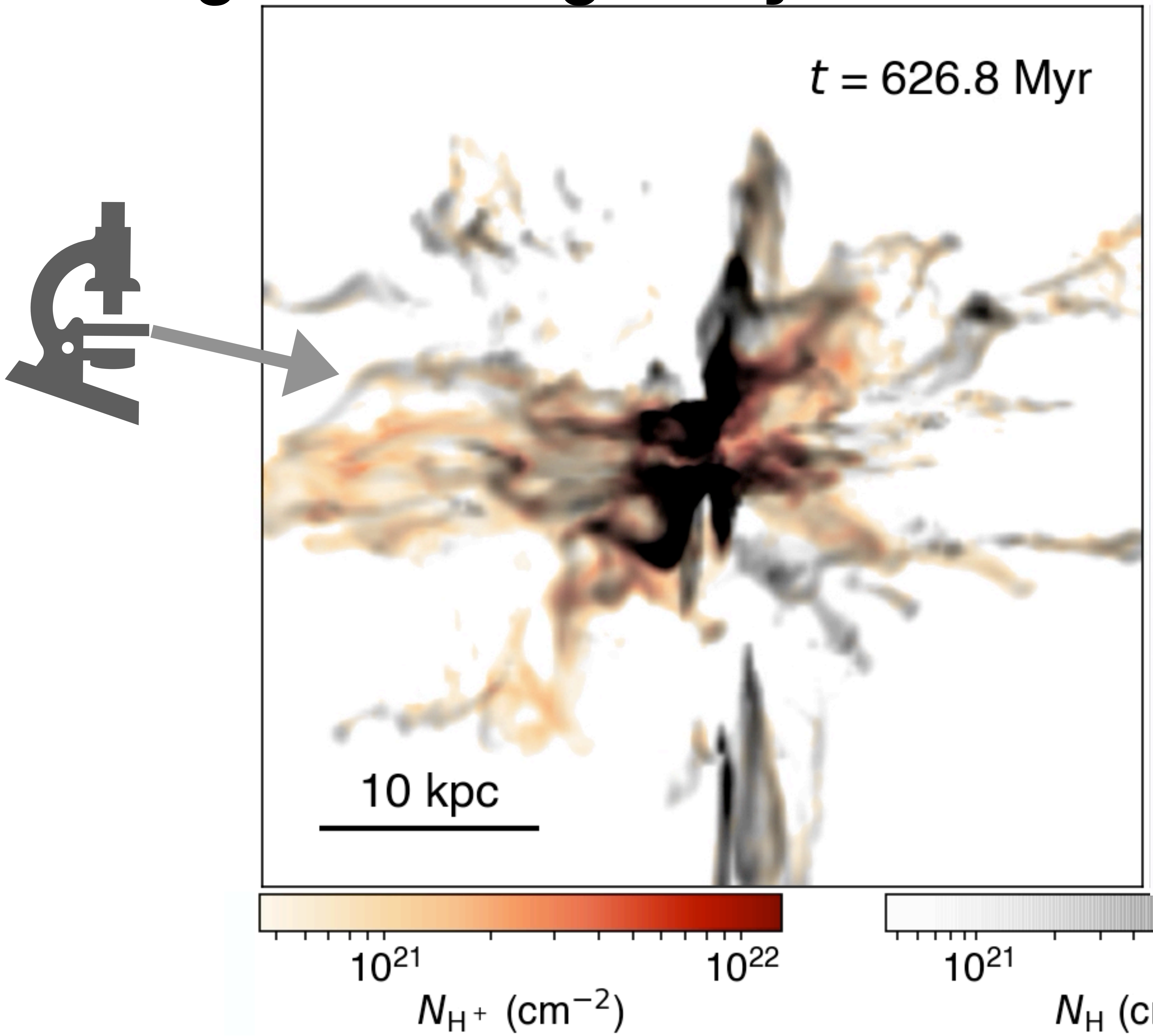
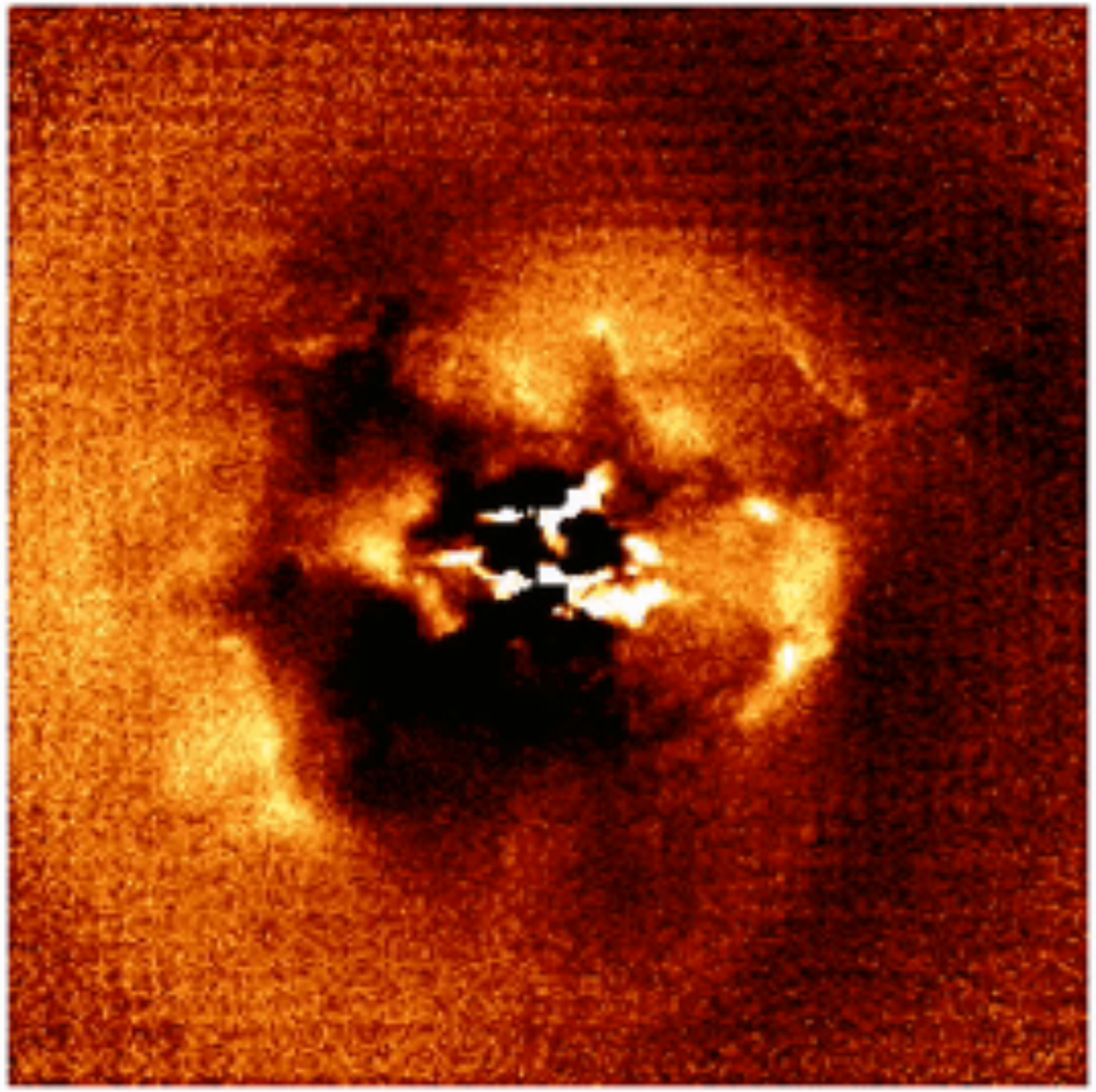
Driving the formation of filaments

along with rising X-ray cavities:





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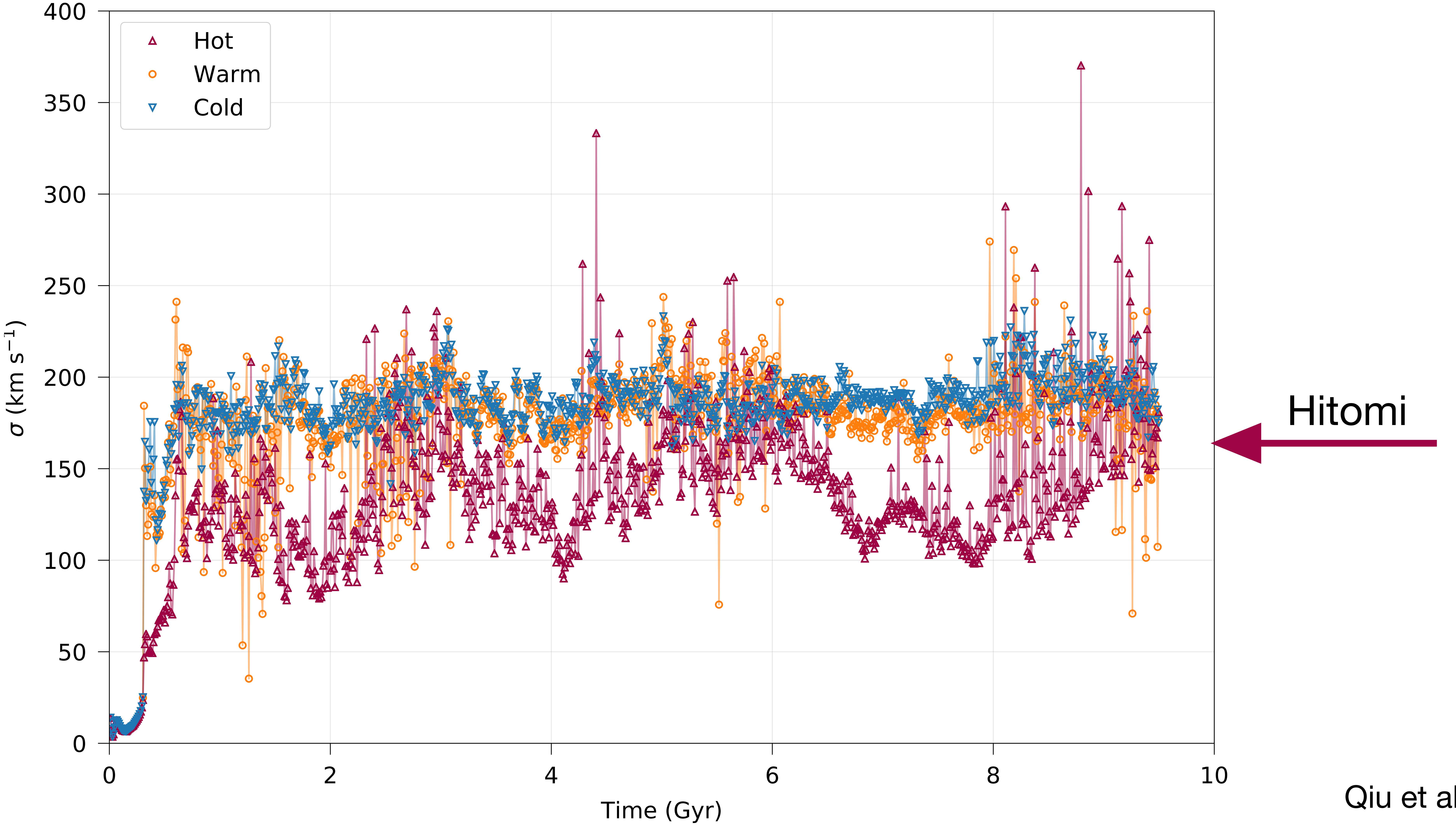
Central (r < 20 kpc) gas kinematics

velocity dispersions



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Summary

✓ AGN transitions between radiatively efficient and inefficient states on times scales of a few Gyr;

✓ Filament properties correlate with feedback power, can be used to probe AGN history

✓ AGN drives multiphase outflows, each having a distinct impact.