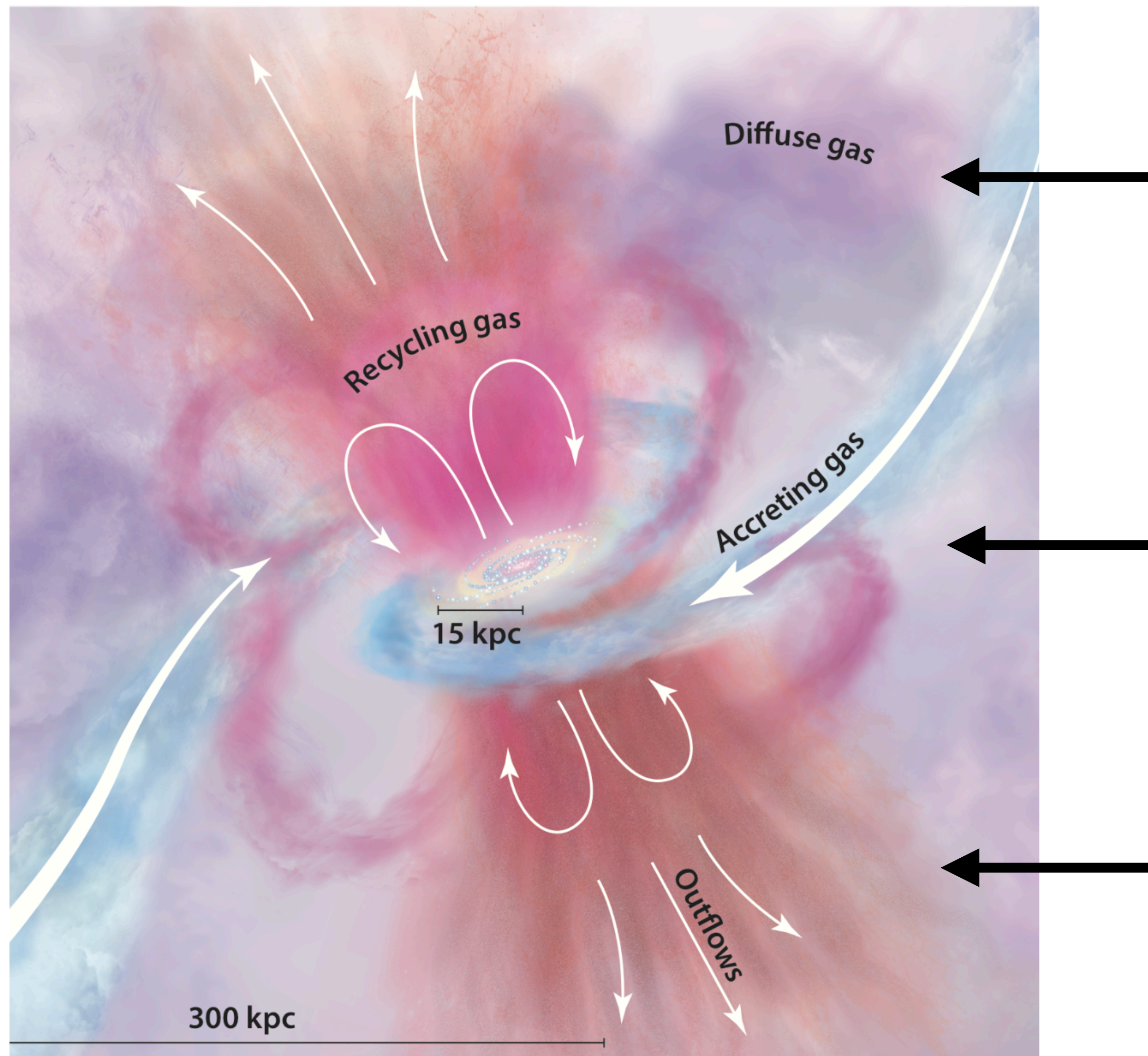


Some open questions on global CGM properties



Tumlinson, Peebles & Werk (ARA&A, 2017)

ICM: $\epsilon_{\text{thermal}} \gg \epsilon_{\text{other}}$
CGM: which **energy term** dominates?

How do galaxies **accrete** gas?

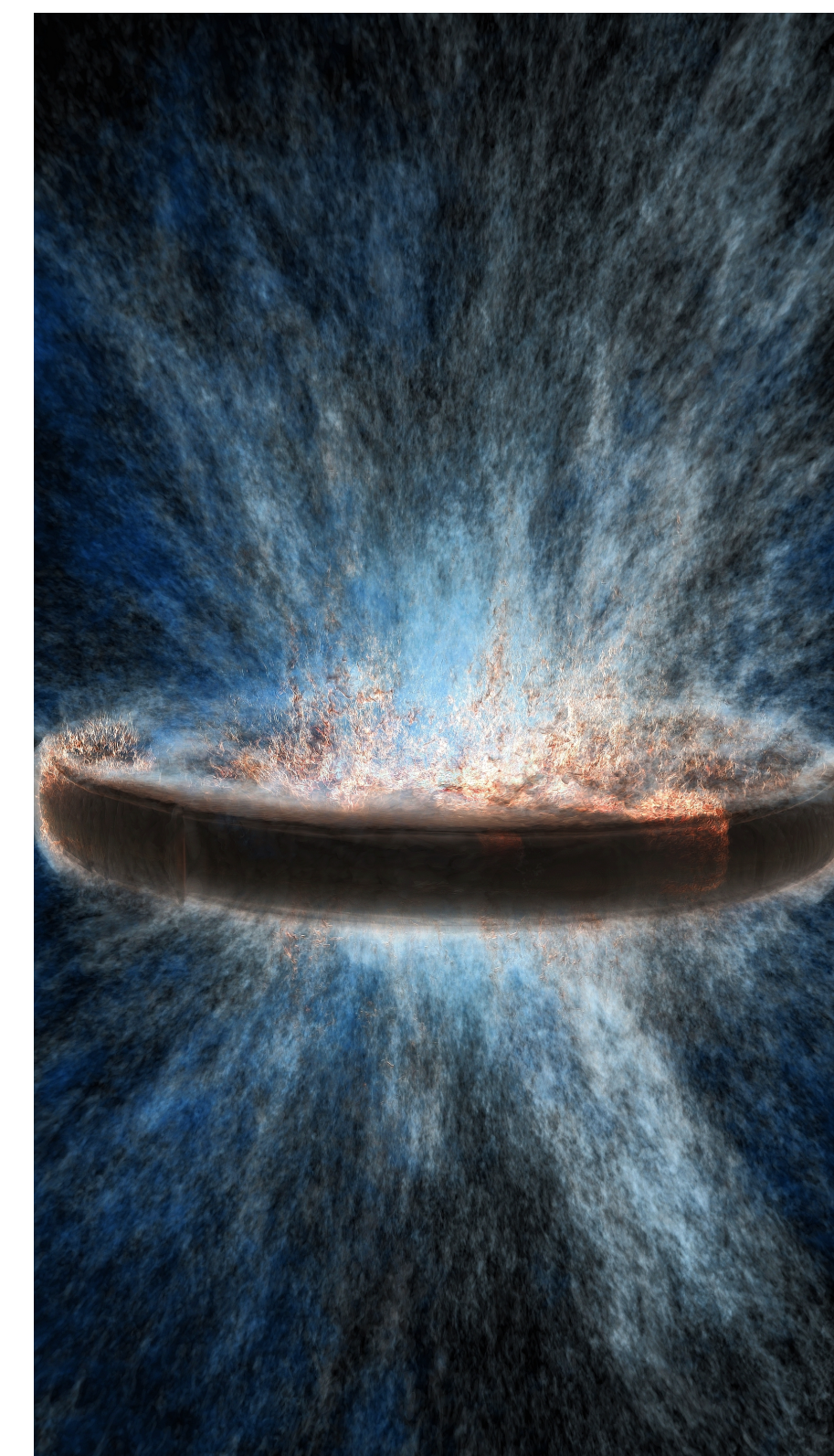
How far into the CGM do **outflows** reach?

answers depend on mass, redshift, radius

How far do *outflows* reach?

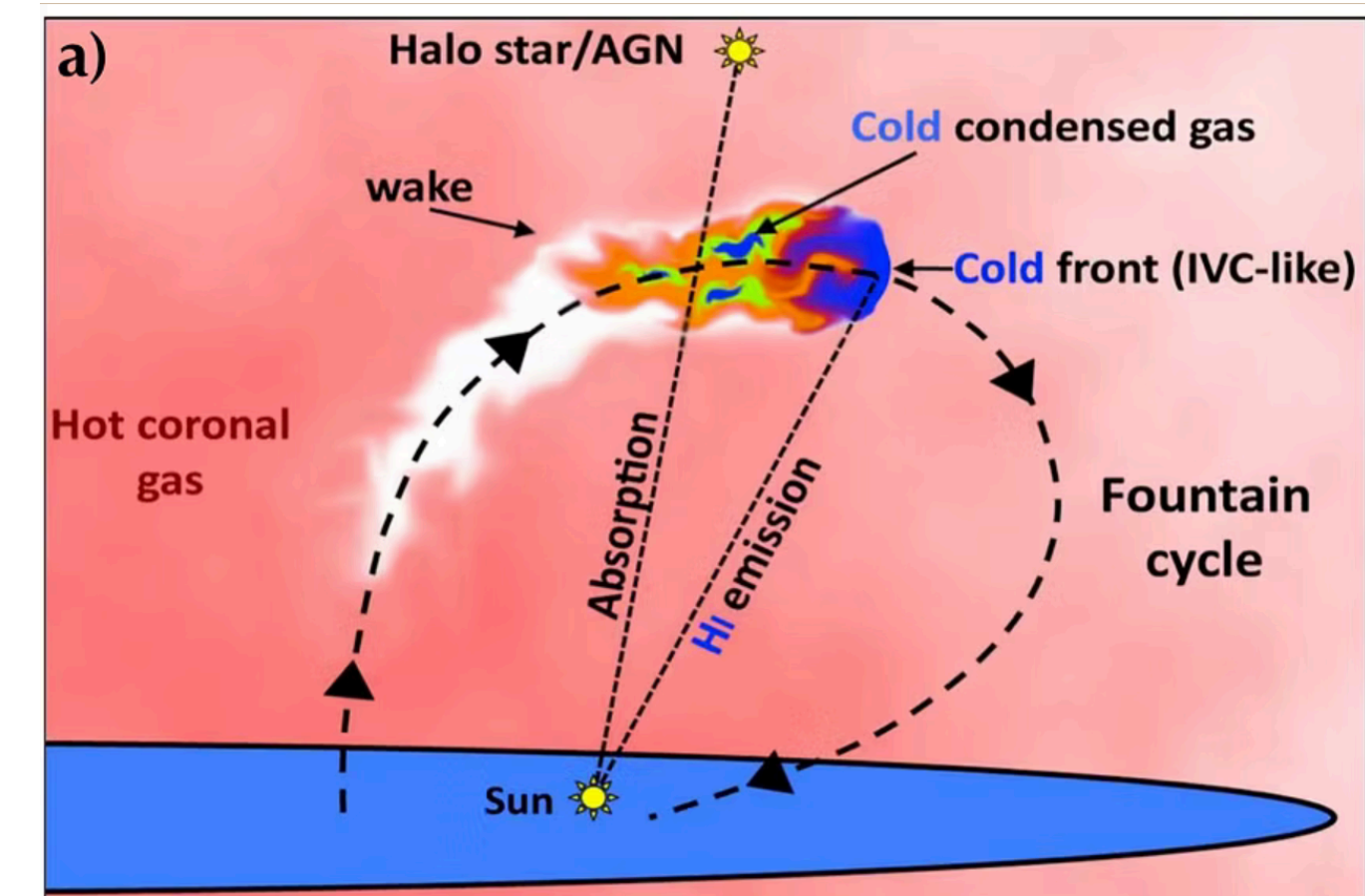
versus halo mass and redshift

- What is the lifetime/duty cycle of strong outflows?
- Where are the outflow mass and energy deposited?
(two distinct questions, e.g. J. Bennett's talk)
- How do different driving mechanisms (hot gas, CRs, ...) affect outflow extent?



Cholla sims
(E. Schneider)

or



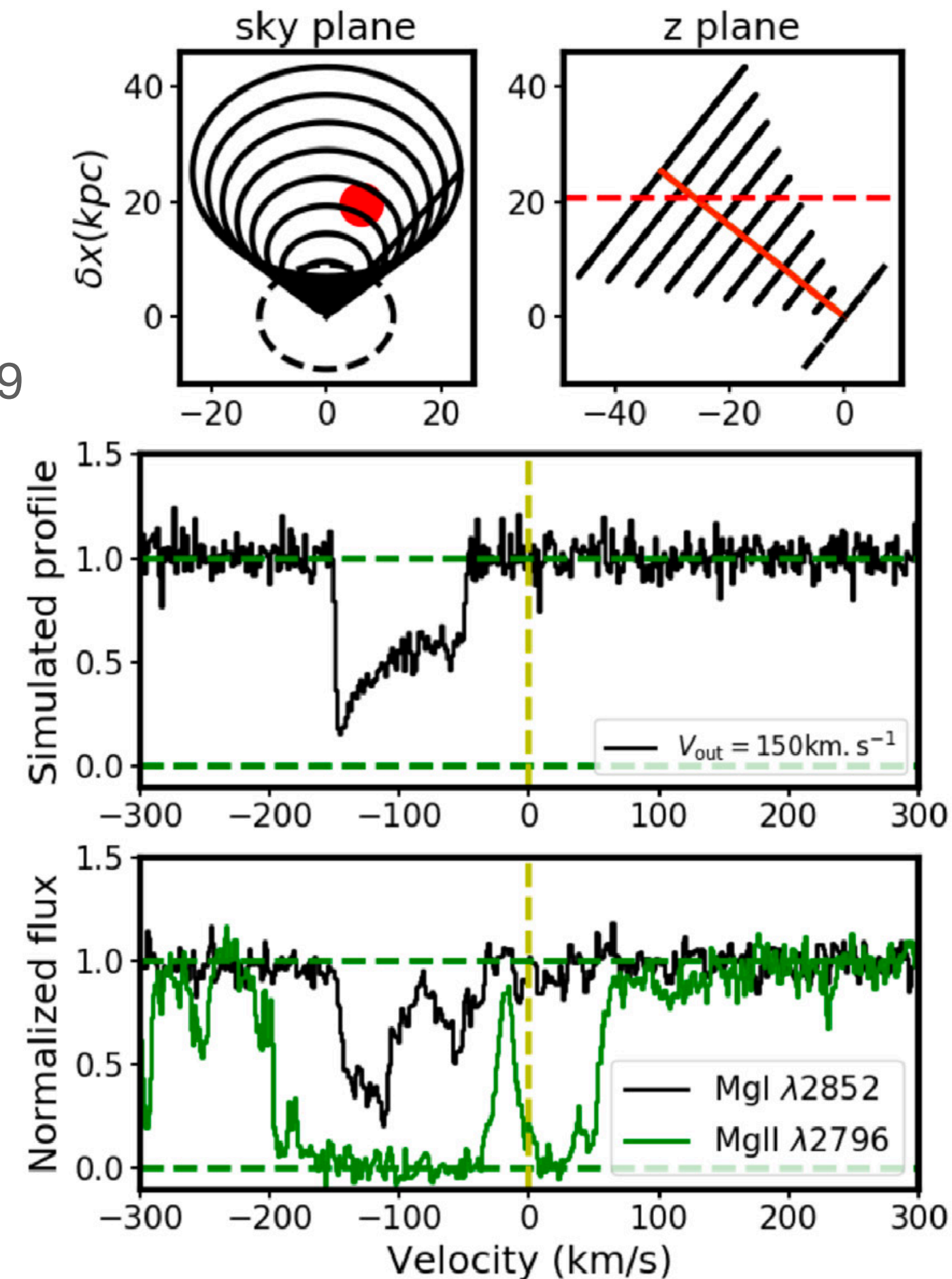
Fountain
flows
(F. Fraternali)

How far into the CGM can we actually trace *outflows*? and for how long do they stay detectable?

Bkgr absorption: mostly 1 sightline per object!

→ large samples + model assumptions

MEGAFLOW;
Schroetter+2019

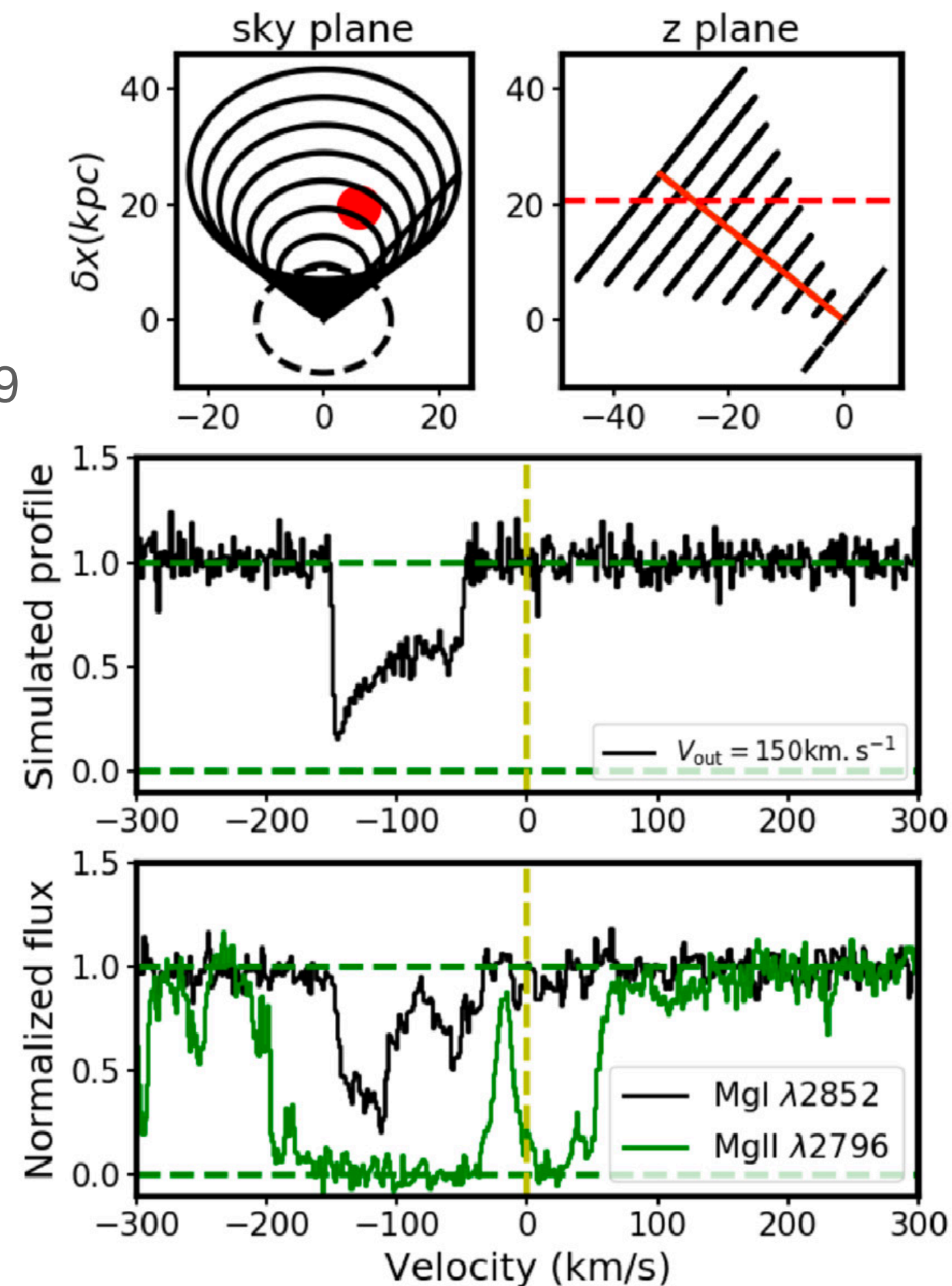


→ talk by Bouché

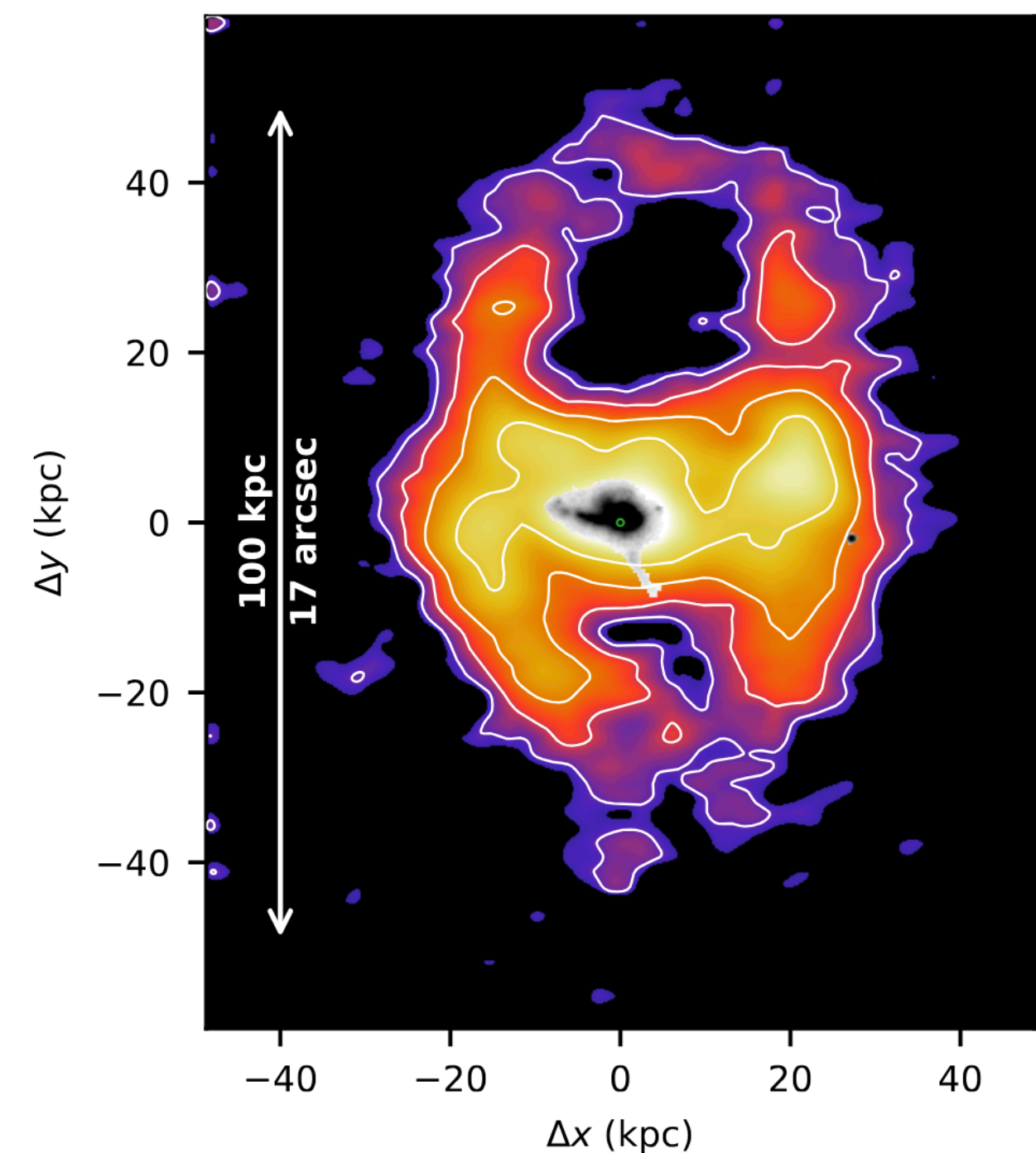
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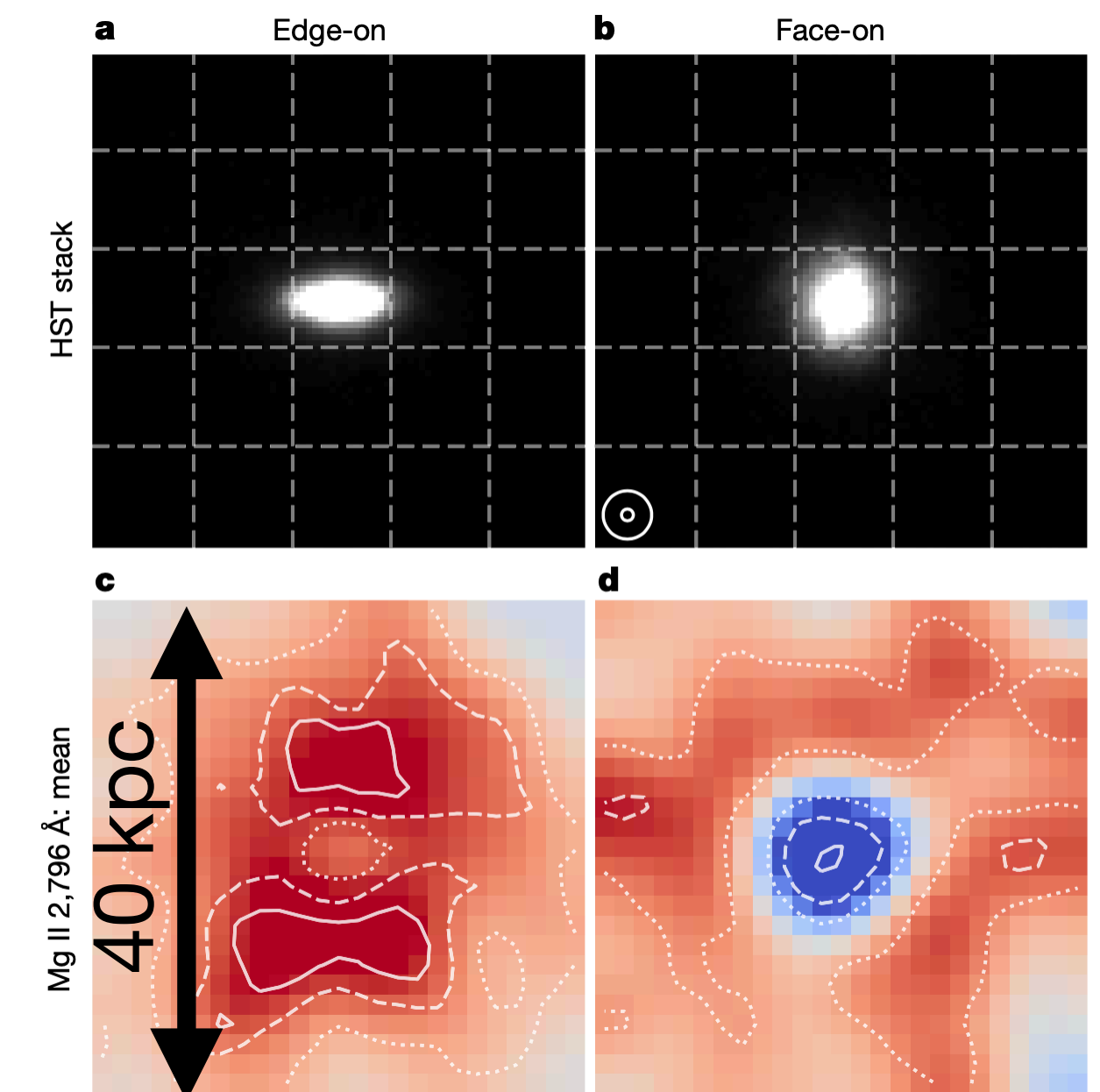
MEGAFLOW;
Schroetter+2019



In emission: very low surface brightness!
→ extreme objects; stacking.



Makani [OII] nebula; Rupke+2019



Stack of MgII from MUSE XDF;
Guo+2023

more individual cases: Zabl+2021; Leclercq+2022, Pessa+2024, Pessa talk ...

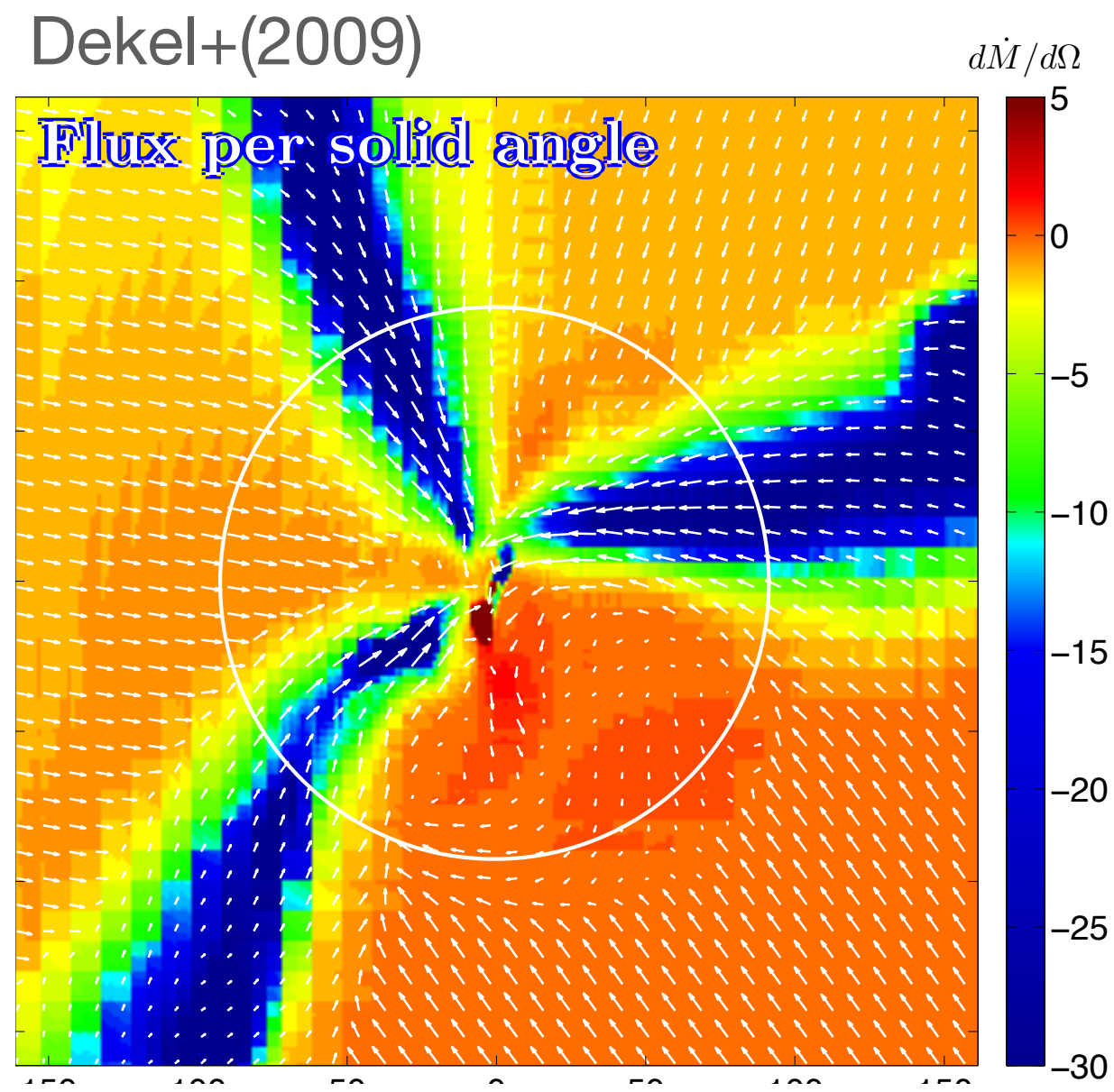
→ probes of the brightest phases, not of final stages.

What can we do? Combine absorption + emission?

→ talk by Bouché

What is the nature of CGM *inflows*?

versus M_{halo} , z and radius



Cold flows

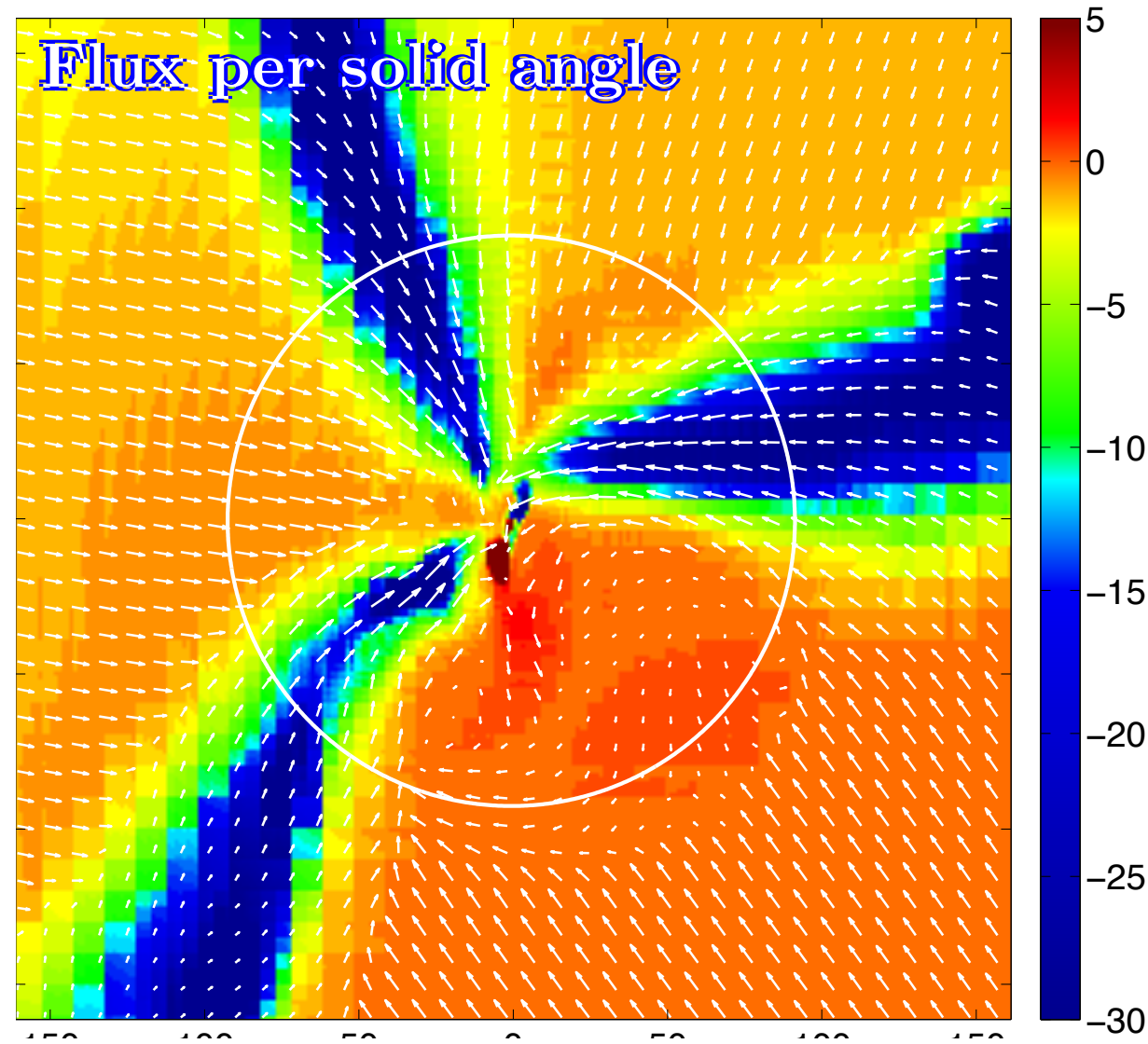
requires:

- narrow filaments
- filaments surviving instabilities

What is the nature of CGM *inflows*?

versus M_{halo} , z and radius

Dekel+(2009)

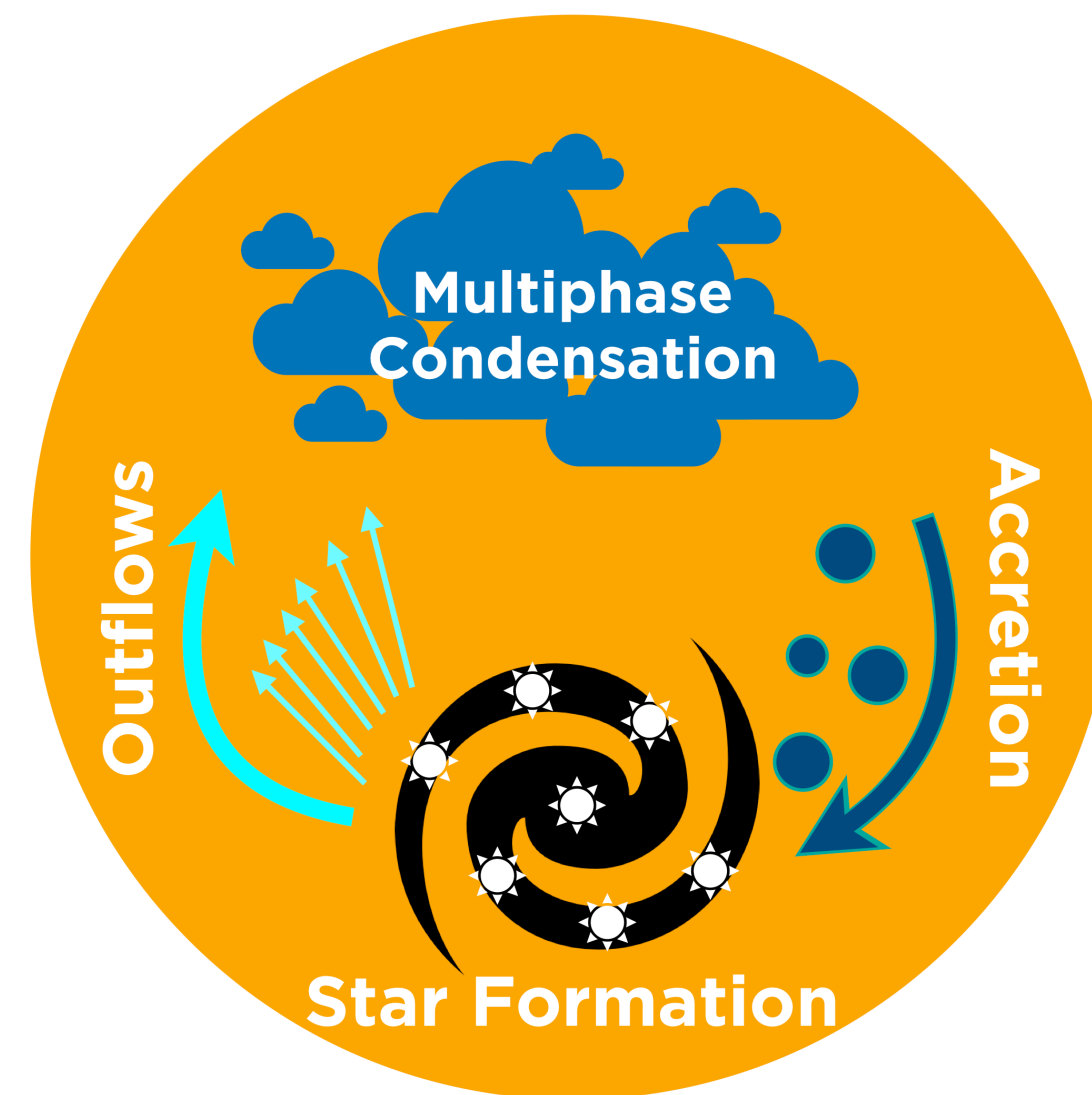


Cold flows

requires:

- narrow filaments
- filaments surviving instabilities

graphic: D. Fielding



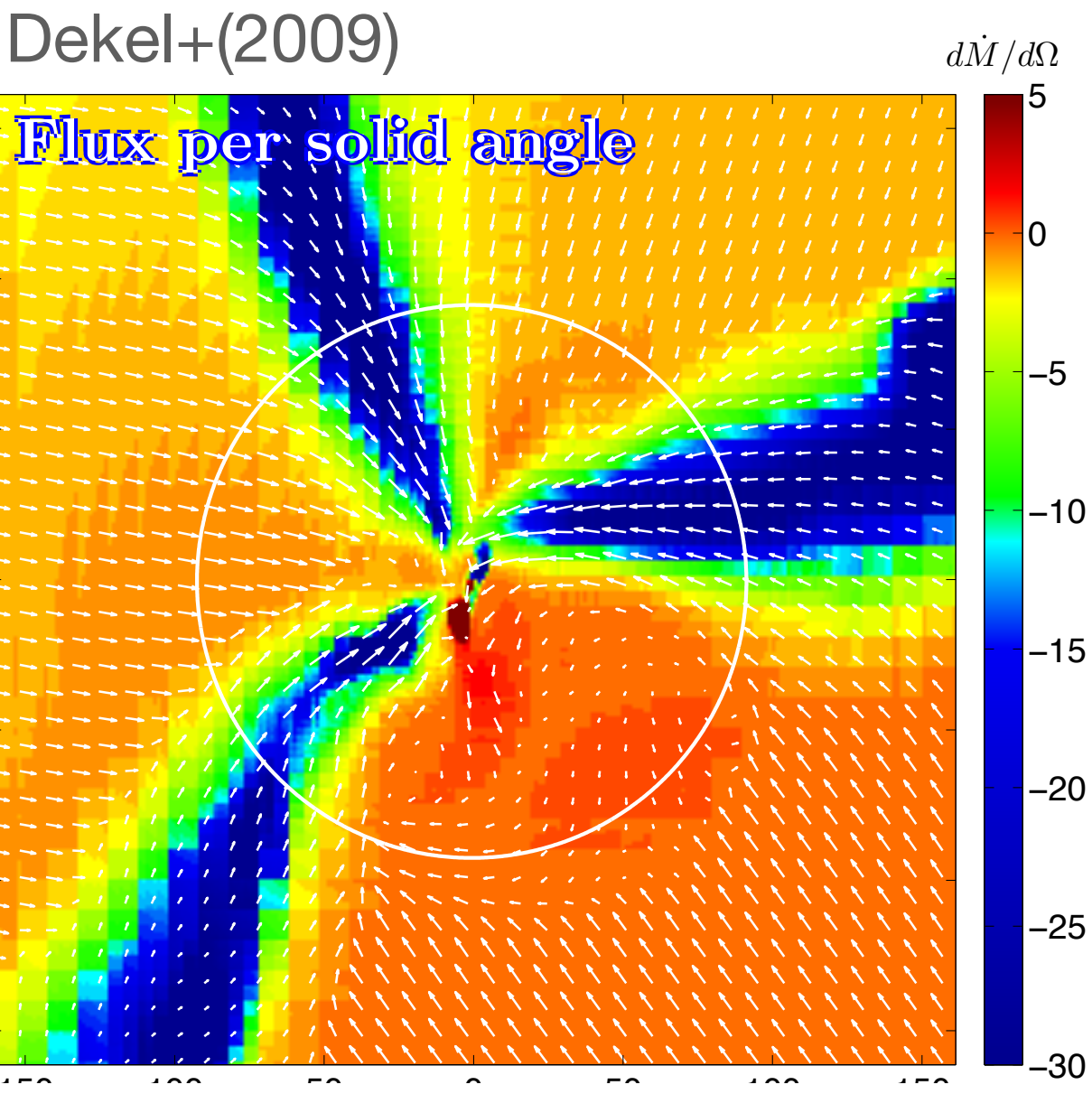
Sinking cool clouds ('precipitation')

requires:

- heating \approx cooling
- clouds surviving instabilities
(Gronke+, Afruni+, Weber+, ...)

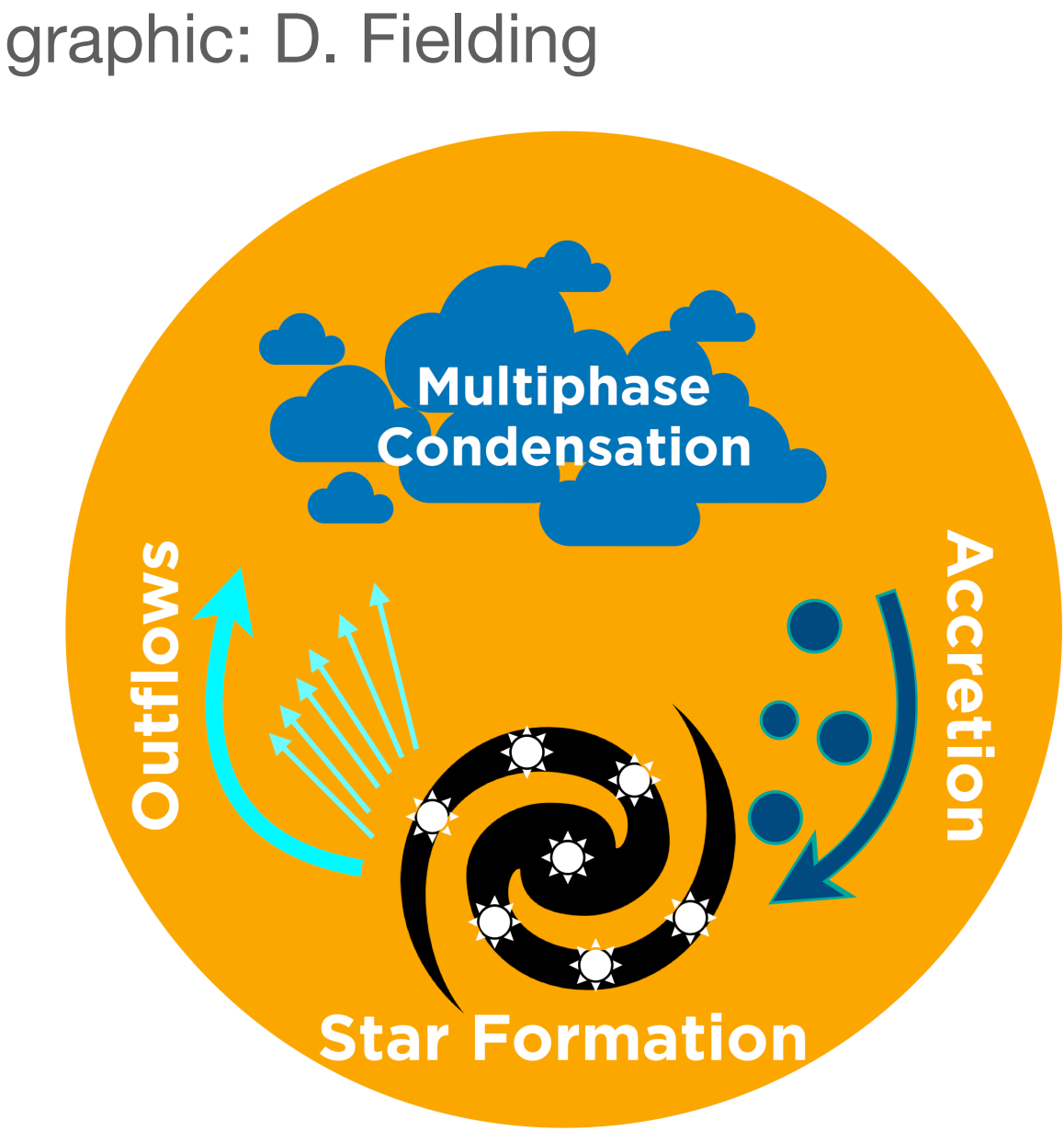
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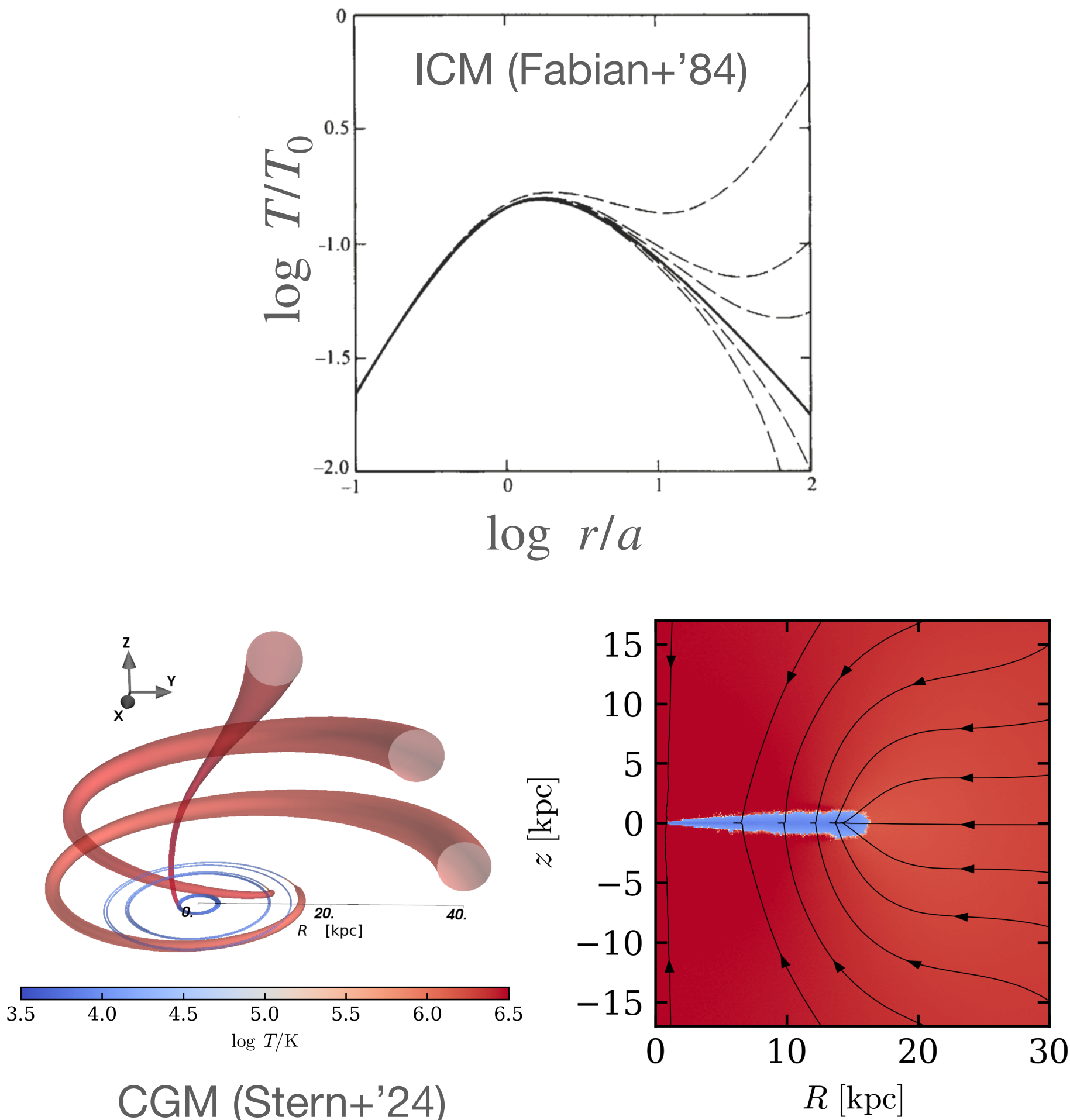
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Sinking cool clouds ('precipitation')

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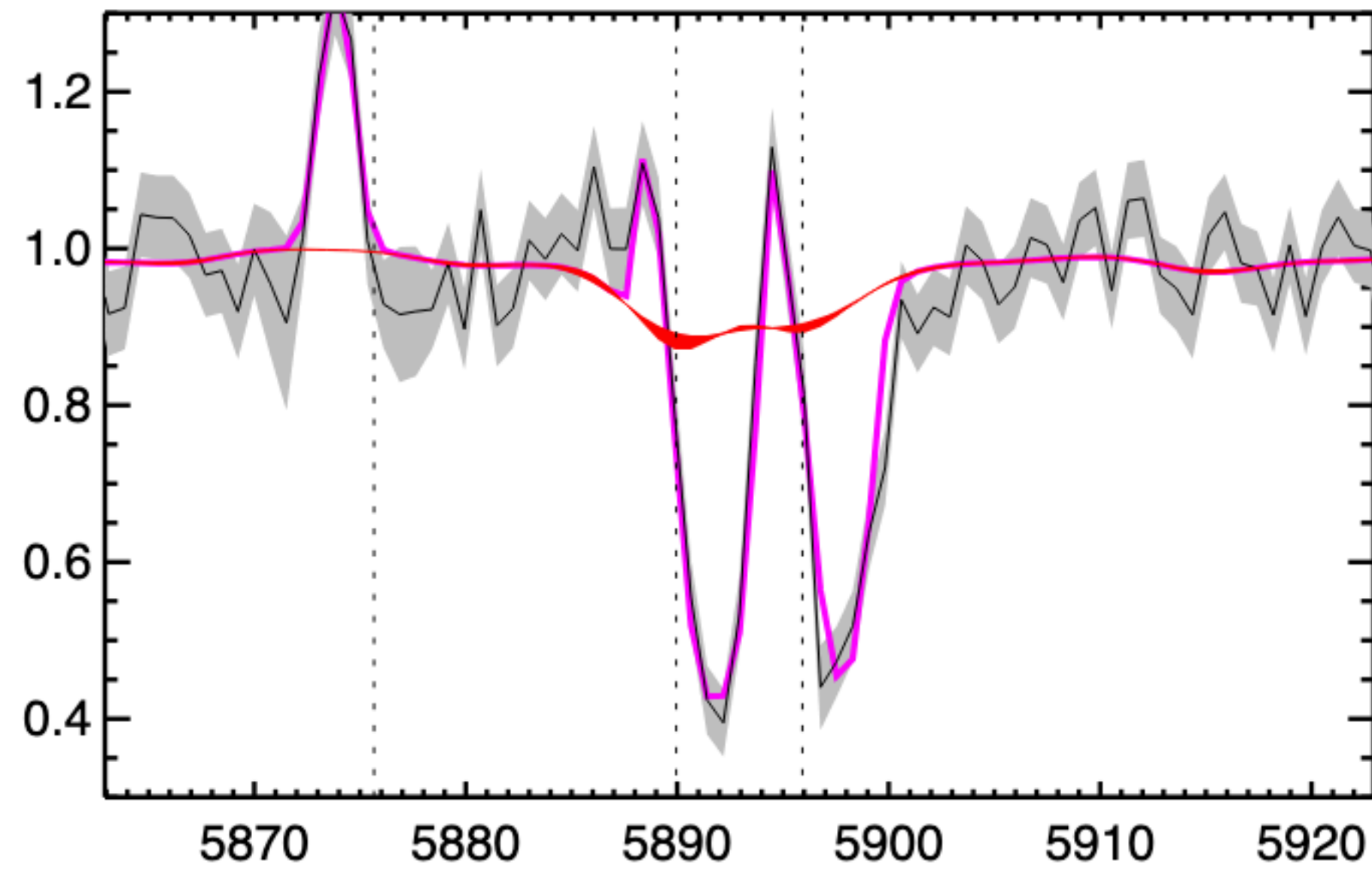


CGM (Stern+'24)

- Inflows in hot phase ('cooling flows')
- requires:
- heating $<$ cooling

What are the prospects to observe *accretion*?

Down-the-barrel redshifted absorption
in some galaxies:

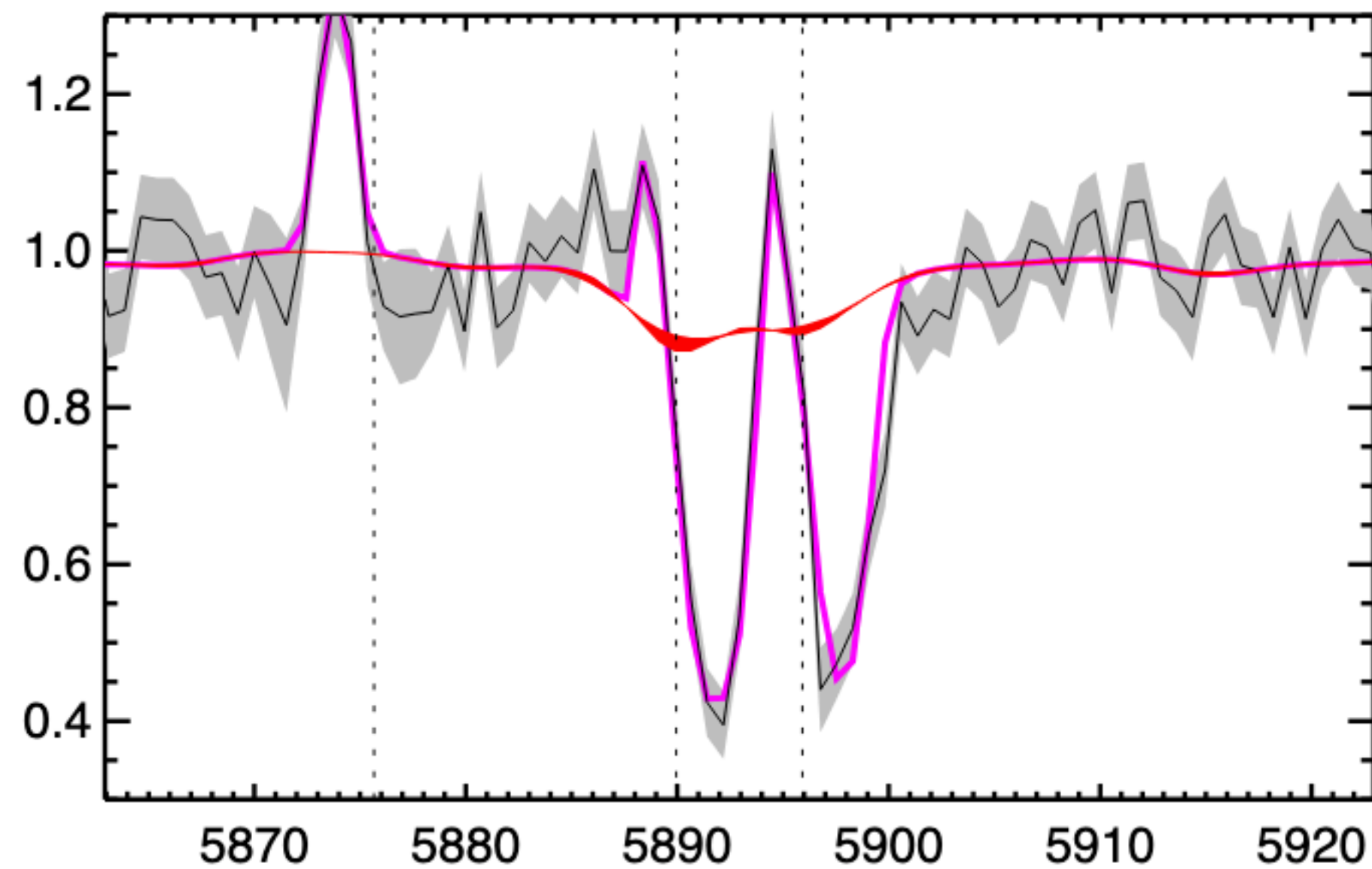


Na I in NGC 1808; Rupke+2021

– but very often swamped by outflows!

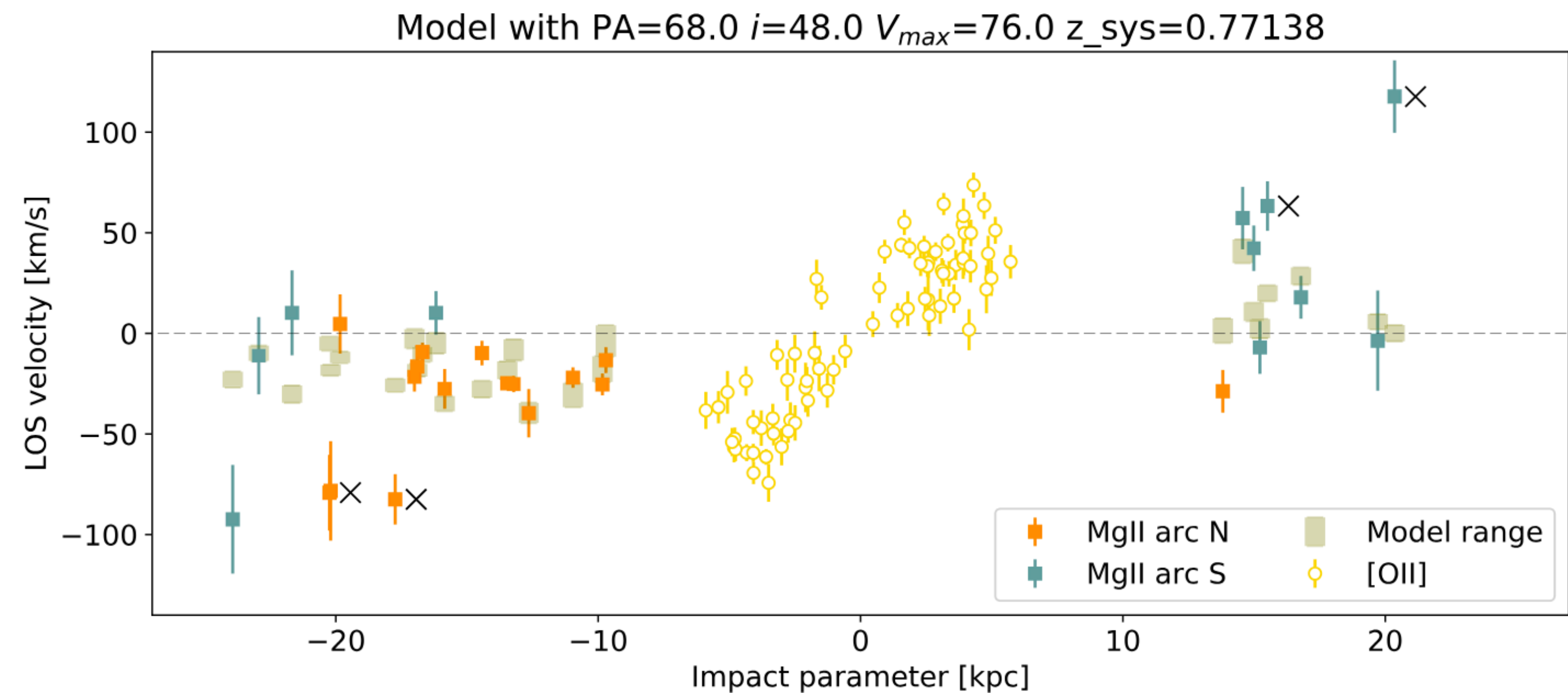
What are the prospects to observe *accretion*?

Down-the-barrel redshifted absorption in some galaxies:



Na I in NGC 1808; Rupke+2021

Bkgr absorption: Kinematic linking to host galaxy disc



MgII absorption & [OII] emission velocities; Tejos+2022

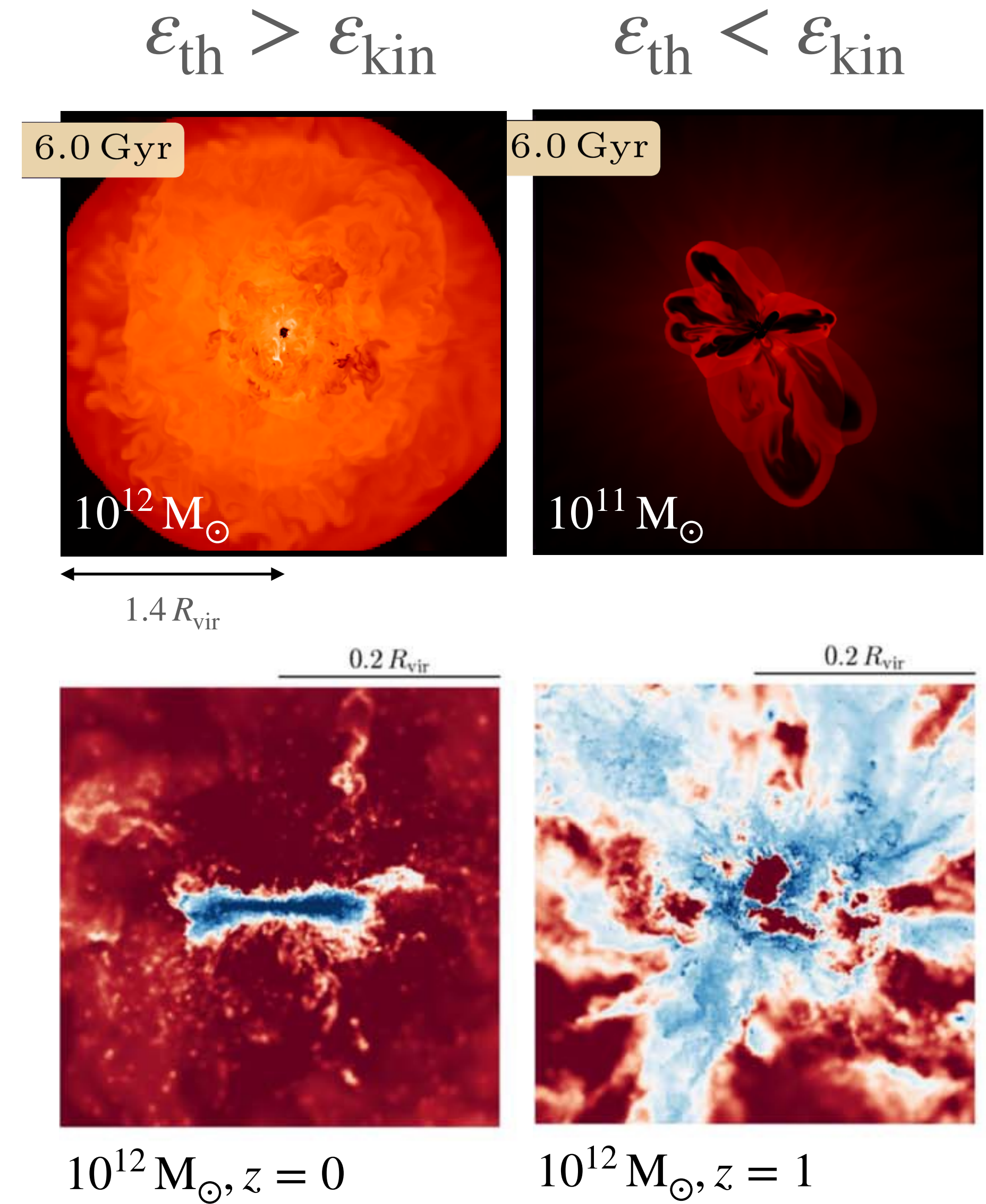
– but very often swamped by outflows!

- But does accretion really happen mainly in the disc plane
- (Are we seeing just what we are looking for?)

Which energy term dominates?

versus M_{halo} , z and radius

- \gtrsim MW mass at $z \sim 0$: sims and observations (X-ray, SZ, low HVC covering fraction) suggest **thermal energy** dominates
- Lower mass/higher z : sims indicate **kinetic energy** may dominate



Top: Idealized sims (Fielding+'17)

Bottom: FIRE sims (Stern+'21)

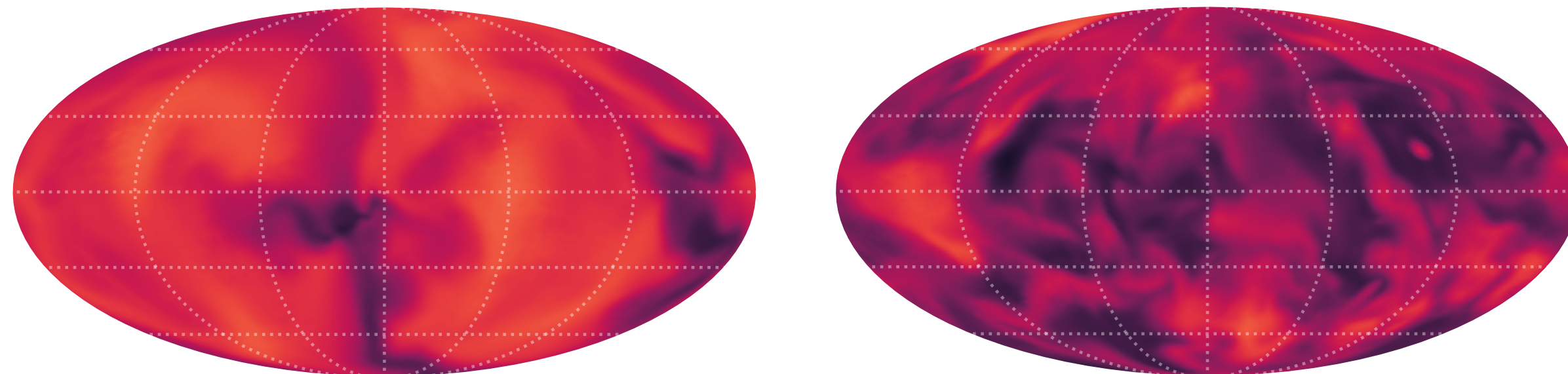
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- Lower mass/higher z : sims indicate **kinetic energy** may dominate
- CRMHD sims: **CR energy** may dominate (F. Rodrigues-Montero and Weber's talk, Ji+'20)

HD: $\epsilon_{\text{th}} > \epsilon_{\text{CR}}$

CRMHD: $\epsilon_{\text{th}} < \epsilon_{\text{CR}}$



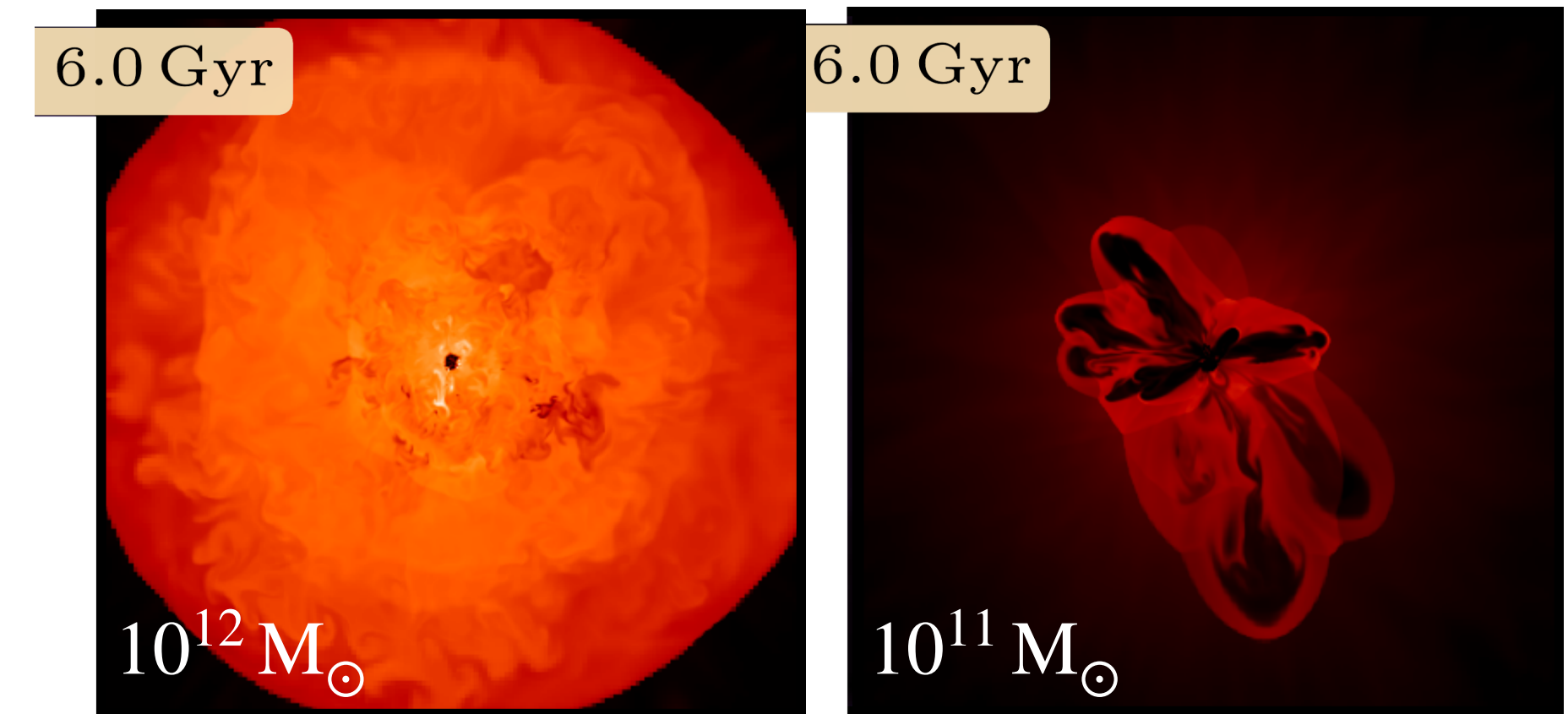
$\log(T/\text{K})$



Rodríguez Montero+'24

$\epsilon_{\text{th}} > \epsilon_{\text{kin}}$

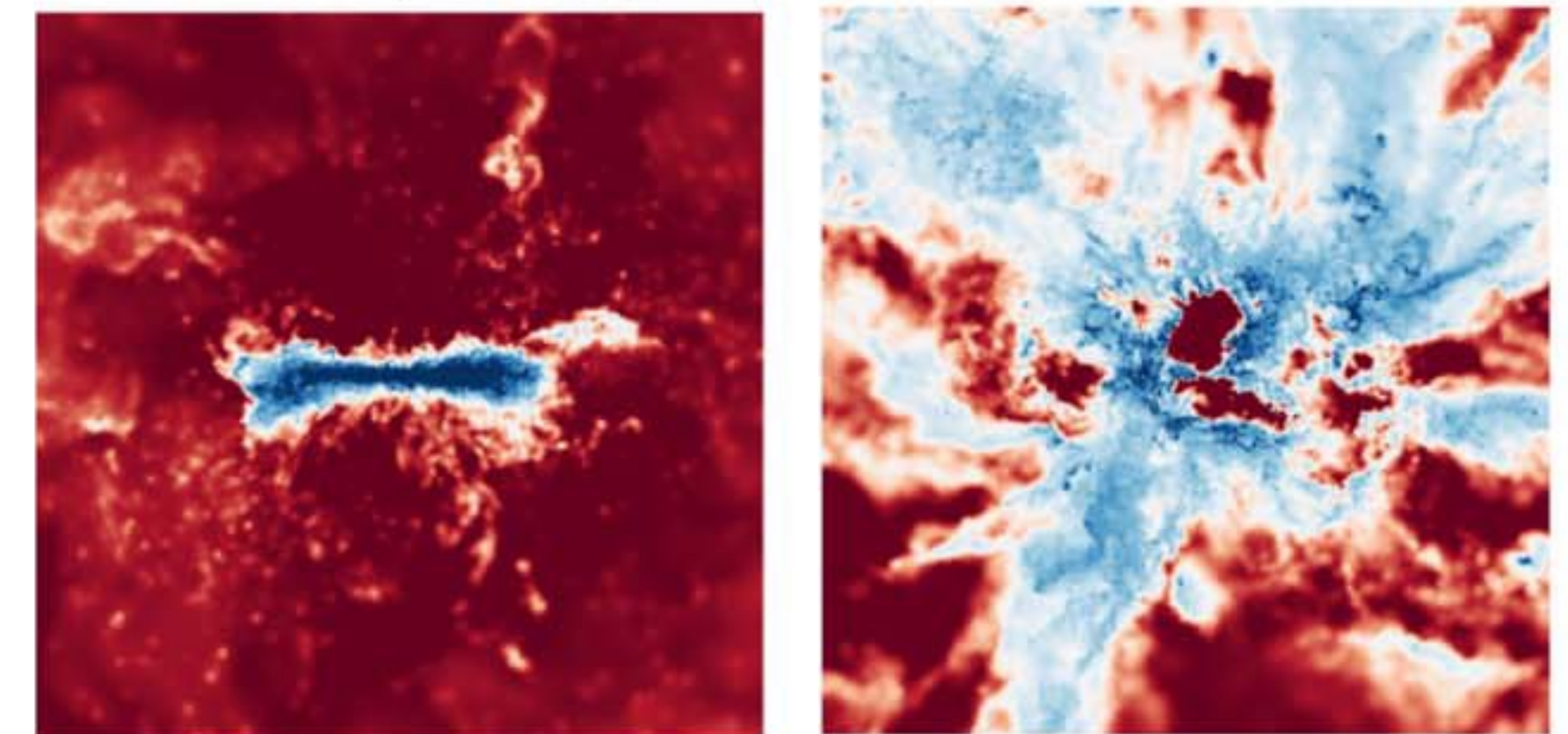
$\epsilon_{\text{th}} < \epsilon_{\text{kin}}$



$1.4 R_{\text{vir}}$

$0.2 R_{\text{vir}}$

$0.2 R_{\text{vir}}$



$10^{12} M_{\odot}, z = 0$

$10^{12} M_{\odot}, z = 1$

Top: Idealized sims (Fielding+'17)

Bottom: FIRE sims (Stern+'21)

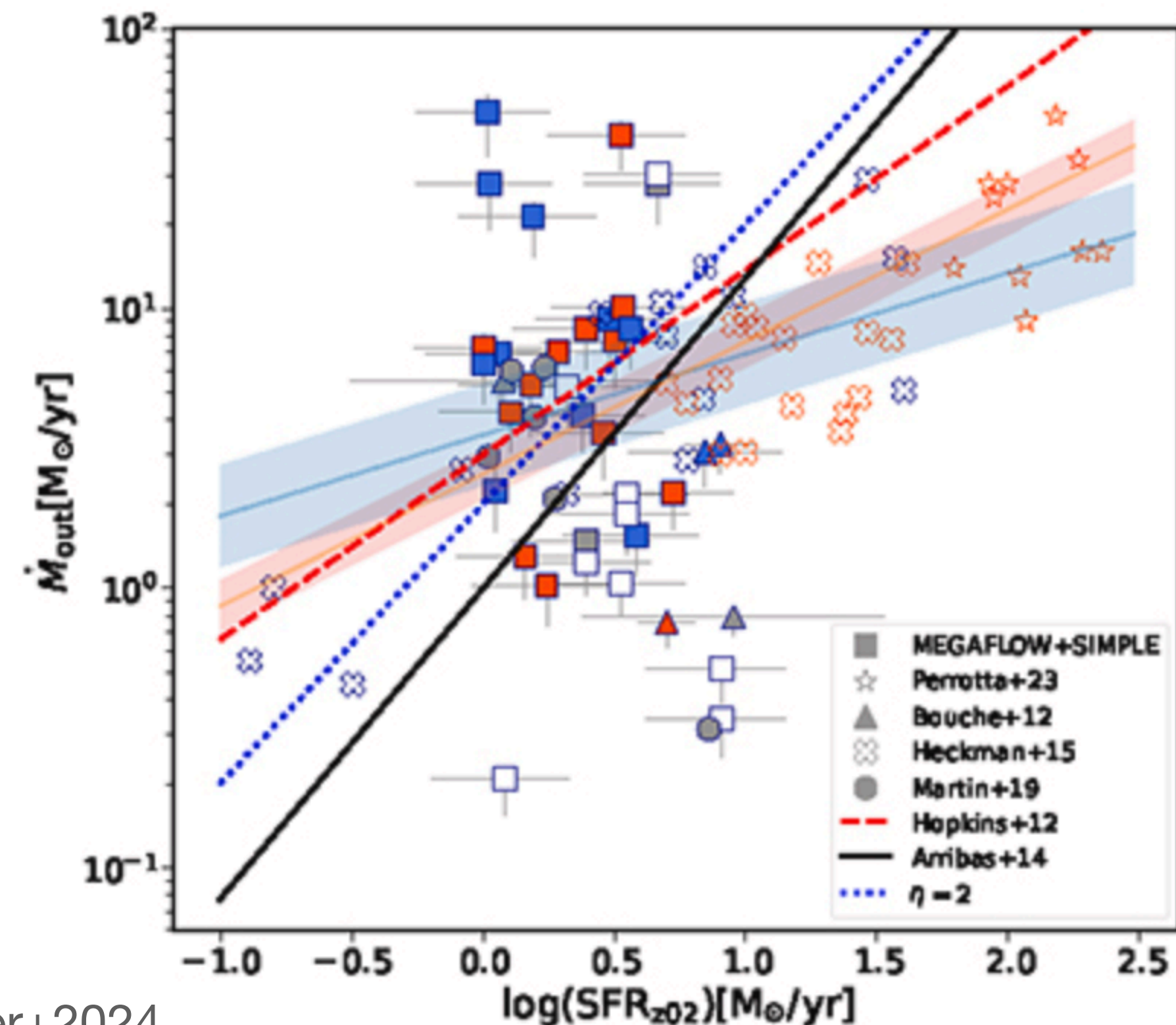
If thermal energy is sub-dominant in CGM, what are the implications for:

- the multi-phase CGM picture?
- ‘wind tunnel’ simulations?
- ‘multi-fluid’ simulations?
(H.-K. Das and R. Weinberger’s talks)
- UV absorption modelling?
e.g. CUBS (H.-W. Chen’s talk), MEGAFLOW (N. Bouche’s talk), COS-Halos/Dwarfs
- Models of MgII-halos and CGM emission? (I. Pessa and N. Bouche’s talks)

Mass and energy input into the CGM: Observational uncertainties

Mass budget in observed outflows: relying on many assumptions (→ talk by Belli)

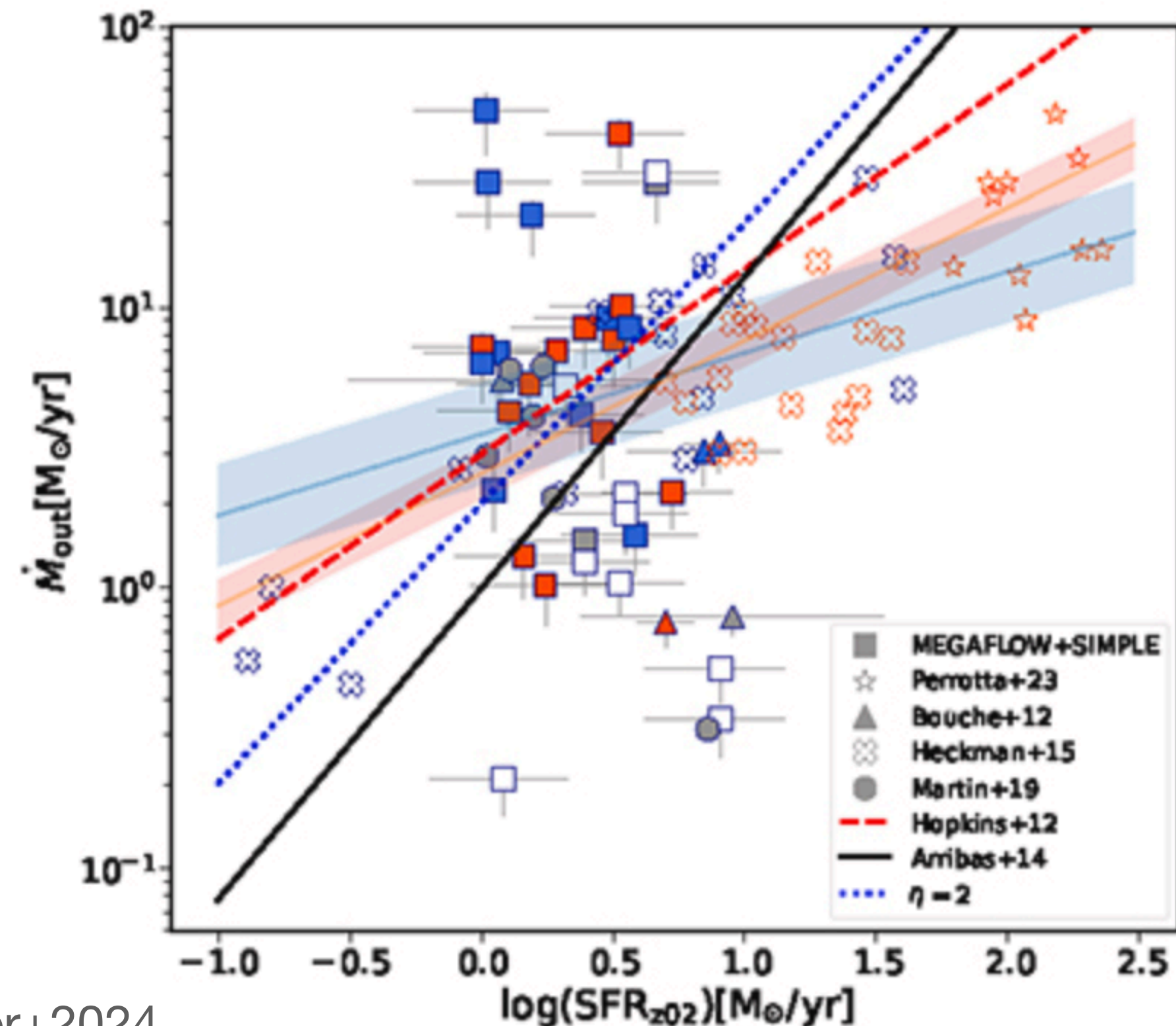
- [M/H]? depletion into dust? ionisation correction?
- Clumping?
- Mass conservation in outflow / wind?



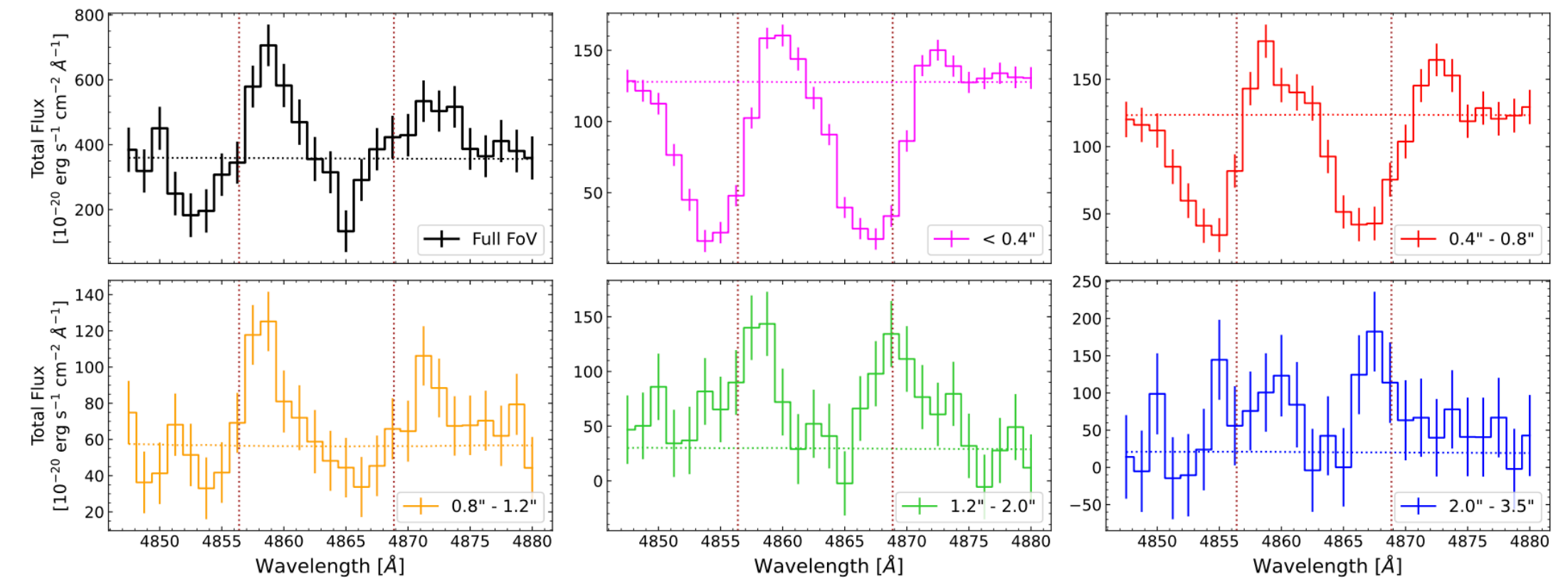
Mass and energy input into the CGM: Observational uncertainties

Mass budget in observed outflows: relying on many assumptions (\rightarrow talk by Belli)

- $[M/H]$? depletion into dust? ionisation correction?
- Clumping?
- Mass conservation in outflow / wind?



Pessa+2024



CGM kinematics:

- Mean/max outflow velocities $\rightarrow v(r) = ?$
- Multi-component lines \leftrightarrow simple models?
- Bulk motion \leftrightarrow turbulence?
- Transverse “frozen” images \leftrightarrow radial velocities?

CGM Discussion

- How far do *outflows* reach?
- What is the nature of CGM *inflows*?
- Which *energy term* dominates in the CGM?
- More questions from the audience?