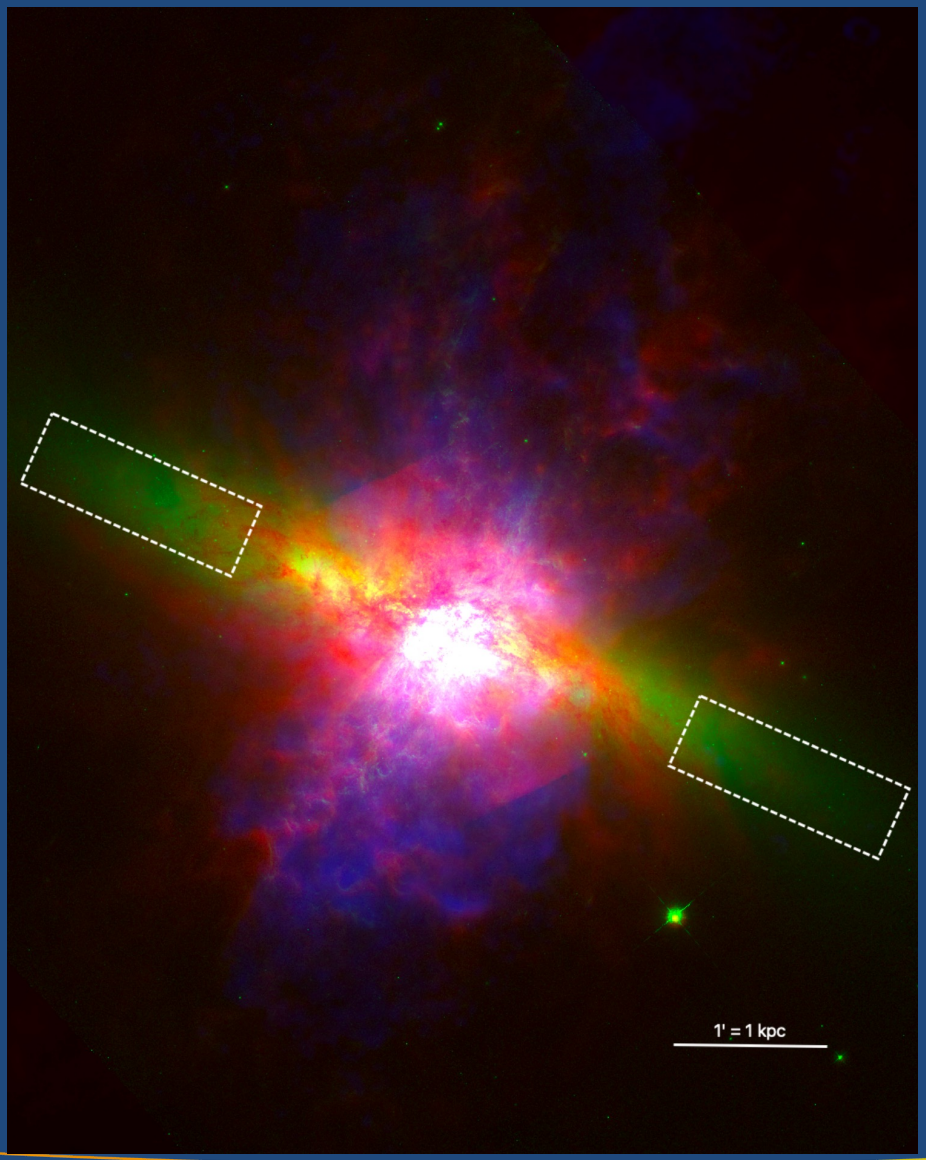
Leibniz-Institut für
Astrophysik Potsdam

Thinkshop Discussion: Simulation Challenges

Simulation challenges: physics

- **Multi-phase ISM & CGM: a multi-scale/multi-physics challenge**
- **Understanding galactic winds: a multi-physics challenge**
- **SN/AGN feedback: resolution gap**
- **The role of filaments**

1. Multi-phase ISM & CGM: a multi-scale challenge



Lopez+ 2025:

- Three color image of M82; blue is broad-band (0.5-7 keV) Chandra X-rays, green is the HST image, and red is Spitzer 8 μm IR emission

- White dashed boxes are the areas used for the continuum subtraction

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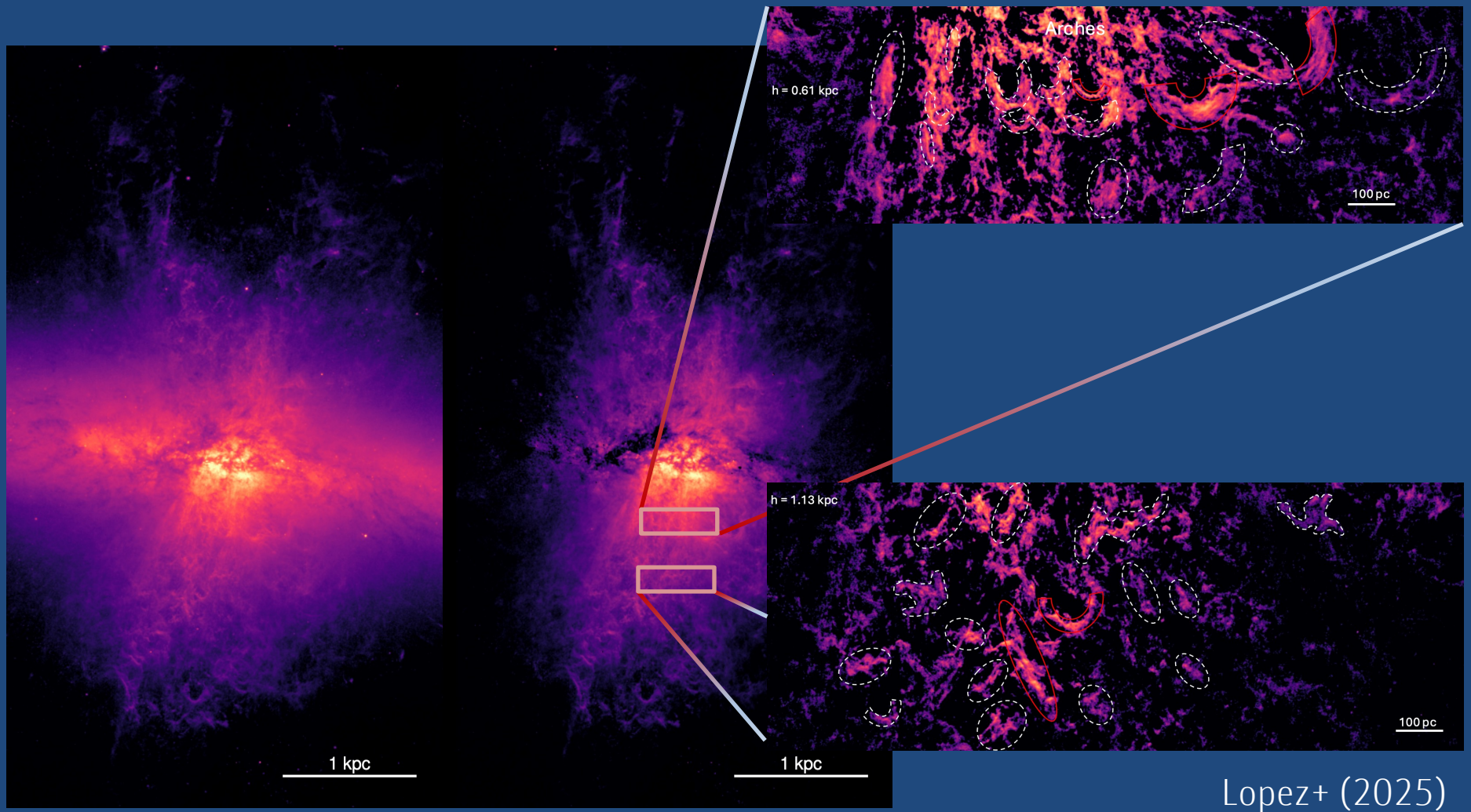

Lopez+ (2025)

Left: HST image with starlight
Right: stellar continuum subtracted image

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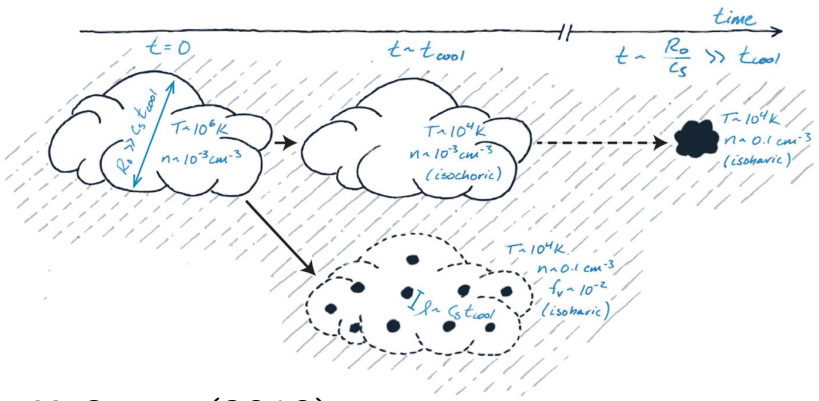
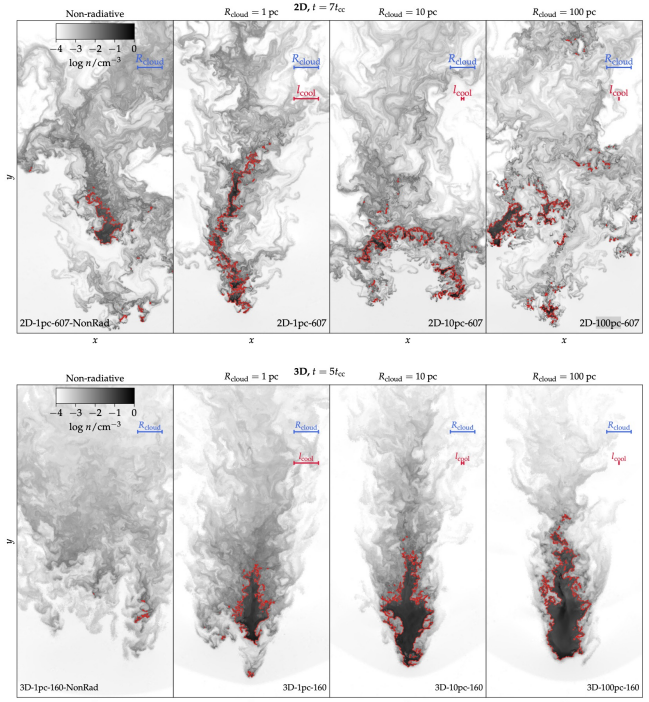


McCourt+ (2018)

$$\ell_{\rm cloudlet} \sim \min\left(c_{\rm s} t_{\rm cool}\right) \sim (0.1\,{\rm pc}) \left(\frac{n}{\rm cm^{-3}}\right)^{-1}$$

$$N_{\rm cloudlet} = n\,\ell_{\rm cloudlet} \sim 10^{17}\,{\rm cm^{-2}}$$



Sparre+ (2019)

→ 3D: geometrical shielding relativ to 2D

Complications:

- Cloud growth/destruction depends on cloud size (or gas transfer rate)
- Gravitational stratification changes background and outcome of the shattering problem for thermal instability and winds
- Multi-physics: magnetic fields, cosmic rays, thermal conduction, turbulence, …
- Crucial for Jellyshish galaxy tails (Sparre+ 2024)

1. Multi-phase ISM & CGM: a multi-scale challenge

- Poll:
  - The multi-phase structure of ISM/CGM is not necessary to understand galaxy formation
  - There is no hope to resolve the dilute hot phase with current-day cosmological simulations
  - We need to push harder on multi-physics, higher-resolution simulations

- Which aspects of the multi-phase structure are critical for which aspect of the galaxy problem, e.g. photon escape fraction for reionization or ionization fraction of cosmic ray transport?

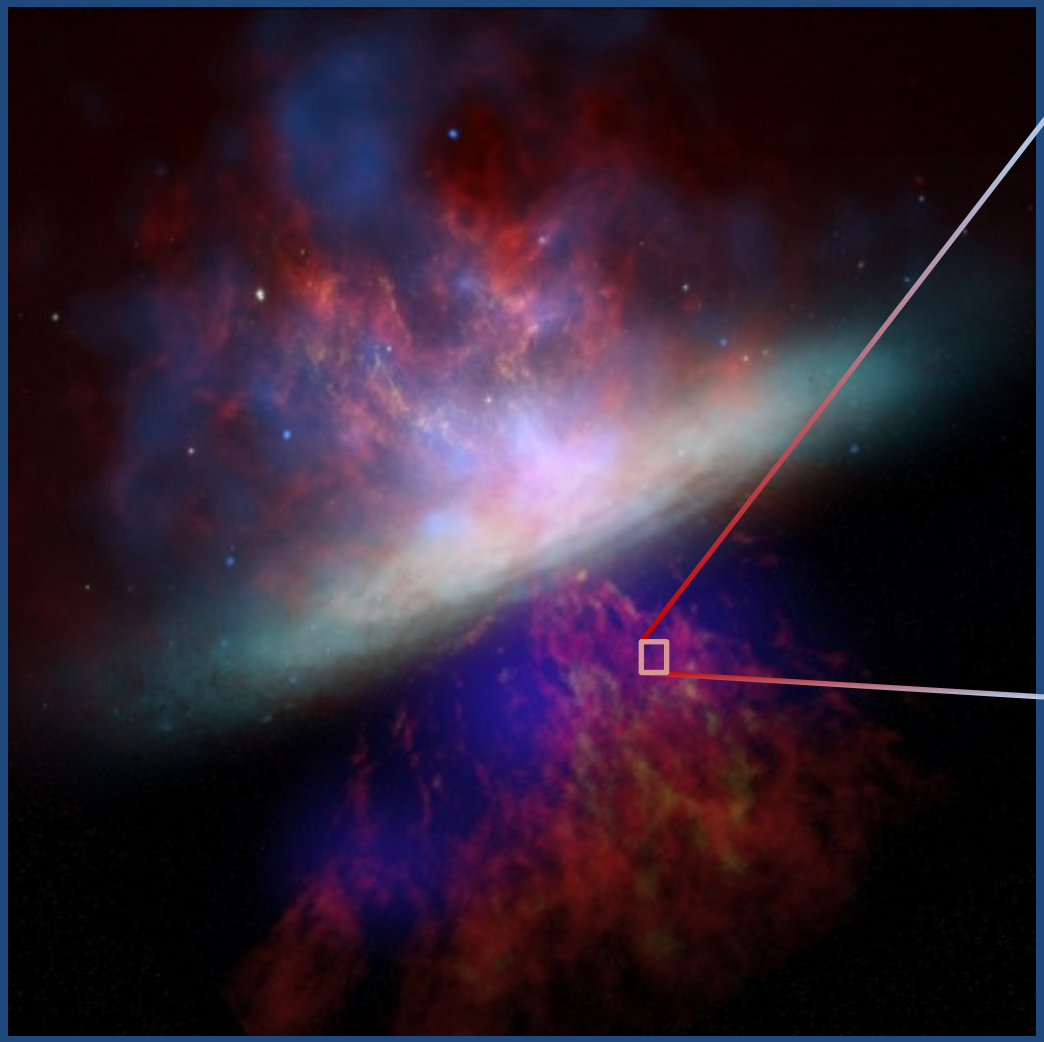
1. Multi-phase ISM & CGM: a multi-physics challenge

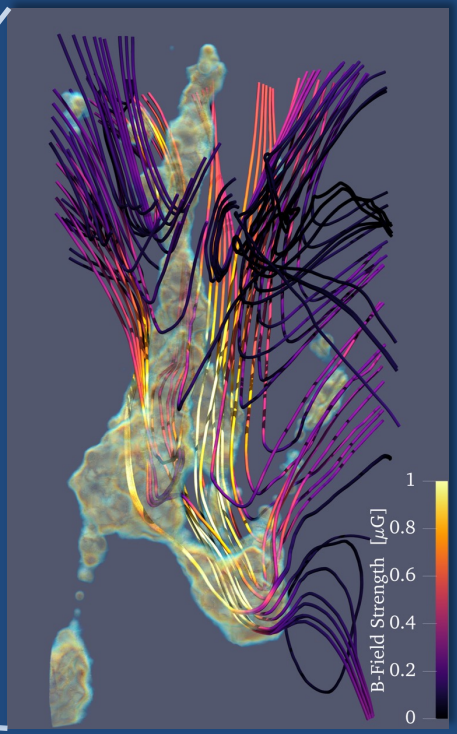
- **Cosmic rays:** Do we need full 2-moment CR transport or can we use an efficient 1-moment/diffusion model? Which CR diffusion coefficient should we choose?

- **Radiation transport:** how much momentum feedback is imparted by radiation (in dense star bursts, star forming galaxies)? how can we model effectively and accurately? is M1 closure enough?

- **Photo-ionisation** is an important local feedback process, changes the ISM phase structure, and enables a hot ISM phase by modifying the ambient density in which SN explode – ISM pre-processing/early stellar feedback: how crucial is this?

2. Understanding galactic winds: a multi-physics challenge





Weber+ (2025)

M82: NASA/ESA
CRISP sim: Thomas/AIP

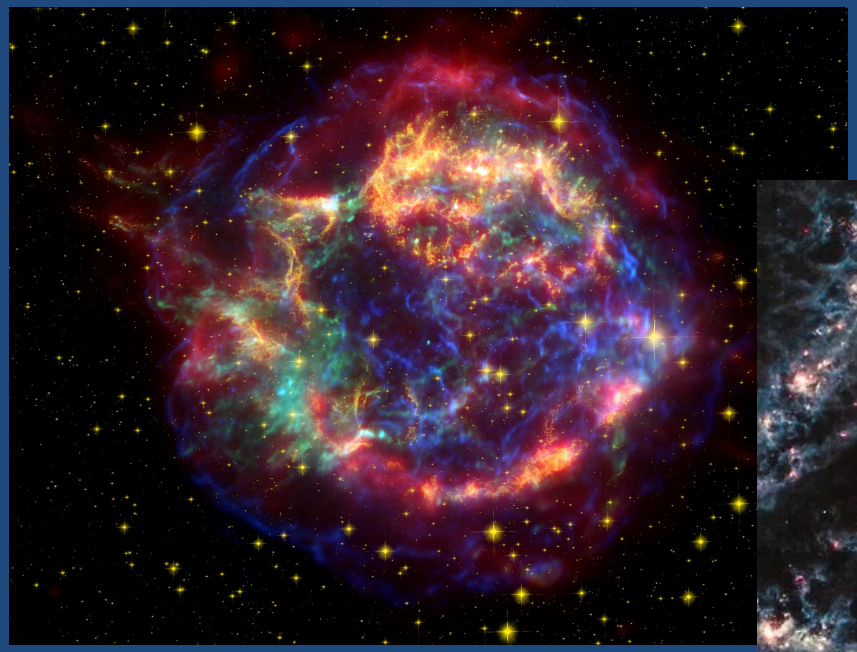
2. Understanding galactic winds: a multi-physics challenge

- How can we progress in modelling multi-phase galactic winds?
  - We ignore the multiphase structure altogether (an implicit choice when using resolutions > 10^4 $M_\odot$)
  - We develop effective models (e.g. multi-fluid models or Lagrangian tracers for the cold phase as in Arcenstone)
  - do we have other ideas?

- How important is the mass ejection model vs. the hot preventive feedback model for understanding the low star conversion efficiency?

- How do we model each in future cosmological simulations?

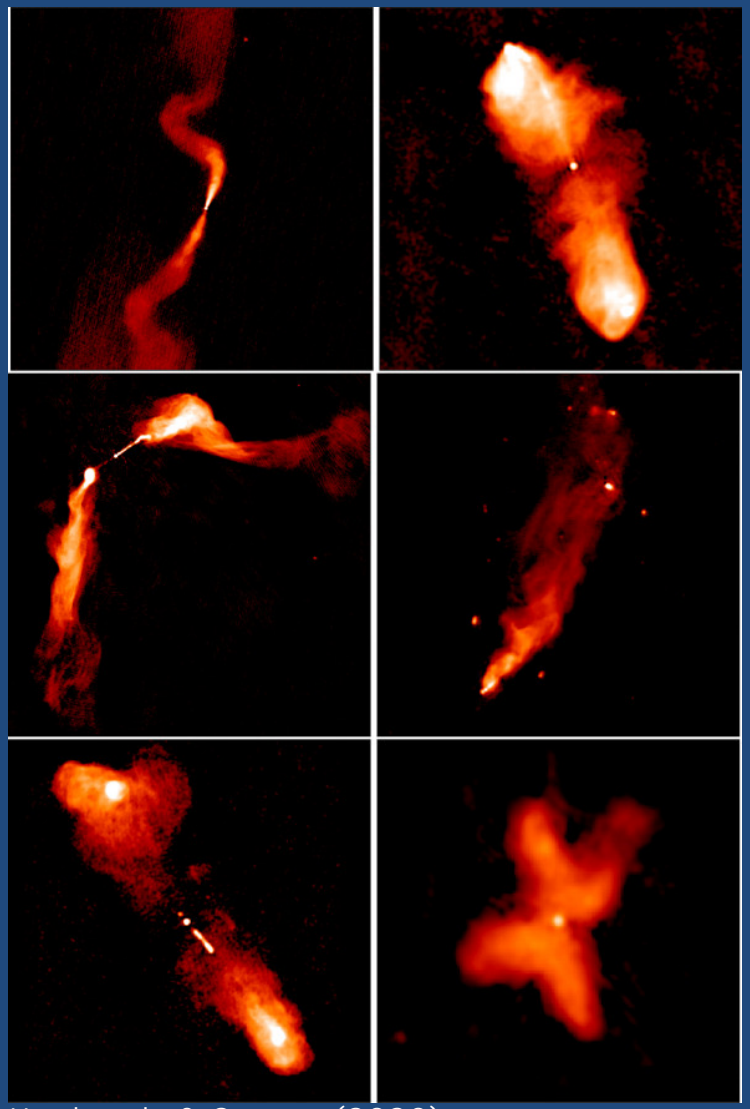
3. Multi-scale challenges for stellar feedback



NASA/ESA/CSA/STSCI/Schmidt

How worried are we about momentum cancelation effects in incompletely resolved of (cosmological) simulations of supernova blown superbubbles?

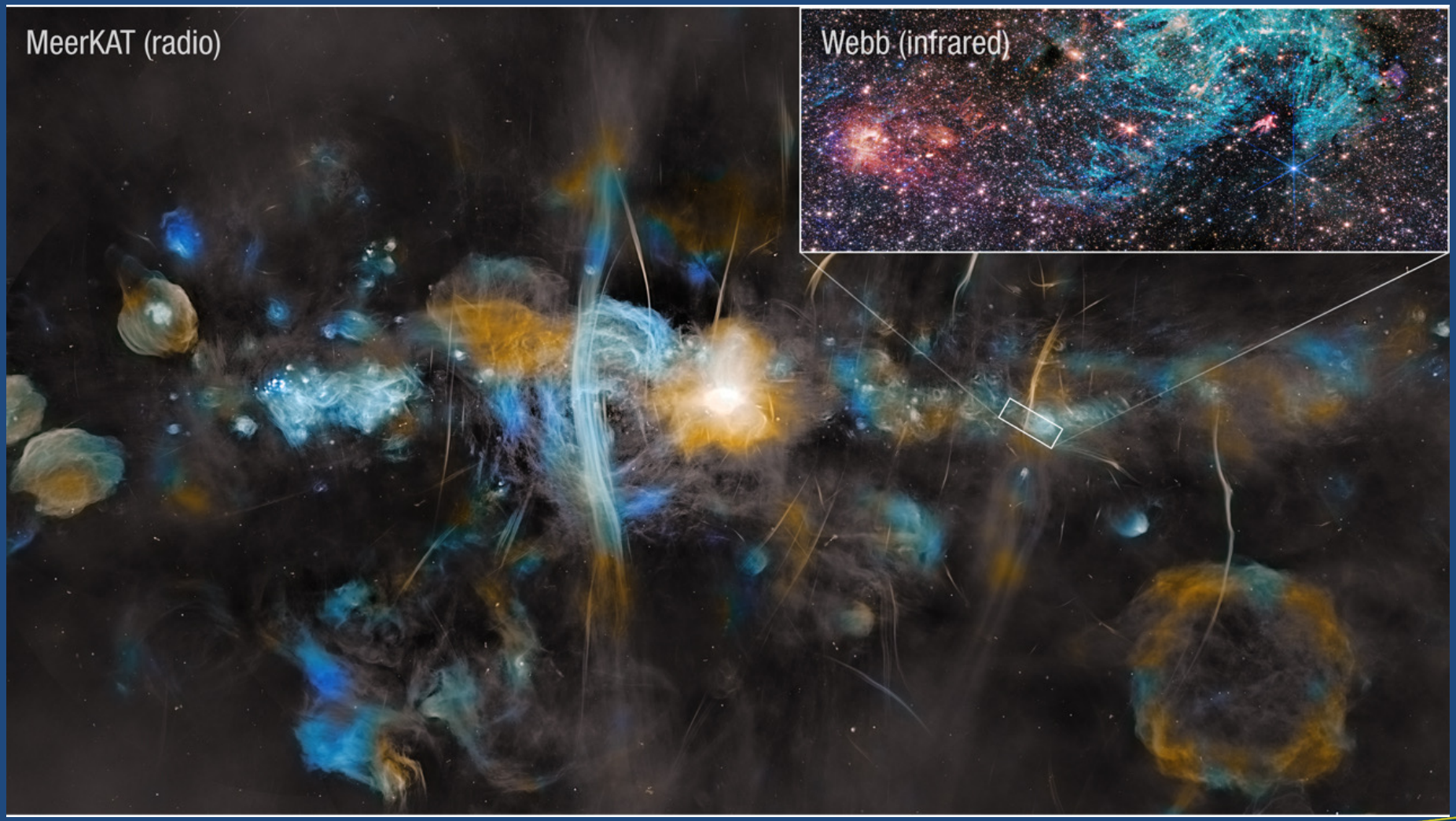
3. Multi-scale challenges for AGN feedback



Hardcastle & Croston (2020)

- Which of the AGN jets makes feedback?
- And what is the minimum requirement to model AGN feedback (thermal vs. kinetic vs. radiative transfer vs. jets)?
- Does the accretion model matter for estimating the AGN luminosity?
- Does SMBH spin matter for AGN feeback in galaxy formation?

4. What is the role of radio filaments?



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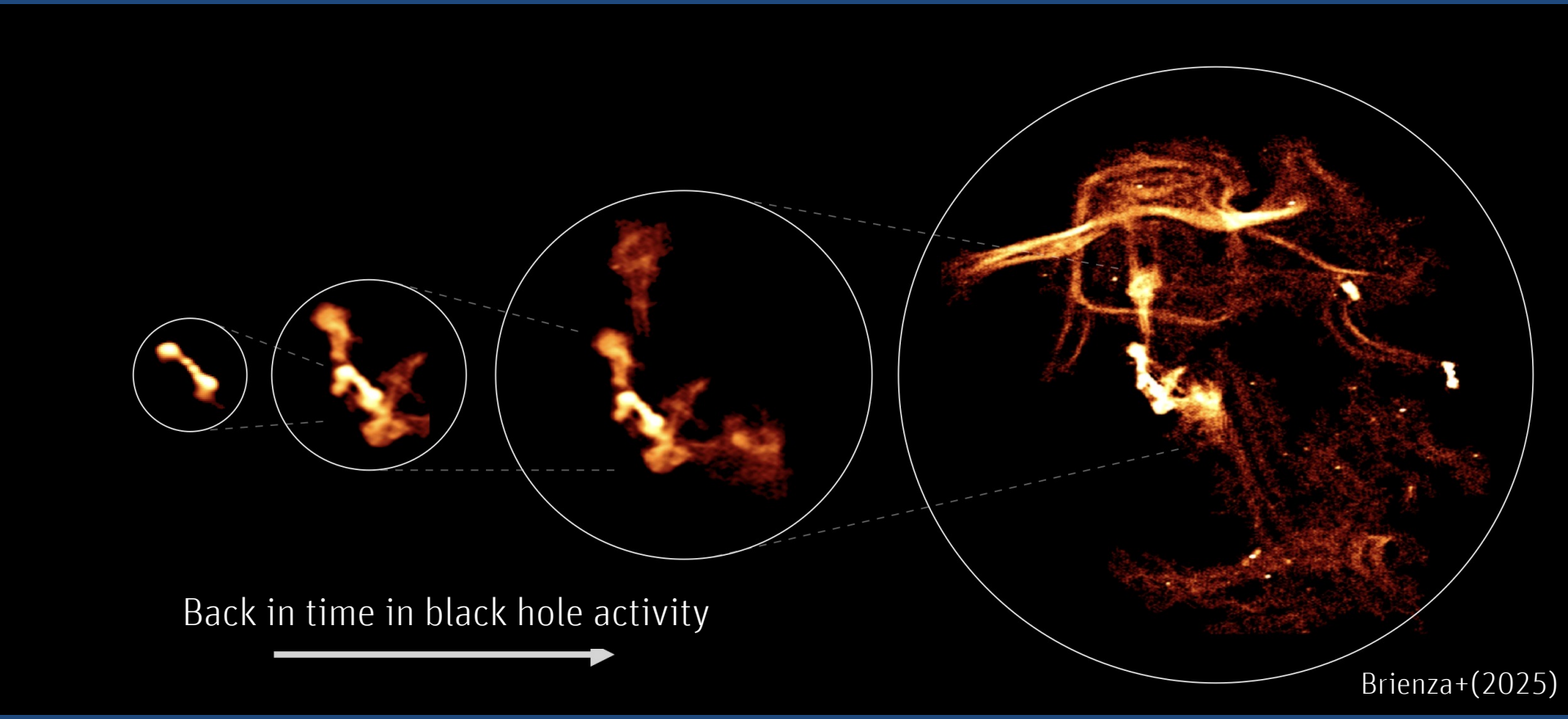

High-resolution radio observations show ubiquitous magnetic filaments on all scales: what is their role? Highly intermittent field structure or radio selection effects where we only see those fields illuminated by cosmic ray electrons?