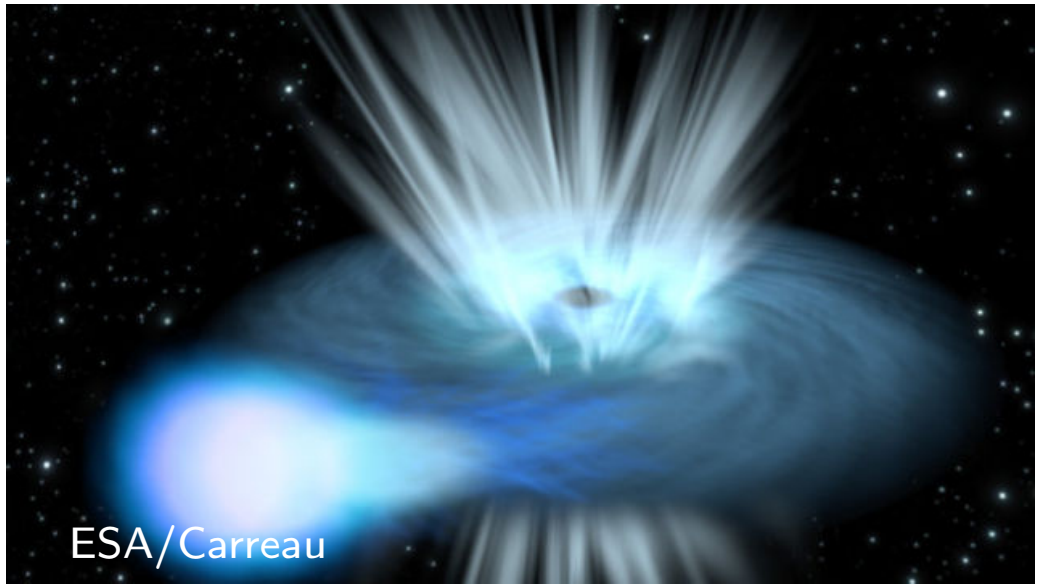
Self-consistent study of feedback in Ultraluminous X-ray sources



Tobias Beuchert (API/Univ. Amsterdam), S. Markoff (API/Univ. Amsterdam), M.J. Middleton (Univ. Southampton), S. Davis (Univ. Virginia), T.D. Russell (API/Univ. Amsterdam), R. Soria (ICRAR/Curtin), M. Díaz Trigo (ESO), M.R. Hogerheijde (Leiden Obs.), F.F.S. van der Tak (Univ. Groningen), J. Schaye (Leiden Obs.), J.S. Kaastra (SRON)

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UNIVERSITY OF AMSTERDAM

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Beyond Stellar Feedback

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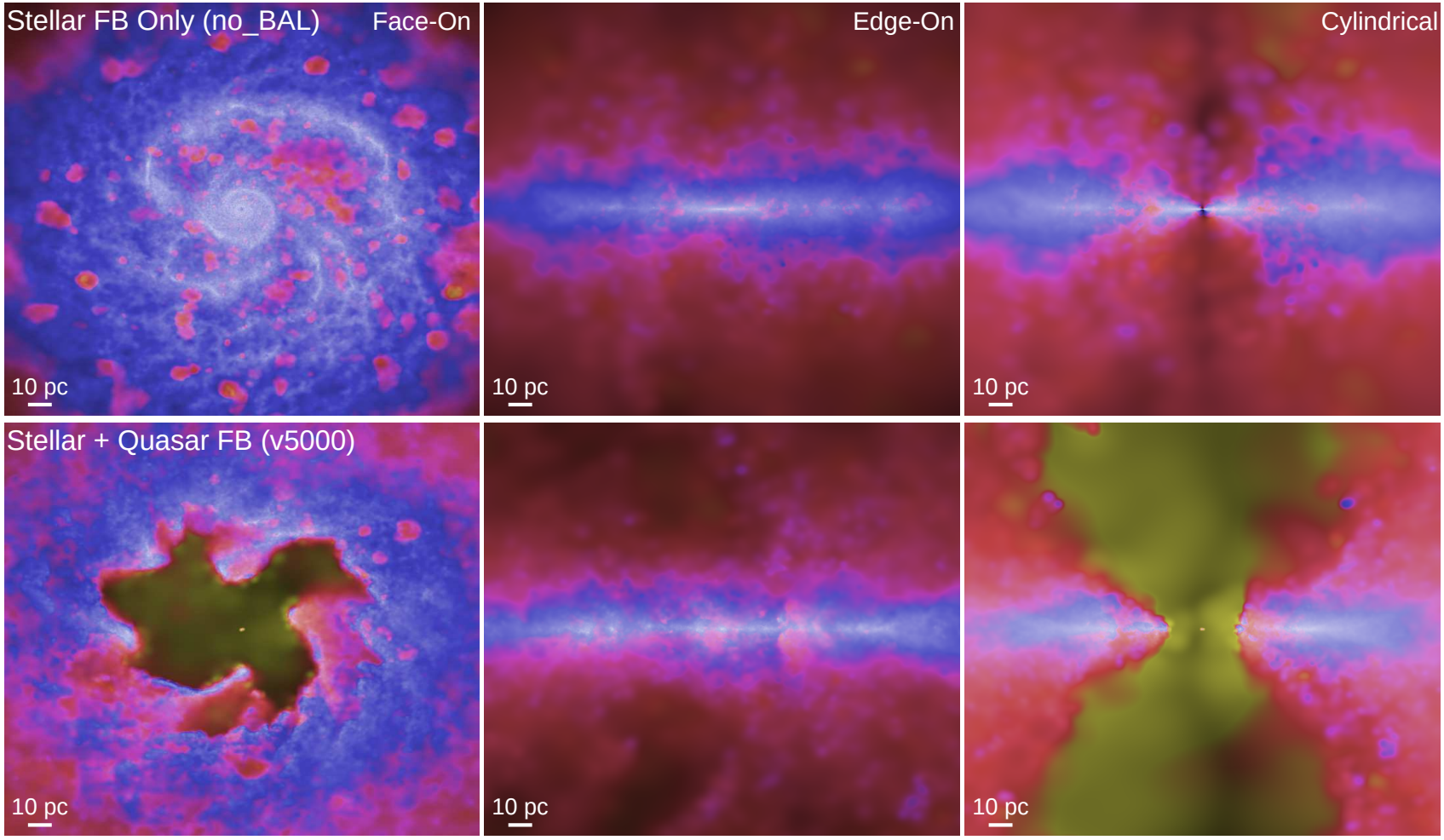

Hopkins et al. (2016)

Beyond Stellar Feedback

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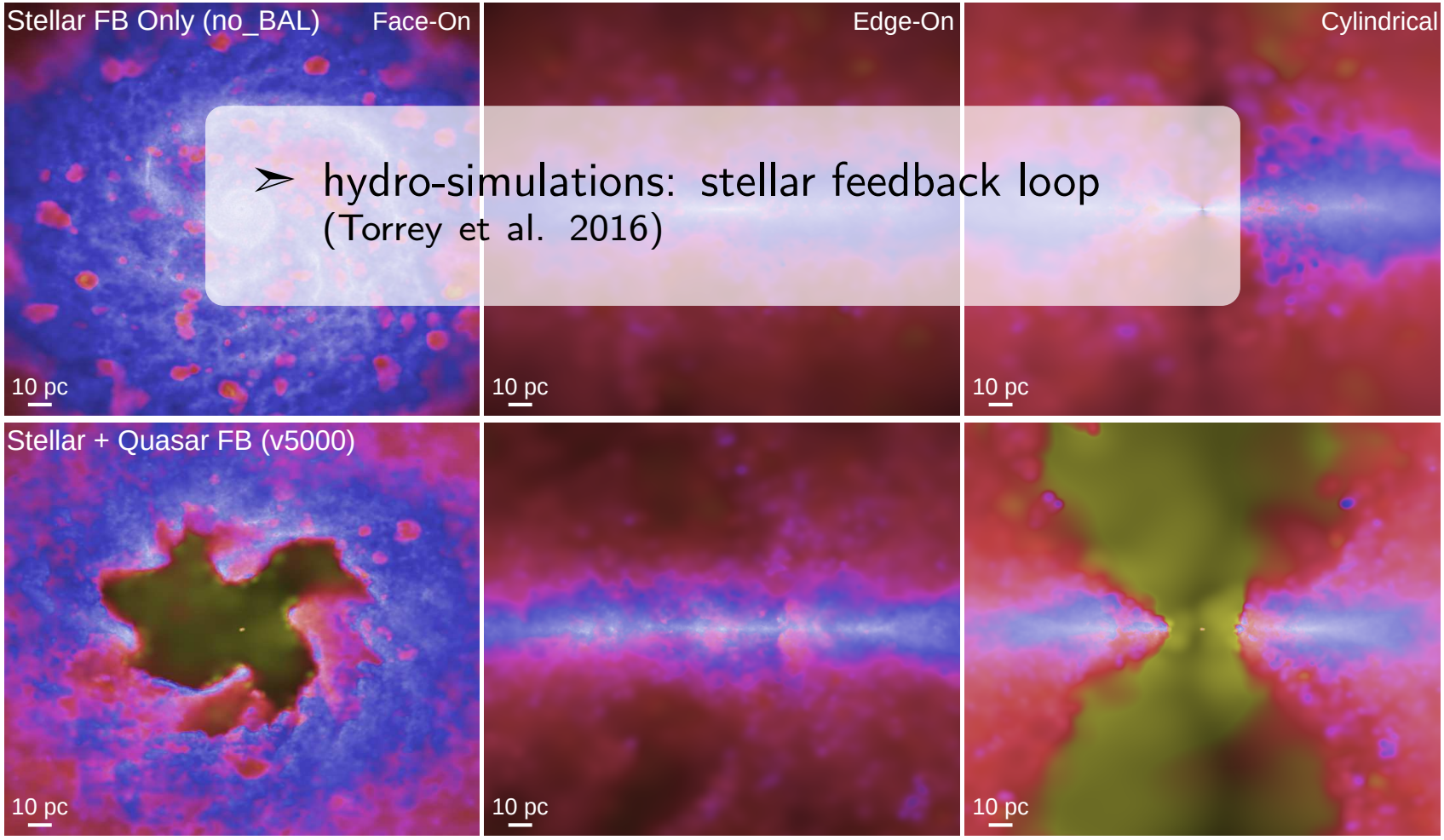

➢ hydro-simulations: stellar feedback loop (Torrey et al. 2016)

Hopkins et al. (2016)

Beyond Stellar Feedback

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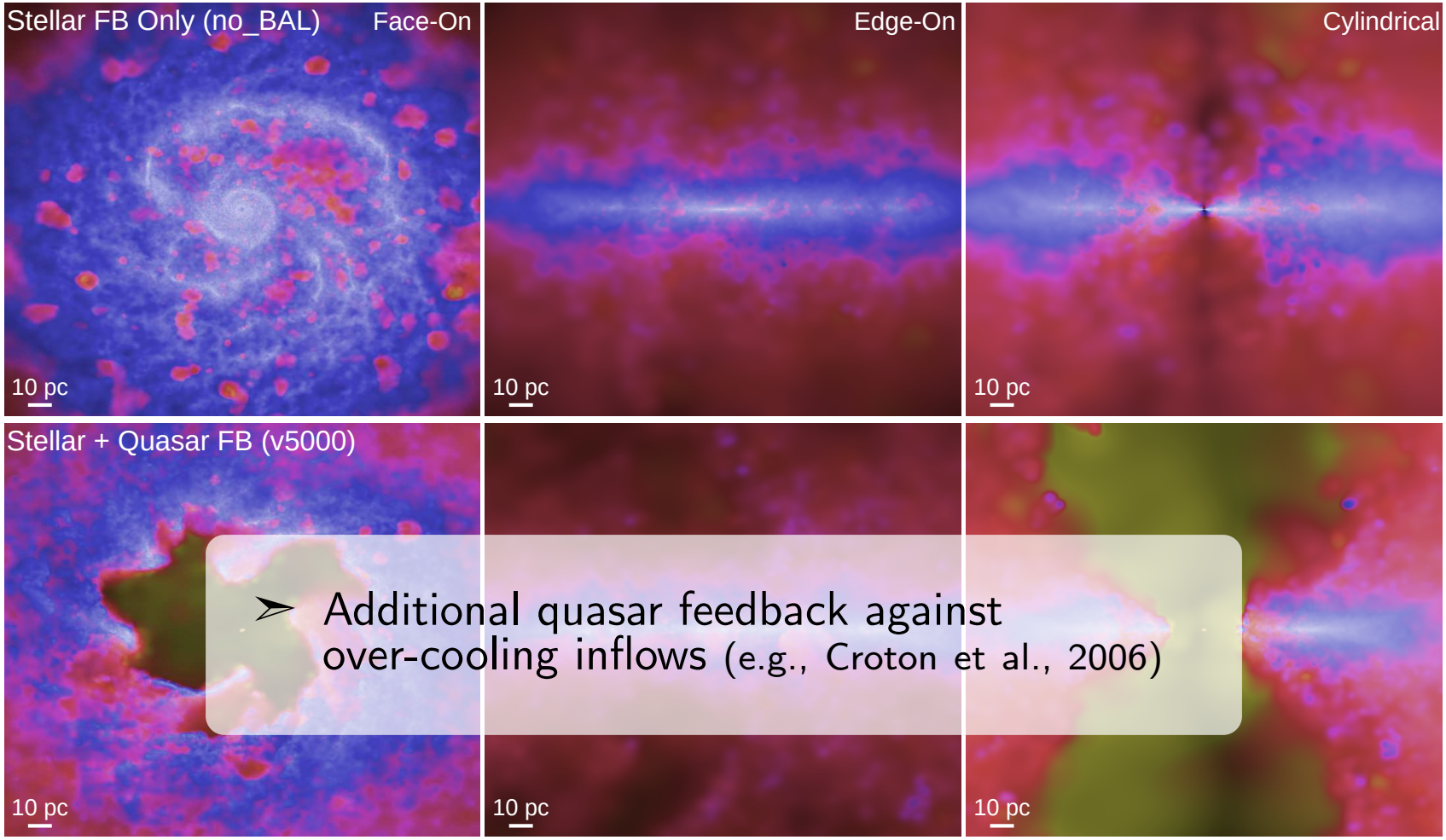

➢ Additional quasar feedback against over-cooling inflows (e.g., Croton et al., 2006)

Hopkins et al. (2016)

Beyond Stellar Feedback

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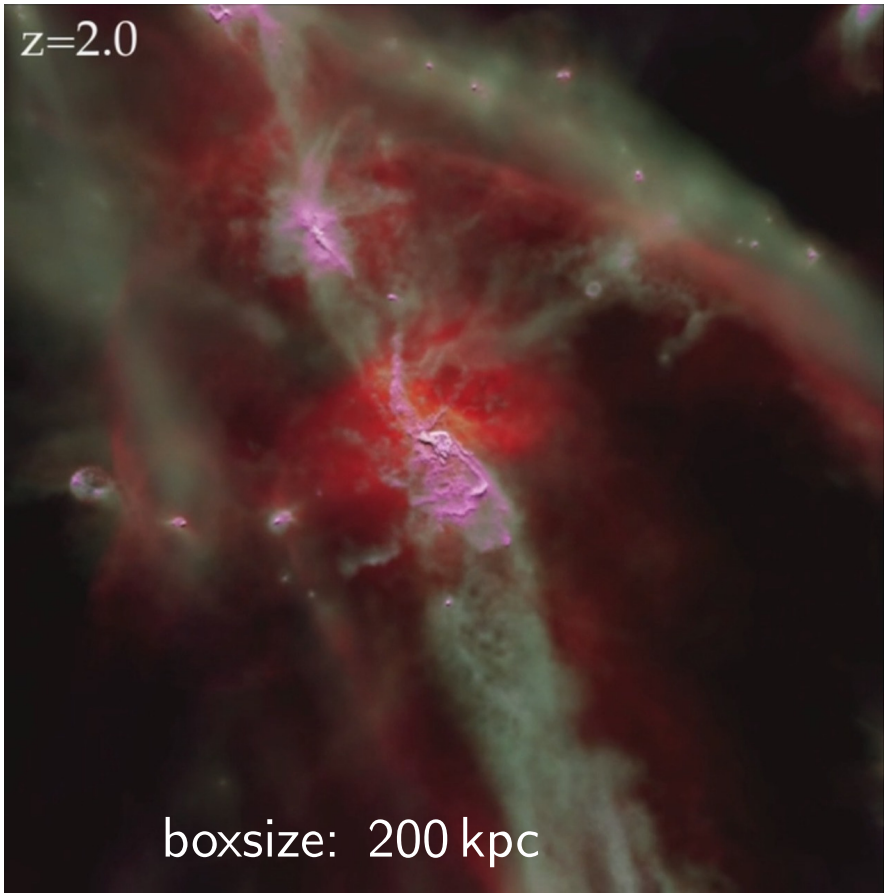

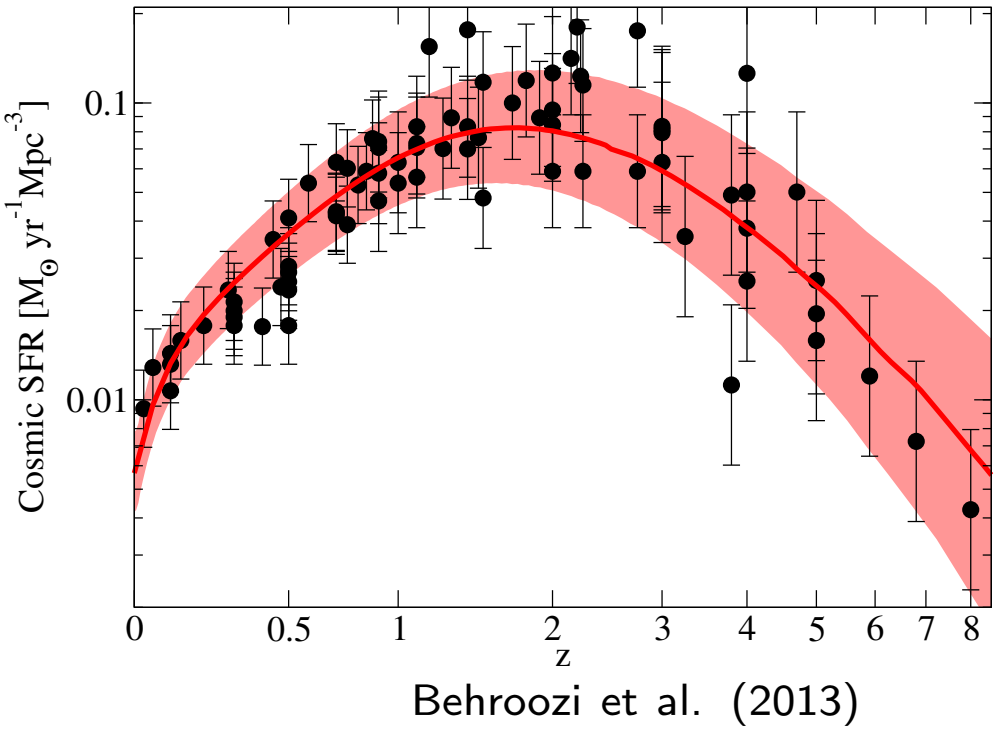

Cosmological simulations of galaxy formation (P. Hopkins: `http://www.tapir.caltech.edu/~phopkins/Site/Movies_cosmo.html`)

Beyond Stellar Feedback

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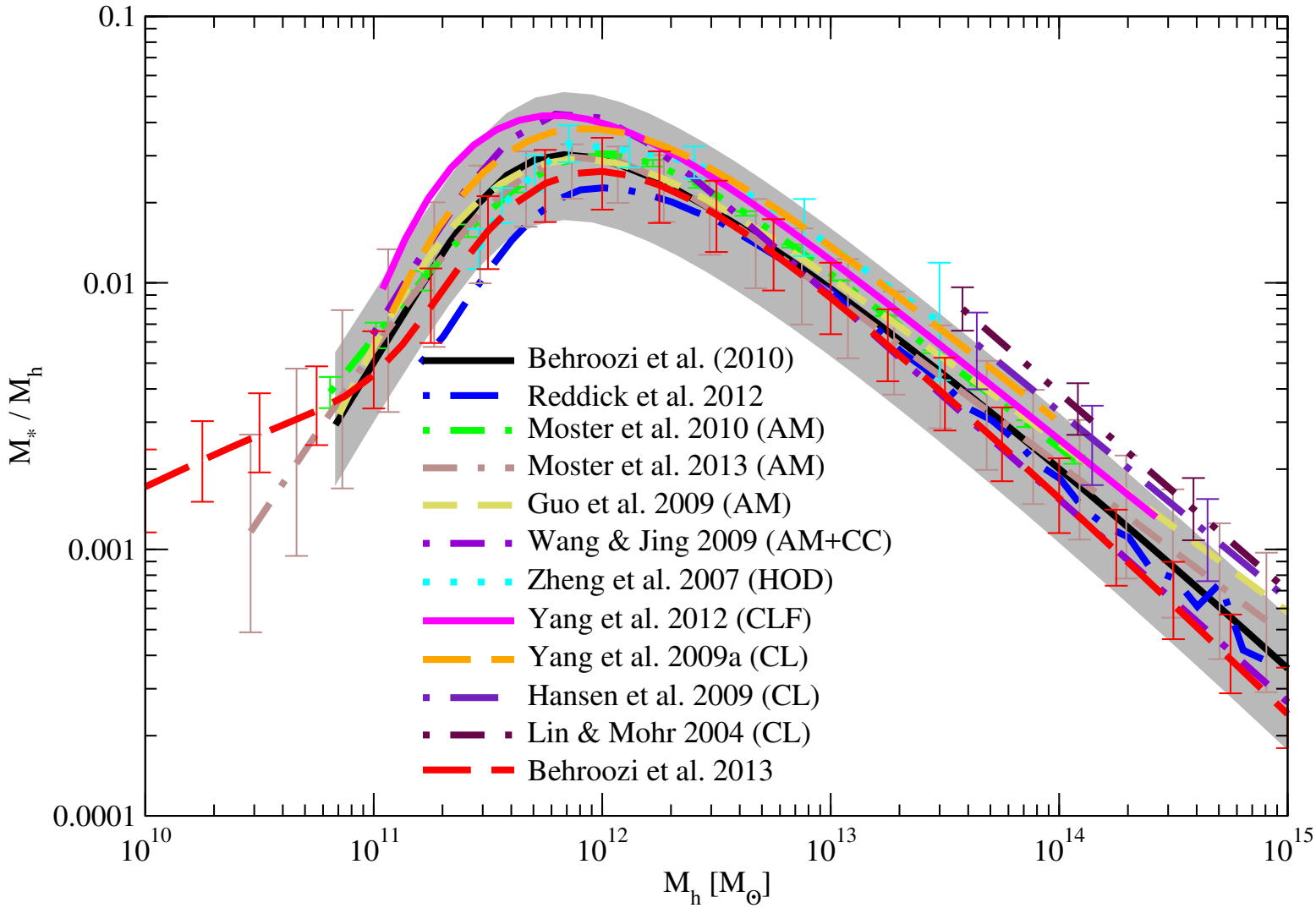

Behroozi et al. (2013)

Beyond Stellar Feedback

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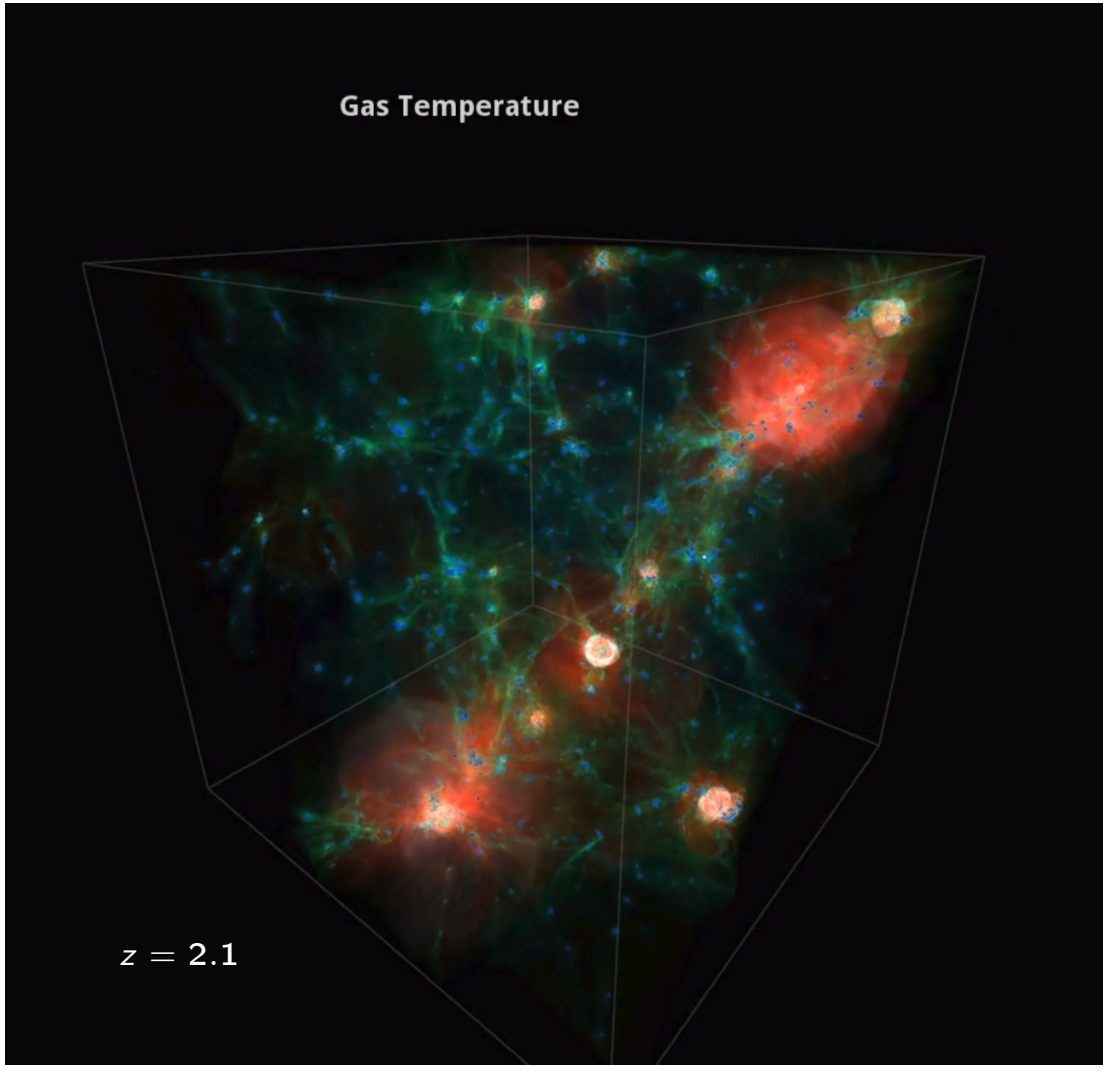

- Self-regulating AGN feedback
- AGN-feedback – SF connection complex in cosmology (e.g. Fiore et al., 2017)

need to understand accretion-feedback in all regimes of

accretion rate

feedback

luminosity

Illustris Simulation; Springel et al. (2016)

Feedback by Compact Objects

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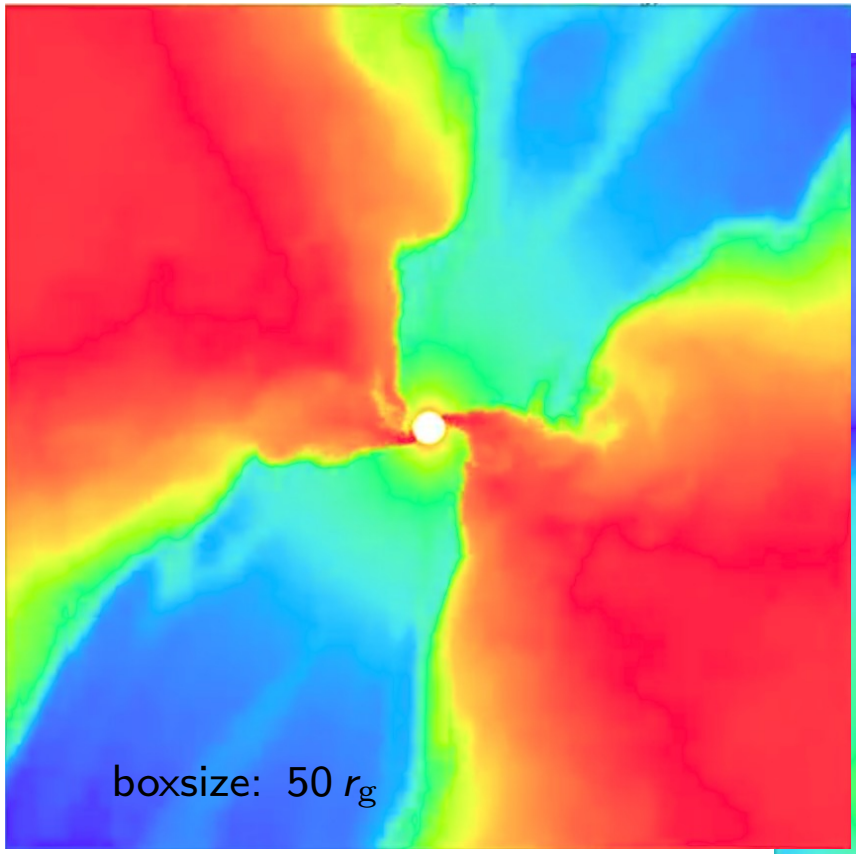

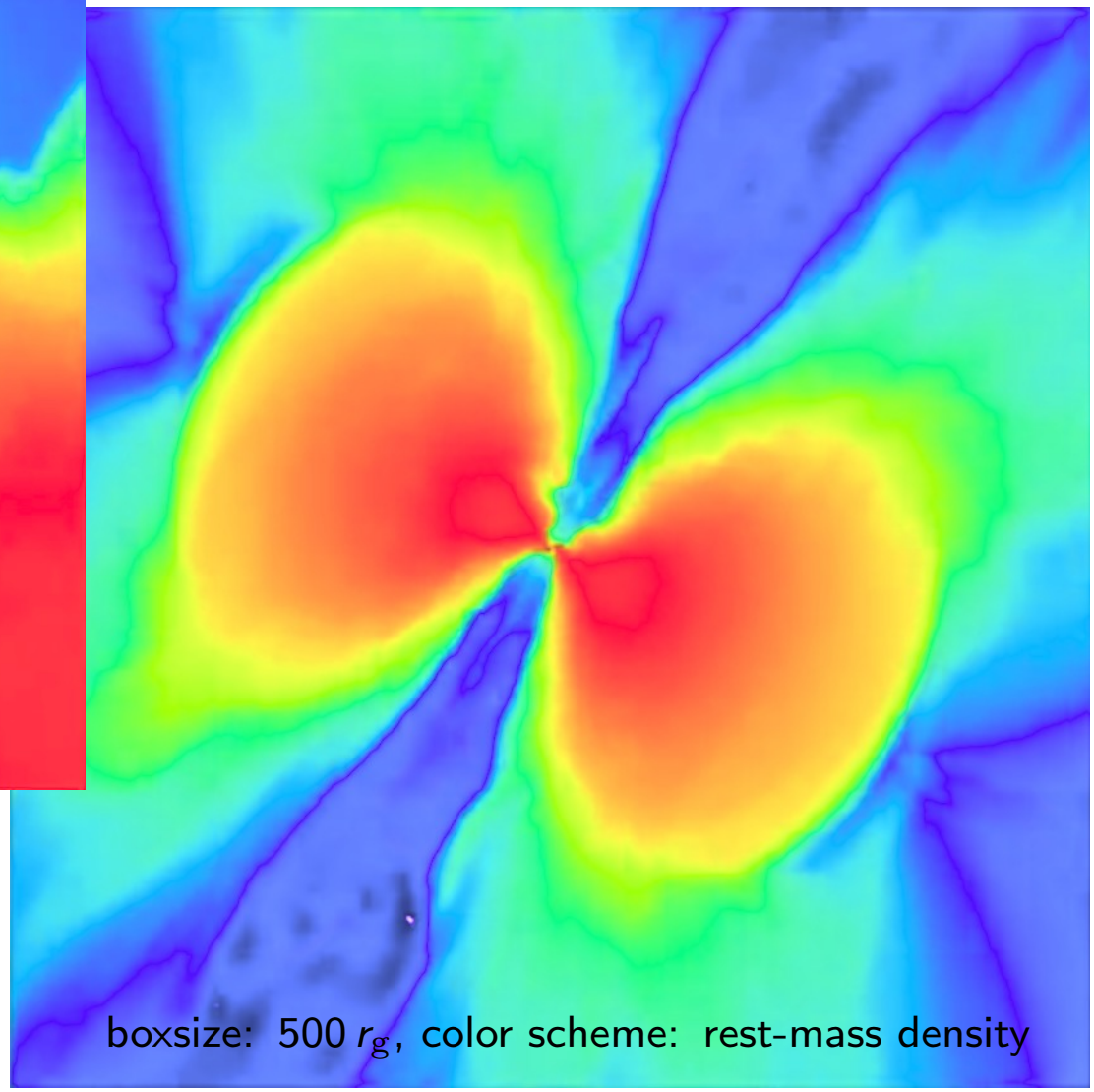

3D-GRMHD simulations (H-AMR): Liska et al. 2018 (API/UvA)

Feedback by Compact Objects

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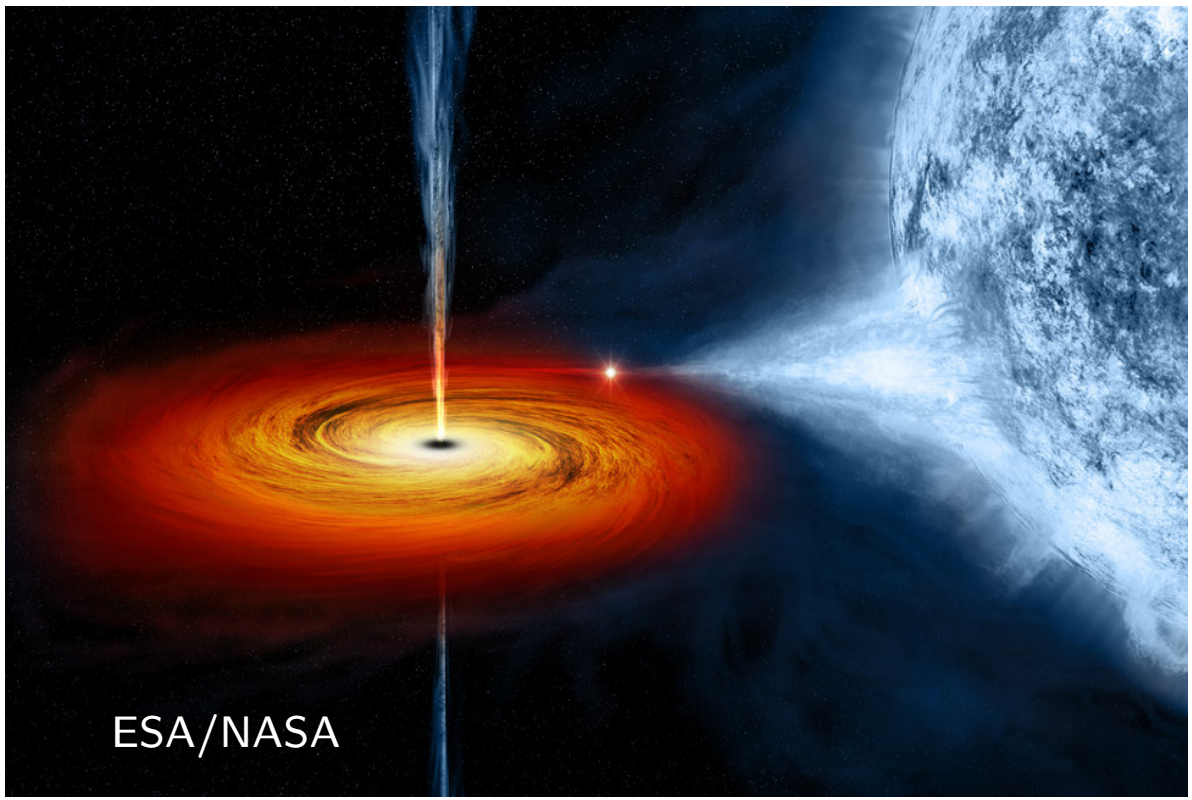
Black-hole X-ray binaries: duty cycles of accretion feedback on **observable** time scales

Fundamental plane (e.g., Falcke et al., 2004; Plotkin et al., 2012)



Feedback of ULXs

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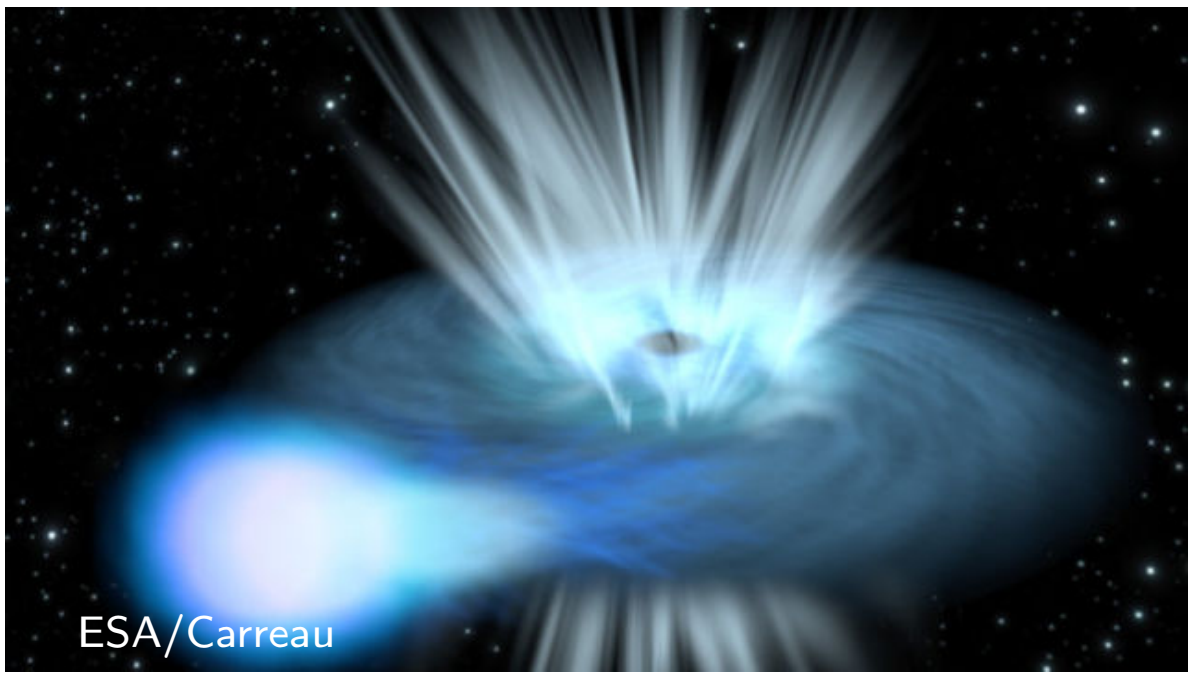
Explore most extreme and unexplored parameter space:
Ultraluminous X-ray Sources (ULX)

- Super-Eddington accretion rates
- Blown up accretion disks, strong winds
- $L \gtrsim 10^{39}\,\mathrm{erg\,cm^{-2}\,s^{-1}}$, can go **extragalactic**!
- **Strong winds! ...Jets?**



Feedback of ULXs

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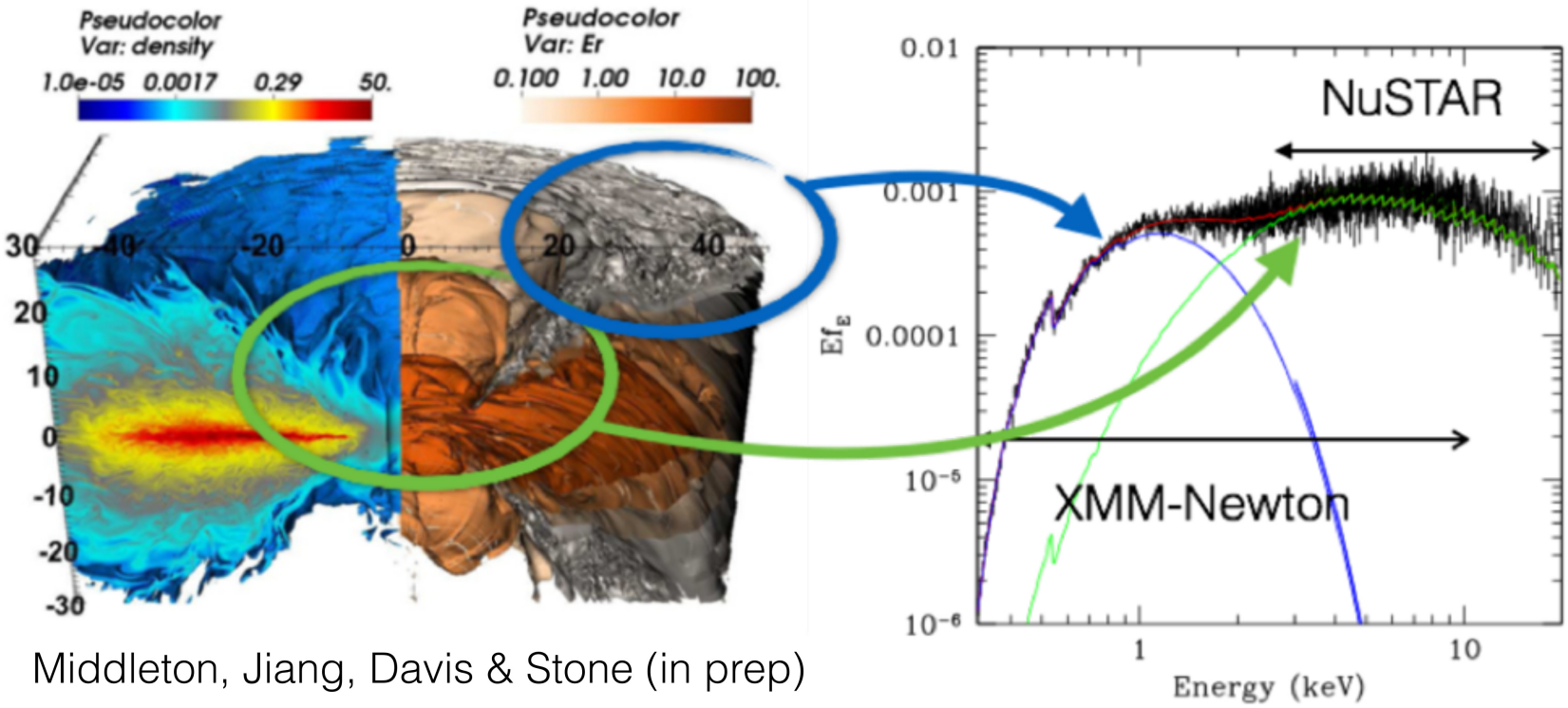
S. Davis, M. Middleton & Yan-Fei Jiang: produce angle-dependent broad-band spectra from RMHD simulations of super-Edd. disks using `Athena++`: work in progress (see Jiang et al., 2014)



Middleton, Jiang, Davis & Stone (in prep)

Physical accretion-wind model

Feedback of ULXs

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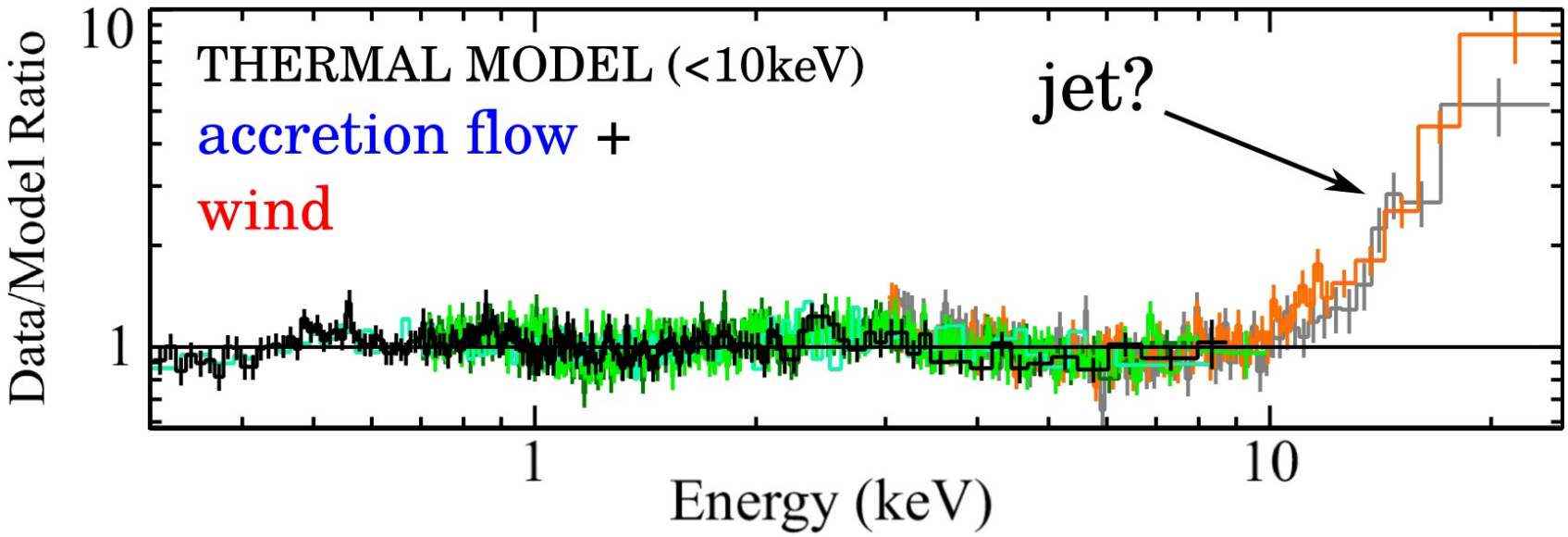
Indications for missing non-thermal (**jet?**) component in X-ray spectra



(Adapted from Walton et al. (2015) for Ho II X-1)

Intriguing note: could ULXs also harbor **NSs?** (Walton et al., 2017/2018)
Can NS magnetospheres harbor jets? (e.g., van den Eijnden et al., 2017)

Feedback of ULXs

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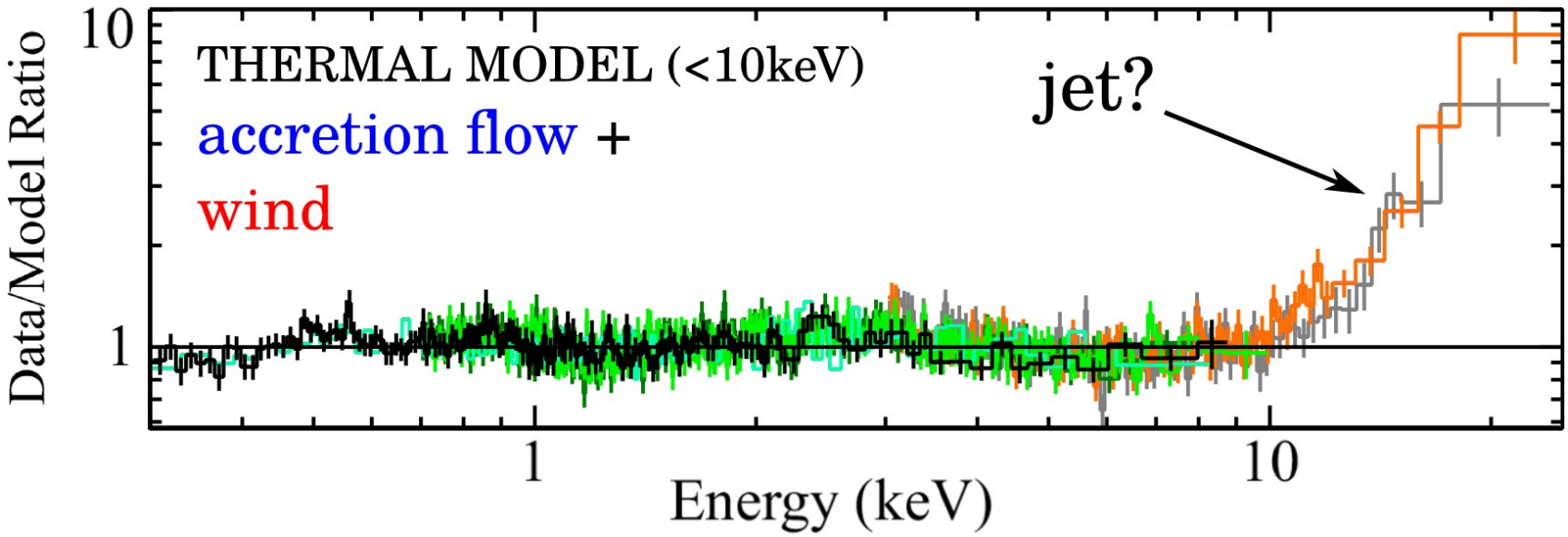
Indications for missing non-thermal (**jet?**) component in X-ray spectra



(Adapted from Walton et al. (2015) for Ho II X-1)

Challenge: ULXs extragalactic; direct observations of putative jets yet impossible.

Feedback of ULXs

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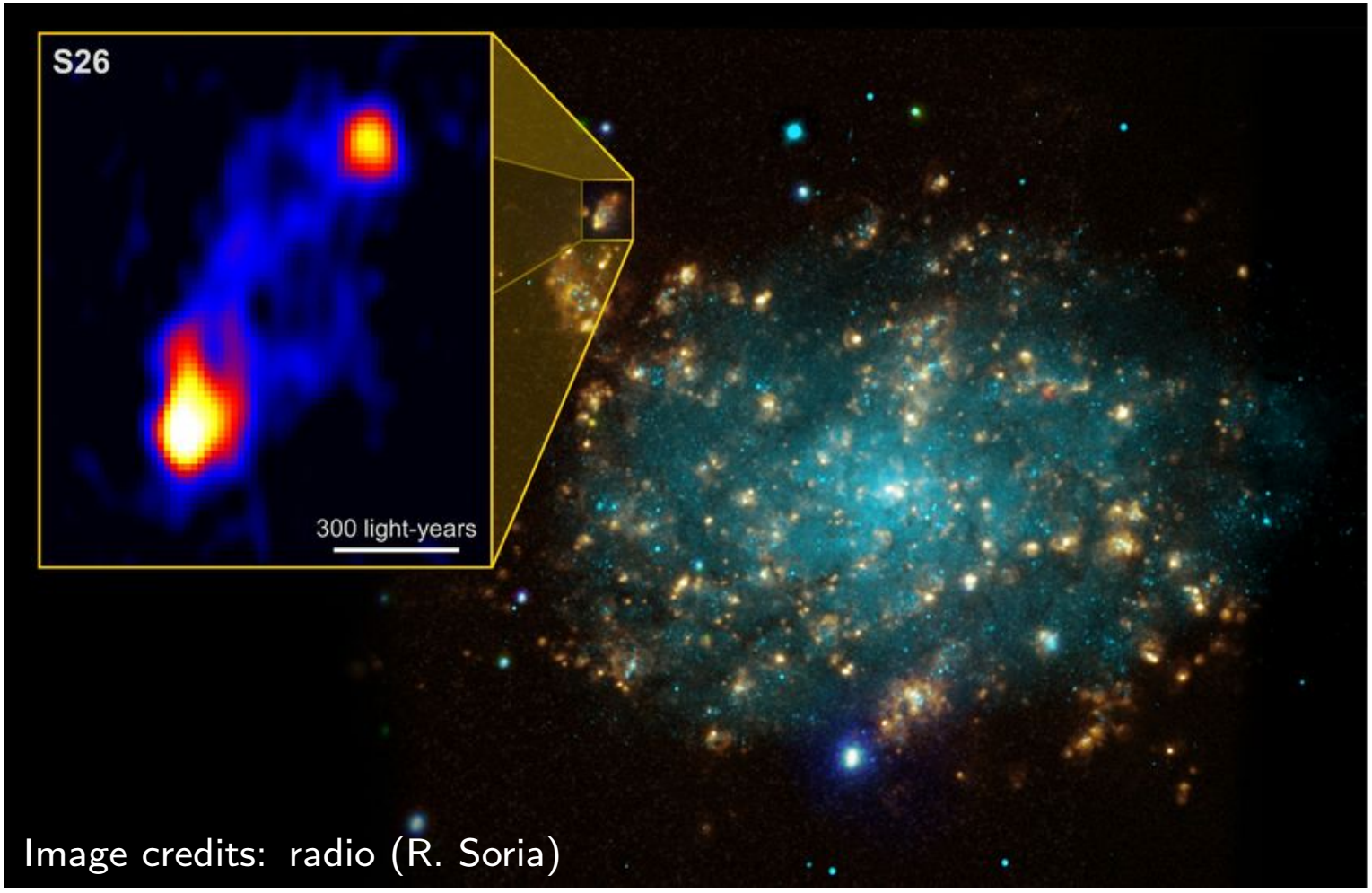

Image credits: radio (R. Soria)

X-ray (NASA/CXC/Univ of Strasbourg/M. Pakull et al);
Optical (ESO/VLT/Univ of Strasbourg/M. Pakull et al);
H-alpha (NOAO/AURA/NSF/CTIO 1.5m)

Feedback of ULXs

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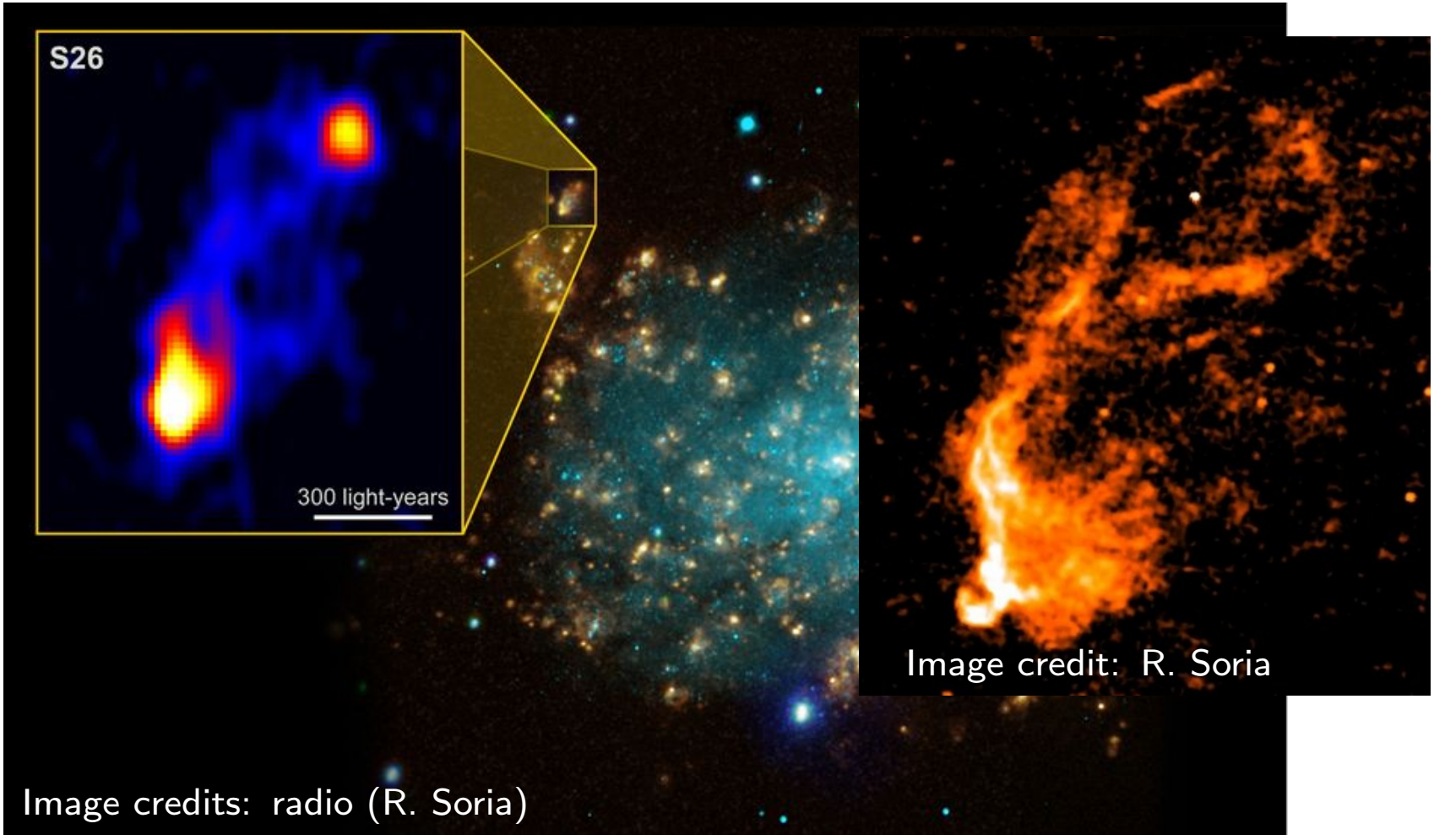

X-ray (NASA/CXC/Univ of Strasbourg/M. Pakull et al);
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H-alpha (NOAO/AURA/NSF/CTIO 1.5m)

Feedback of ULXs

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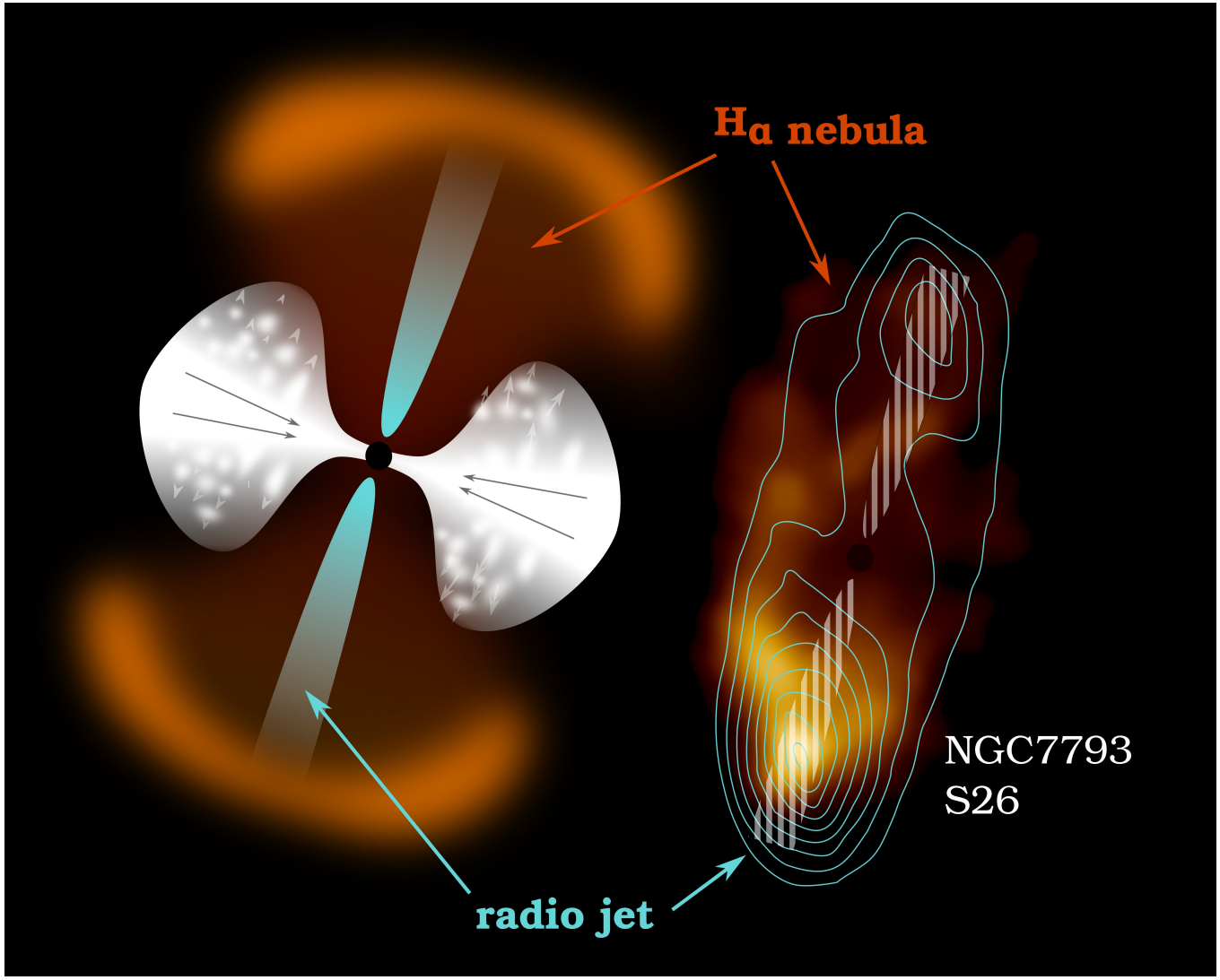
Breaking degeneracies: self-consistent feedback study



Self-consistent Feedback Study

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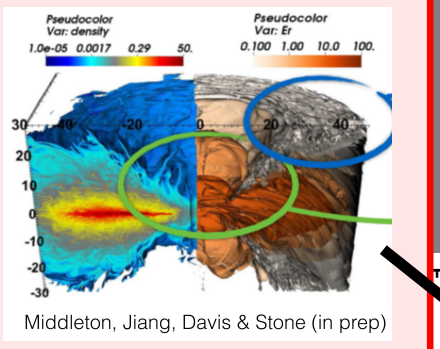
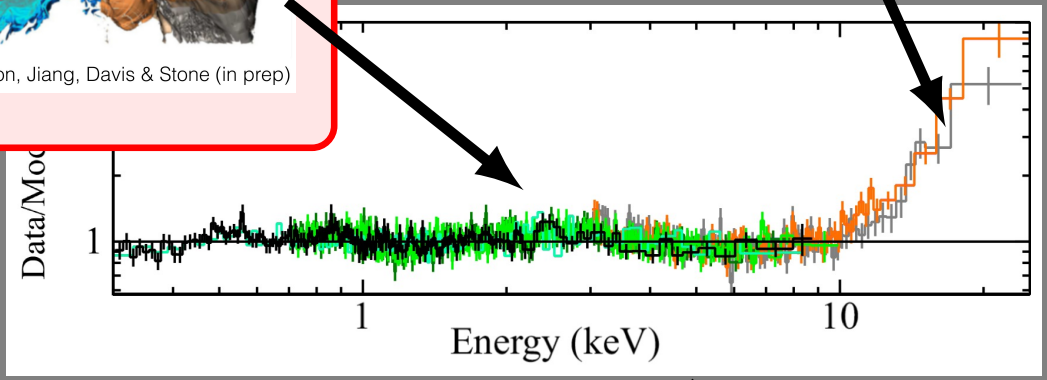
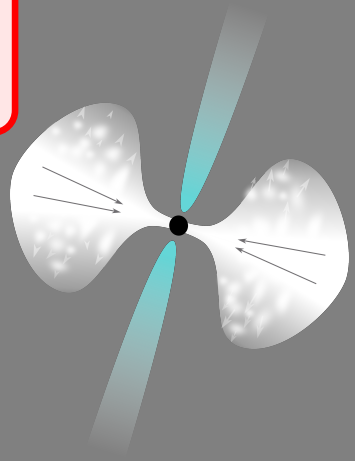


Middleton, Jiang, Davis & Stone (in prep)

Physical jet model:

Markoff et al. (2005)





Plasma Codes (`Cloudy`, `Mappings`, `PyPDR`),
Ferland et al. (2013), Allen et al. (2008)

Bruderer et al. (2009)

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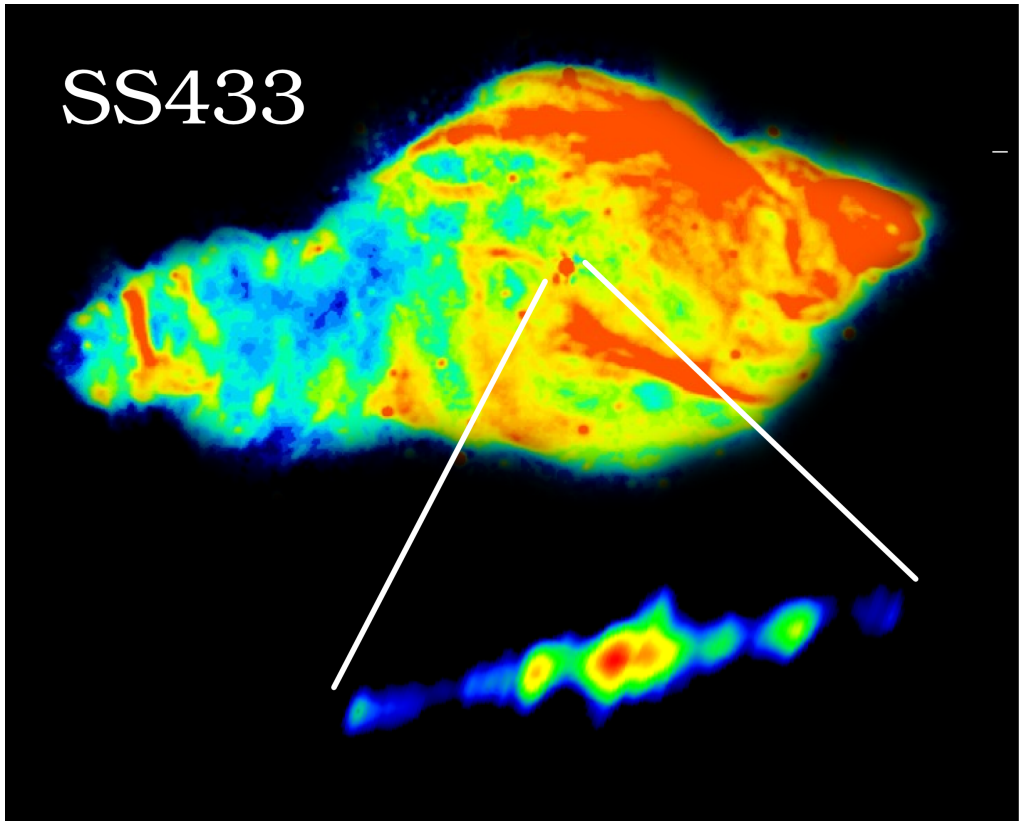
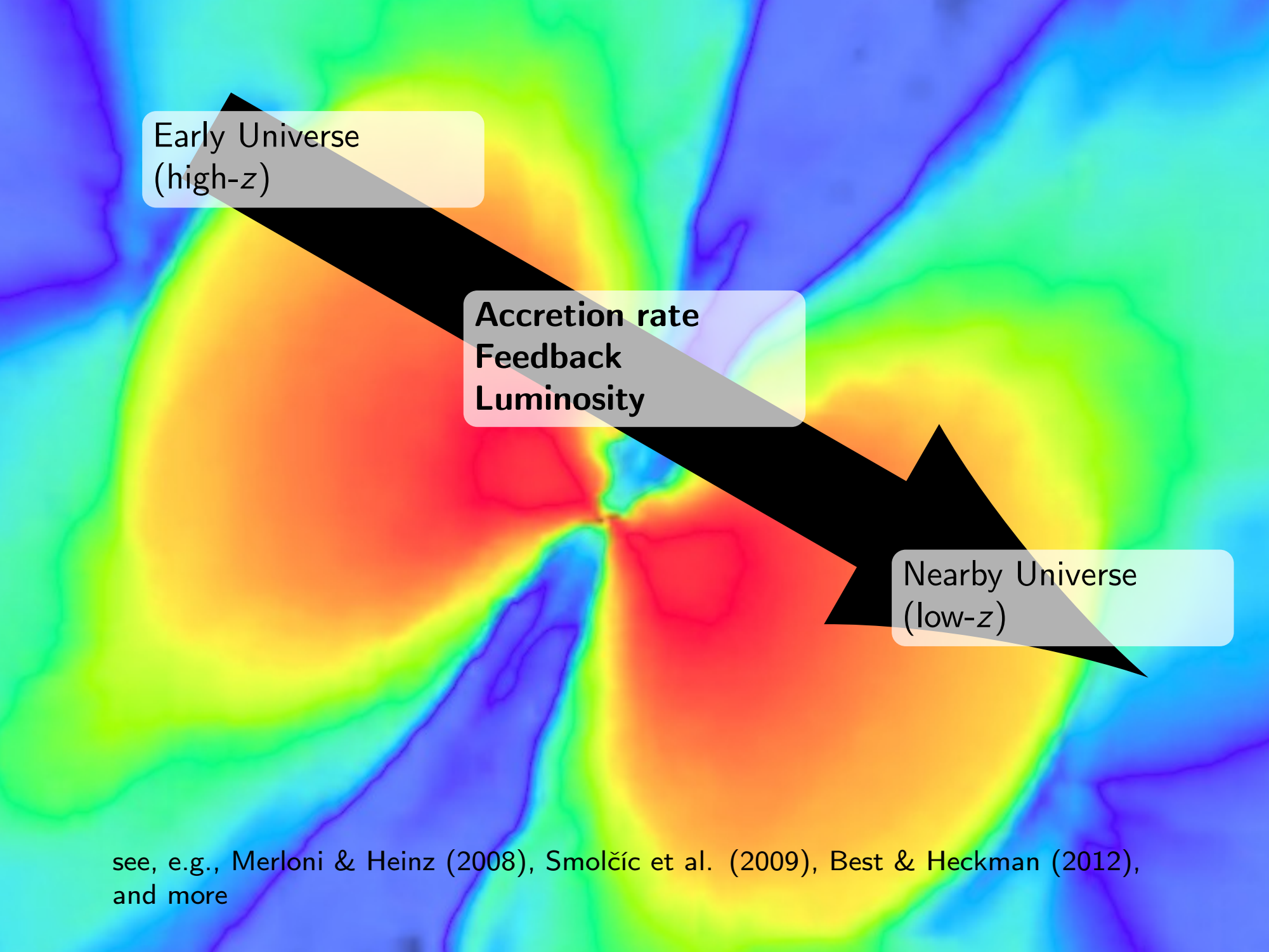
Method Calibration



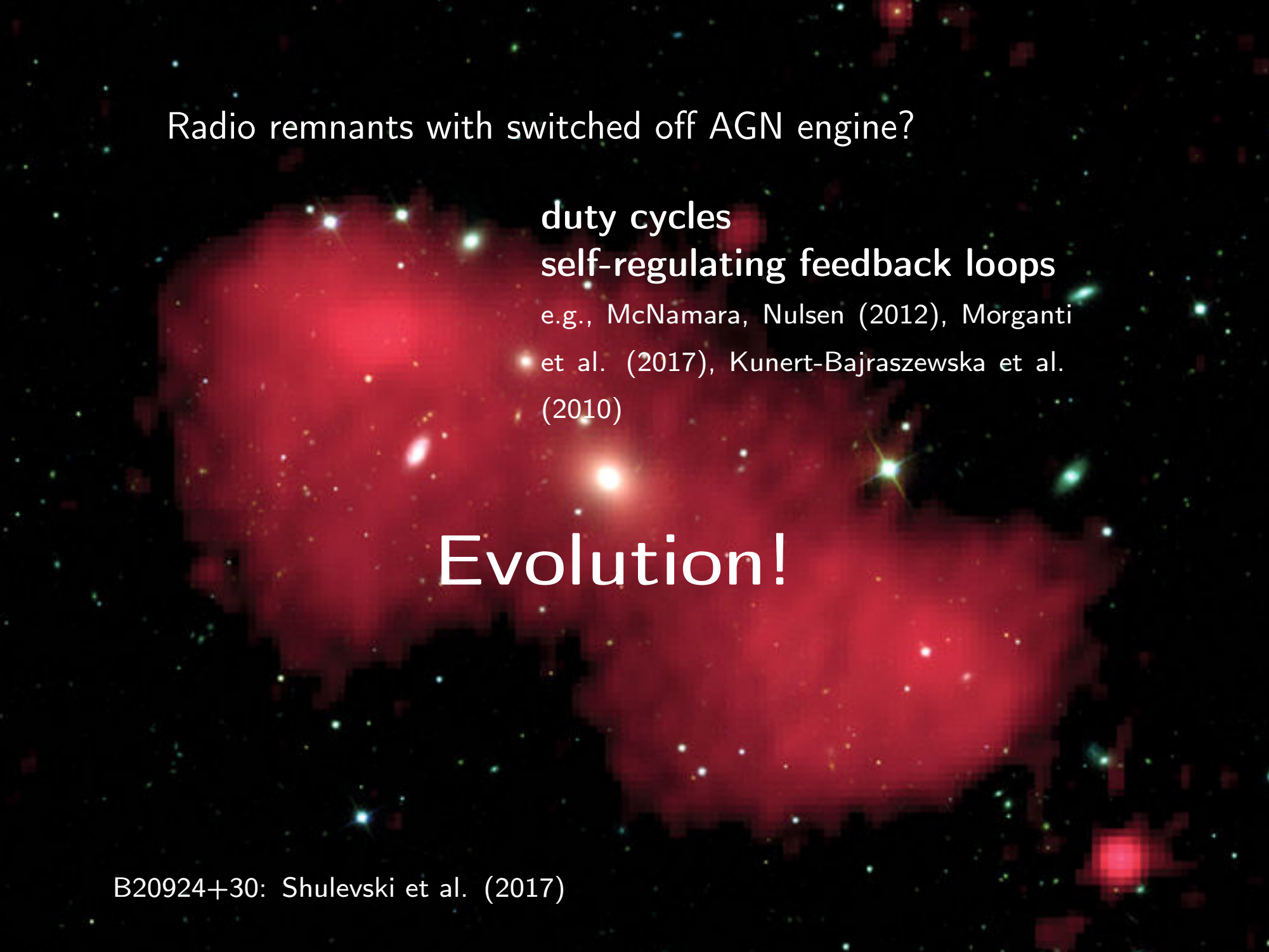
- Only super-Eddington accretor in our Galaxy
- Strong winds (e.g., Blundell et al., 2008) and jets (e.g., Roberts et al., 2008)
- Precession (e.g., Stirling et al., 2002)
- Interaction with SNR W40 (e.g., Fabrika et al., 2006; Blundell et al., 2011; Panferov, 2016; Farnes et al., 2017
- Full multiwavelength coverage (e.g., Marshall et al., 2013)

Conclusions

- ULXs: **extreme accretion/feedback** processes in **extragalactic** universe in **real time**
- Jets in super Eddington environment?
- Break model degeneracies
- Describe extreme winds and possibly jets with **physical models**
- **Response of ambient** medium: fine-tuning of model for compact feedback (winds/jets)
- **Calibrate** using well-studied SS 433
- Stay tuned!



see, e.g., Merloni & Heinz (2008), Smolčíc et al. (2009), Best & Heckman (2012), and more



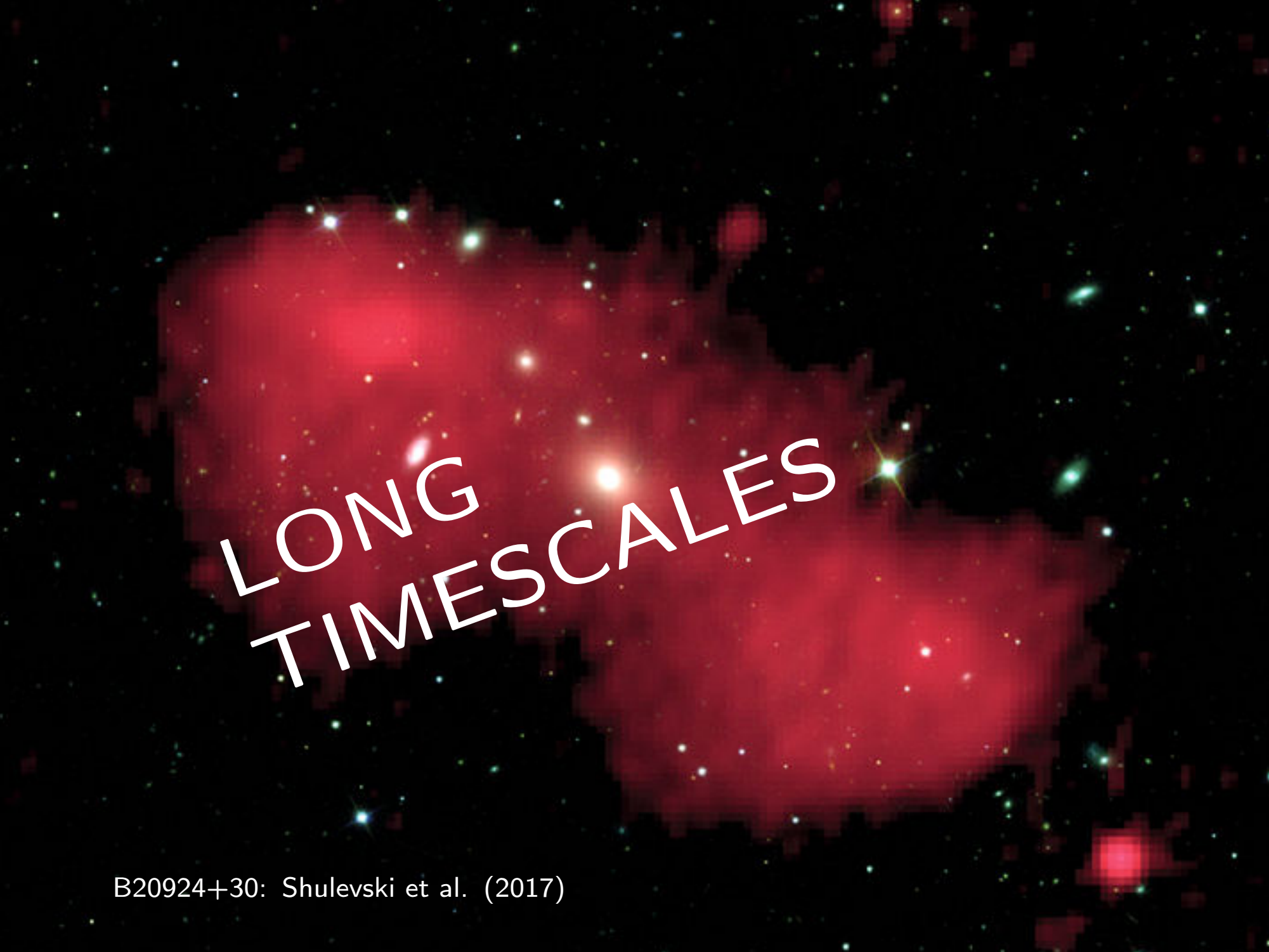
Radio remnants with switched off AGN engine?

duty cycles
self-regulating feedback loops

e.g., McNamara, Nulsen (2012), Morganti et al. (2017), Kunert-Bajraszewska et al. (2010)

Evolution!

B20924+30: Shulevski et al. (2017)



B20924+30: Shulevski et al. (2017)