

FUELLING SUPERMASSIVE BLACK HOLES WITH MISALIGNED GAS

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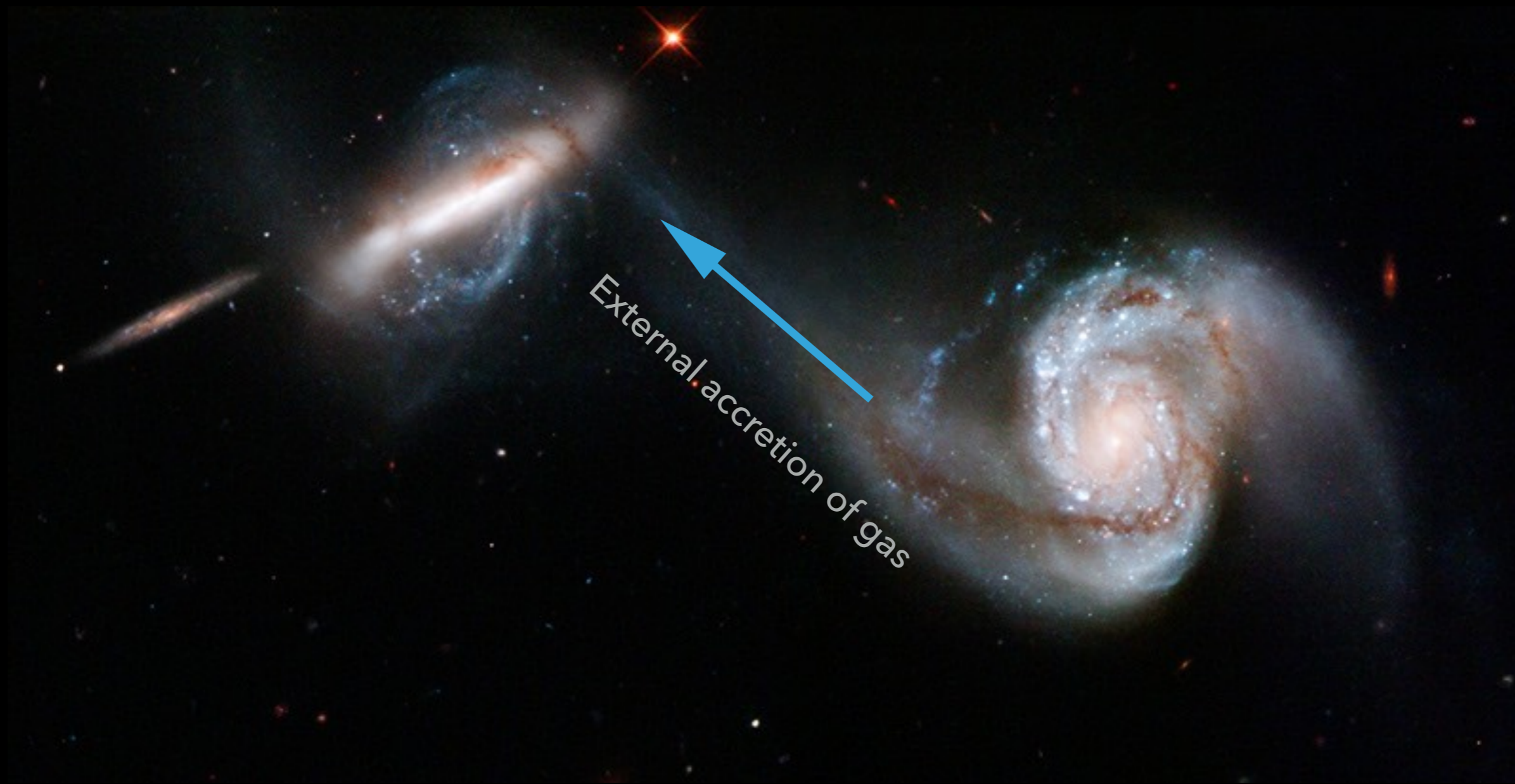


BLACK HOLE FUELLING

- ▶ Black holes grow by the accretion of gas
- ▶ How does the gas reach the black hole?
- ▶ Why are some black holes active (AGN) and others inactive?
- ▶ Black hole fuelling requires: 1) a supply of gas and 2) mechanisms to transport the gas



INTERACTING GALAXIES – SUPPLY OF GAS



NASA, ESA, and the Hubble Heritage Team (STScI/AURA)

Mergers, tidal interactions with neighbours, flybys, gas filaments

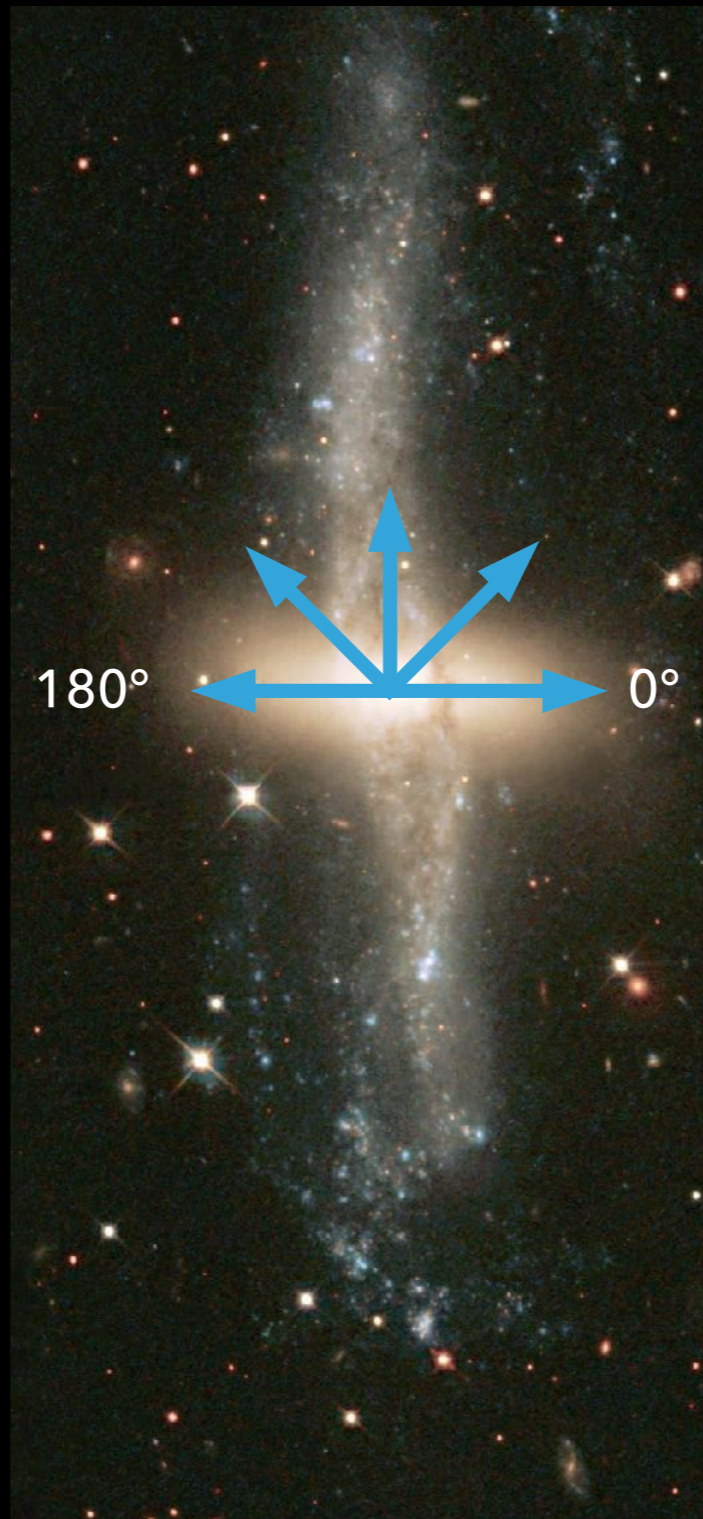
INTERACTING GALAXIES

Misalignment angle
between stellar and gas rotation



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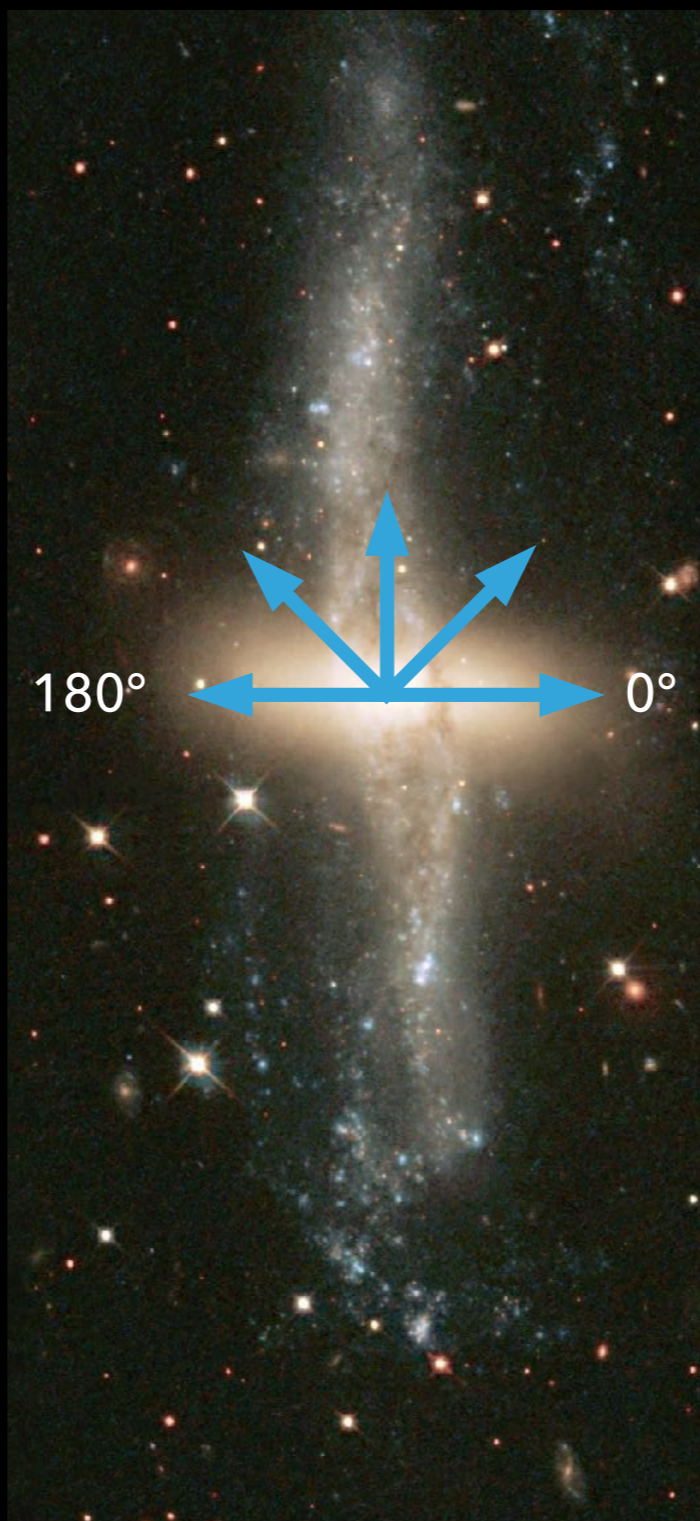


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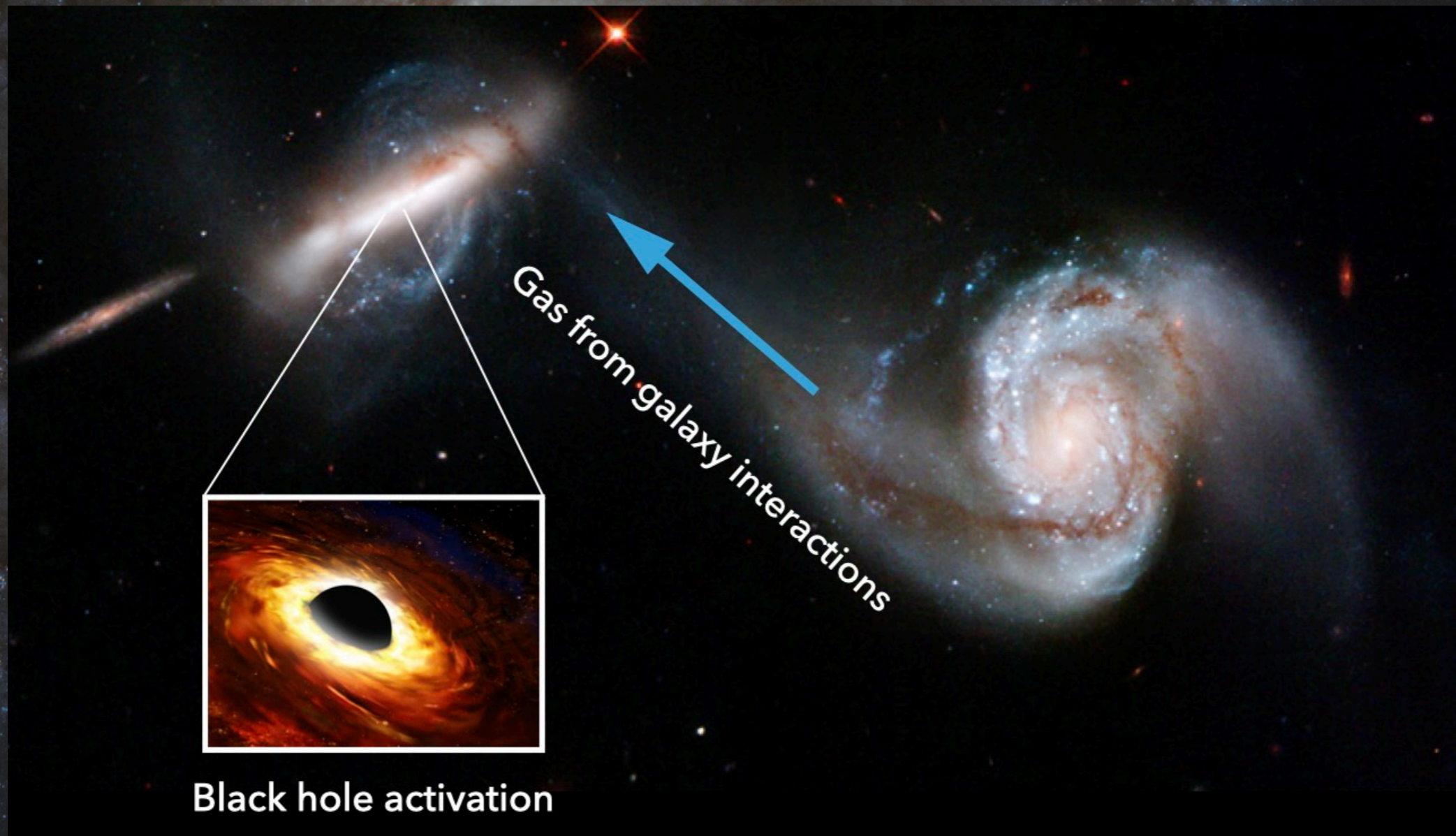
Misalignment angle
between stellar and gas rotation

Clear signature of a past interaction

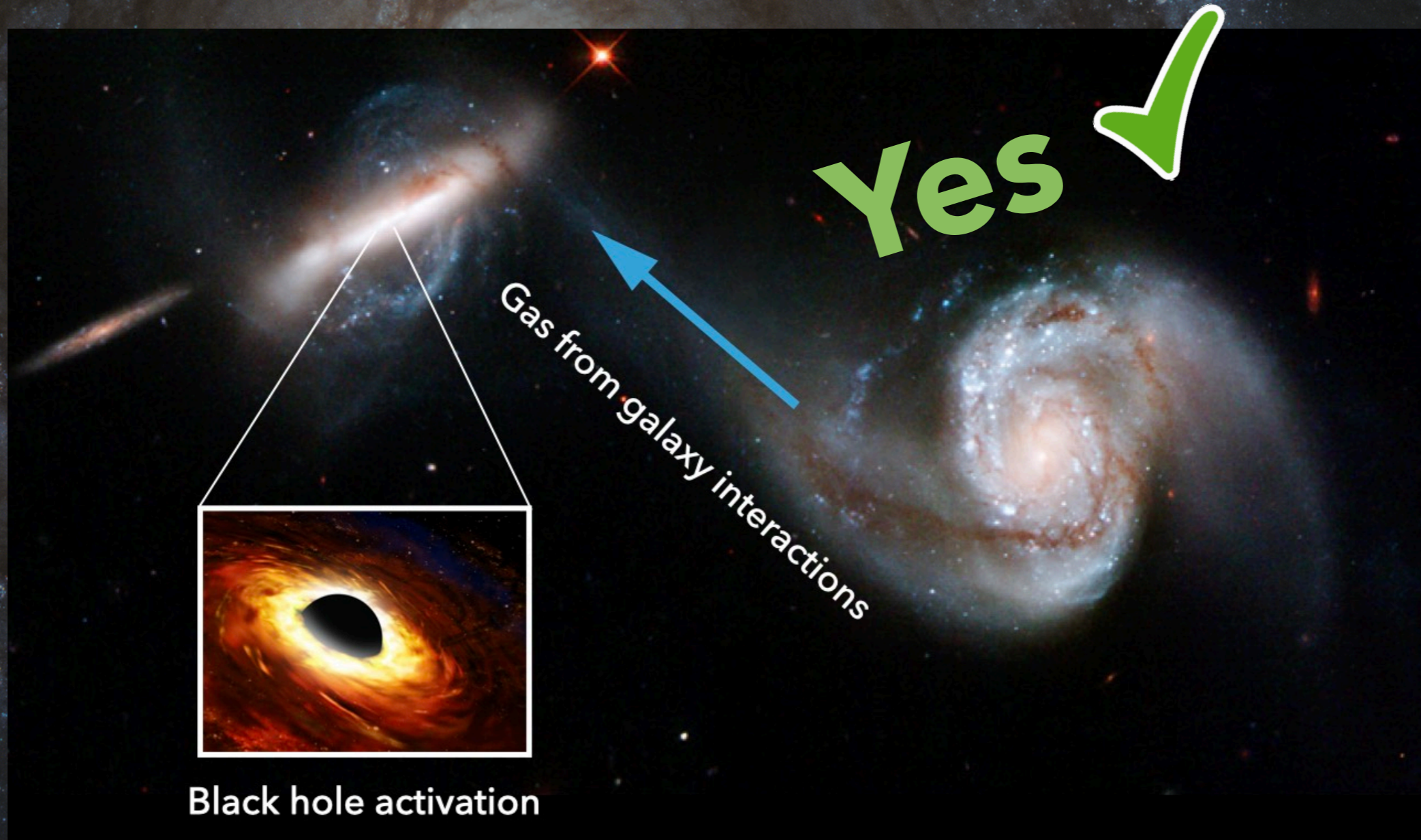
'Misaligned galaxies' $> 30^\circ - 45^\circ$



DOES MISALIGNED GAS FROM GALAXY INTERACTIONS FUEL AGN?



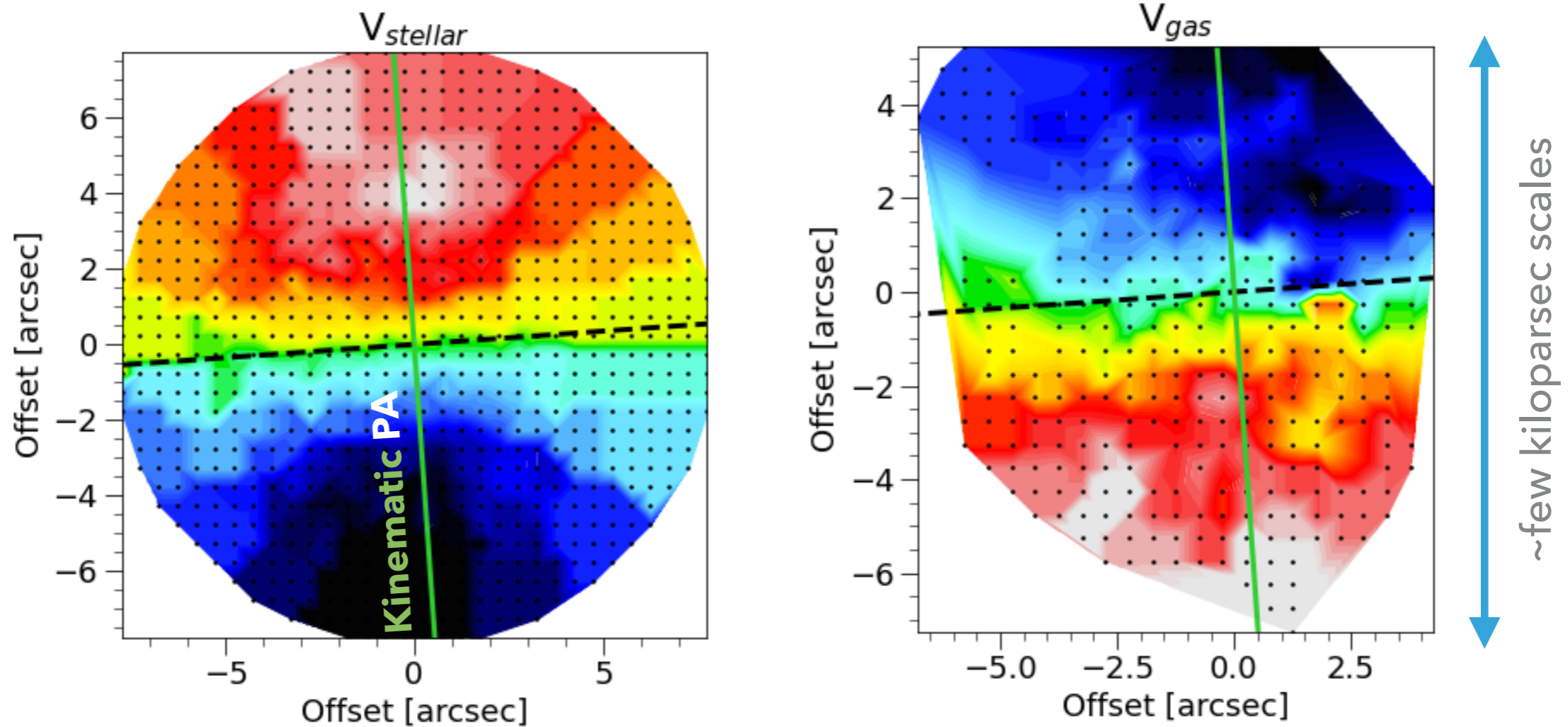
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IS MISALIGNMENT RELATED TO BLACK HOLE FUELLING?

Sample of 3068 galaxies from the SAMI survey
with 3D data and $0.004 < z < 0.095$ (Croom et al. 2021)

STELLAR AND IONISED GAS VELOCITY FIELDS



Kinematic principal axis (PA)

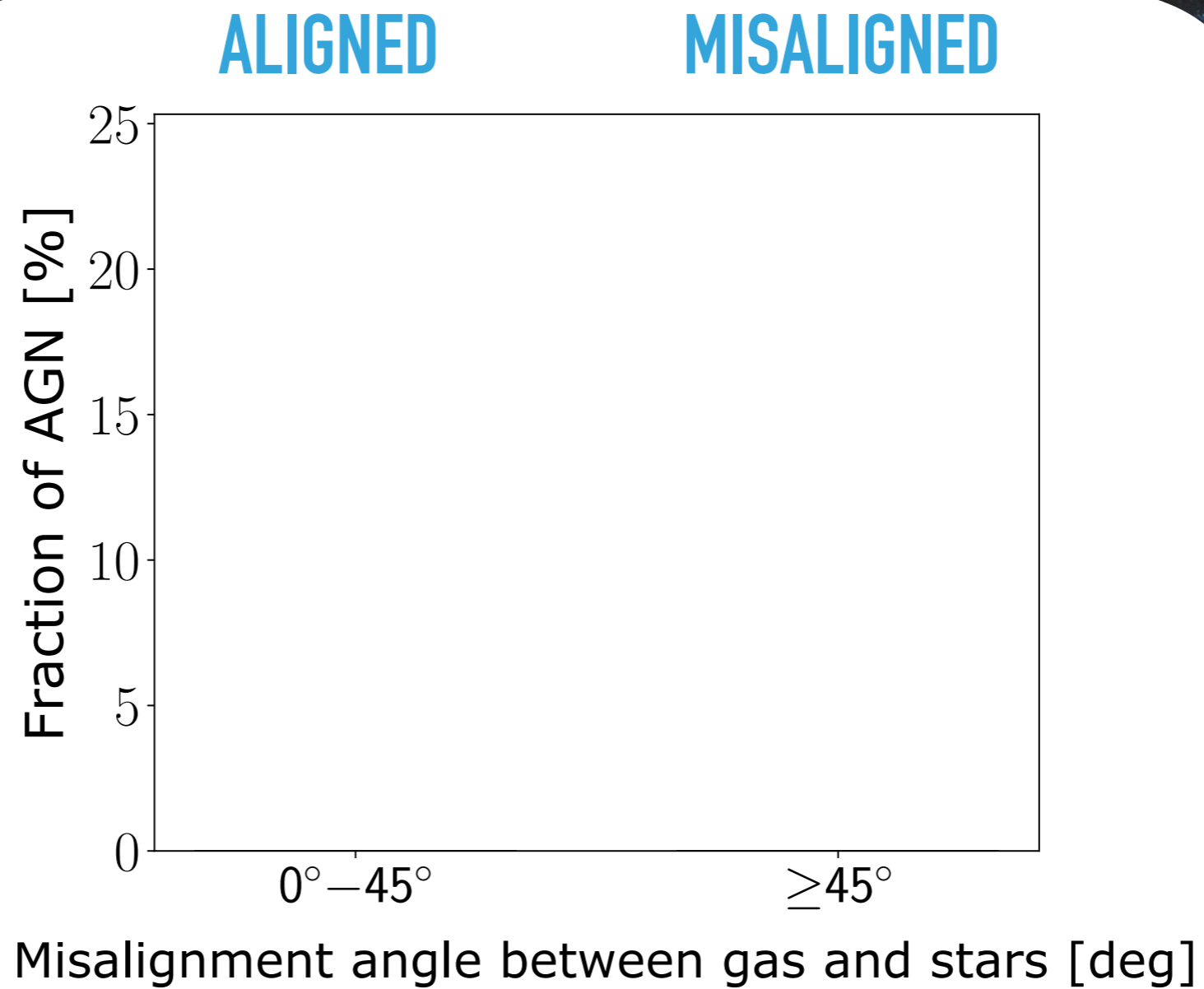
Misalignment angle: $\Delta PA = |PA_{stellar} - PA_{gas}| = 180$ degrees (counter-rotation)

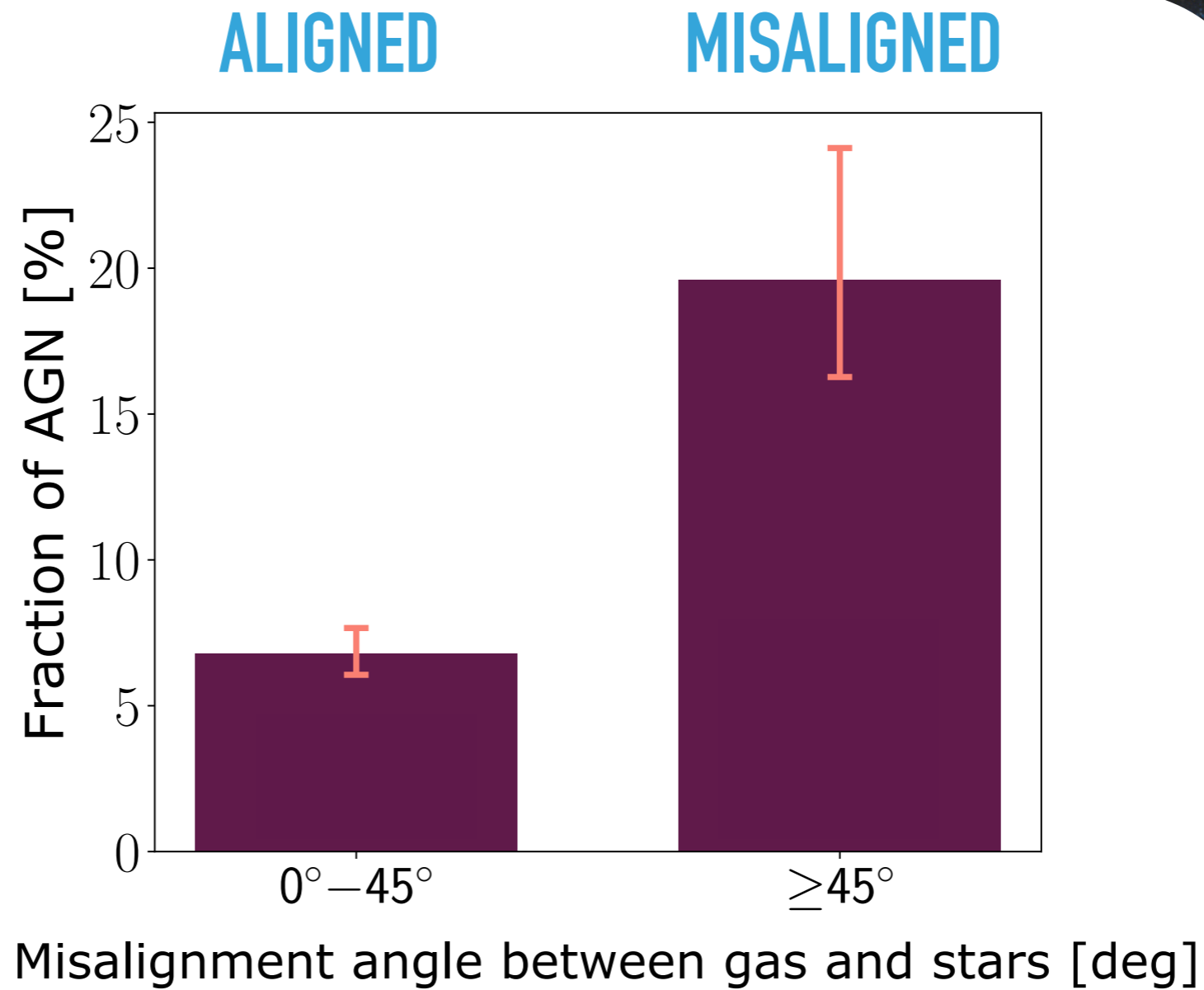
IS MISALIGNMENT RELATED TO BLACK HOLE FUELLING?

AGN identified by optical line ratio and
multi-wavelength diagnostics

(Raimundo et al. 2023)

Goal: determine how the AGN fraction depends on
the misalignment angle between stars and gas



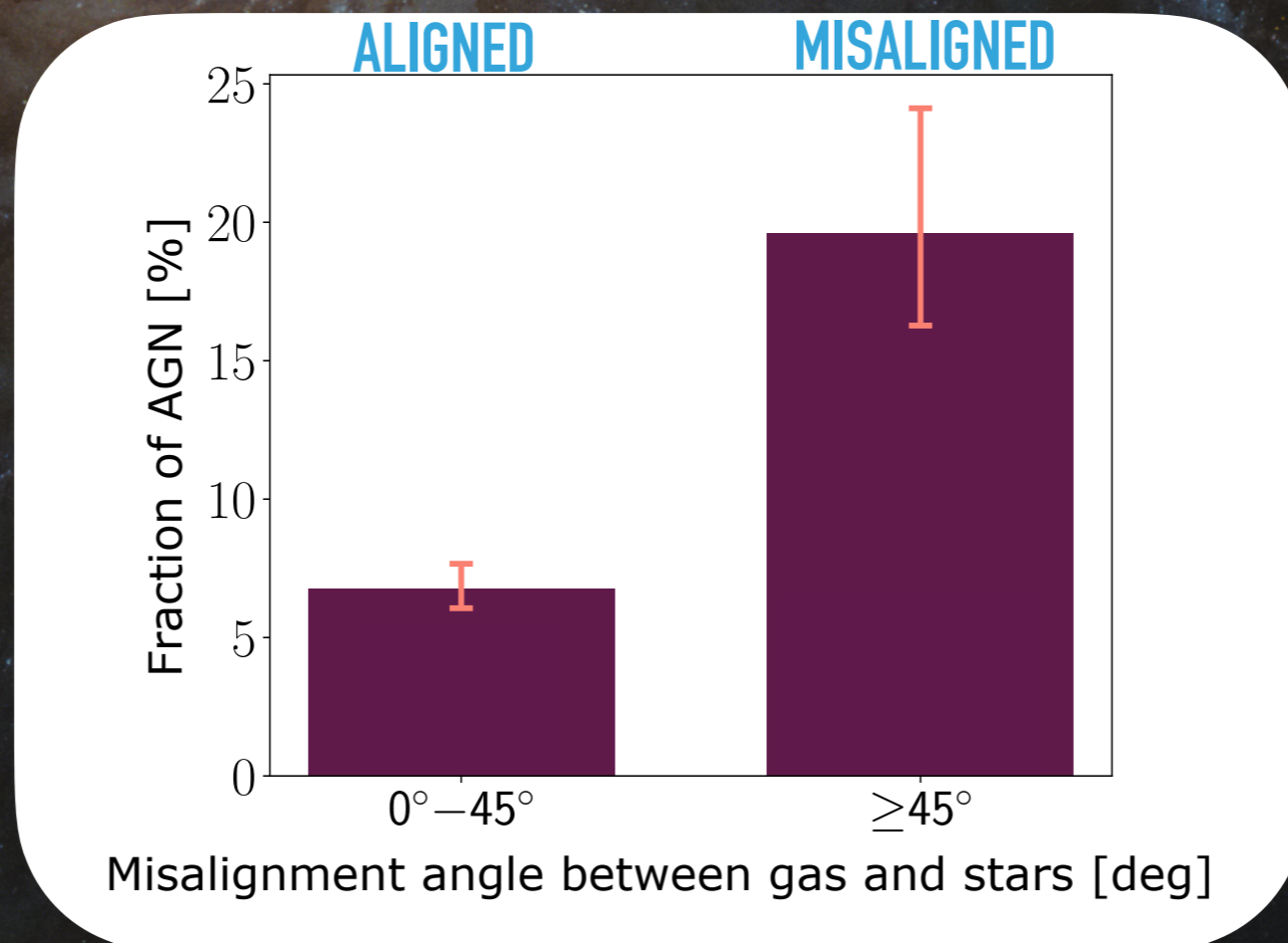


First observation that AGN occur at a higher fraction in galaxies with misalignment

MISALIGNMENT AND BLACK HOLE FUELLING

Early-type galaxies dominate the trend we observe

(Raimundo et al. 2023)



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Observed fraction of misaligned gas
40% in early-type galaxies with gas

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Numerical simulations show
misaligned stars/gas
promote inflow of gas to the nucleus

e.g. via gas dissipation, stellar torques, shocks

(e.g. Negri et al. 2014, van de Voort et al. 2015, Capelo & Dotti 2017,
Taylor et al. 2018)

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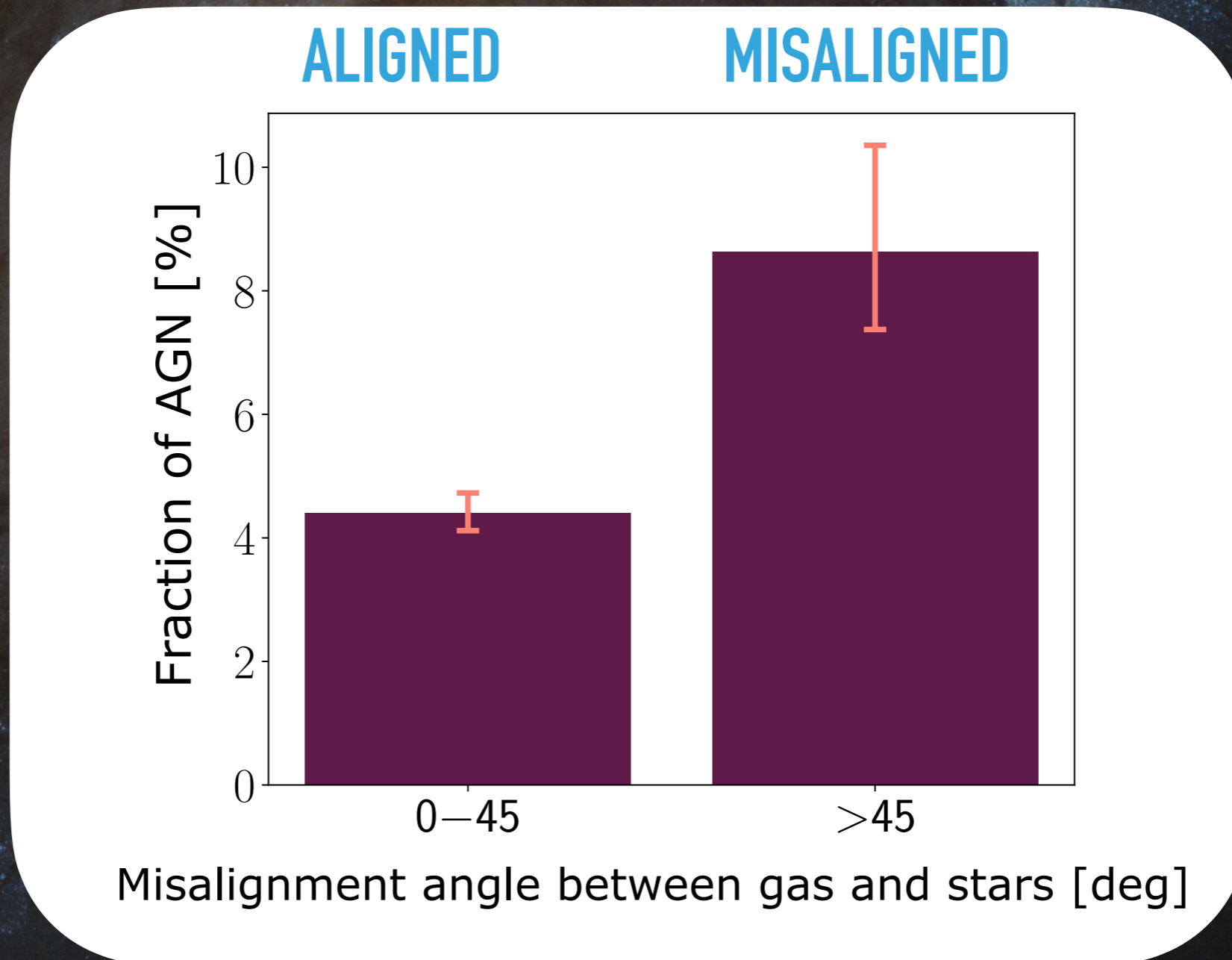
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Two ingredients: gas supply + mechanism to drive gas to the black hole

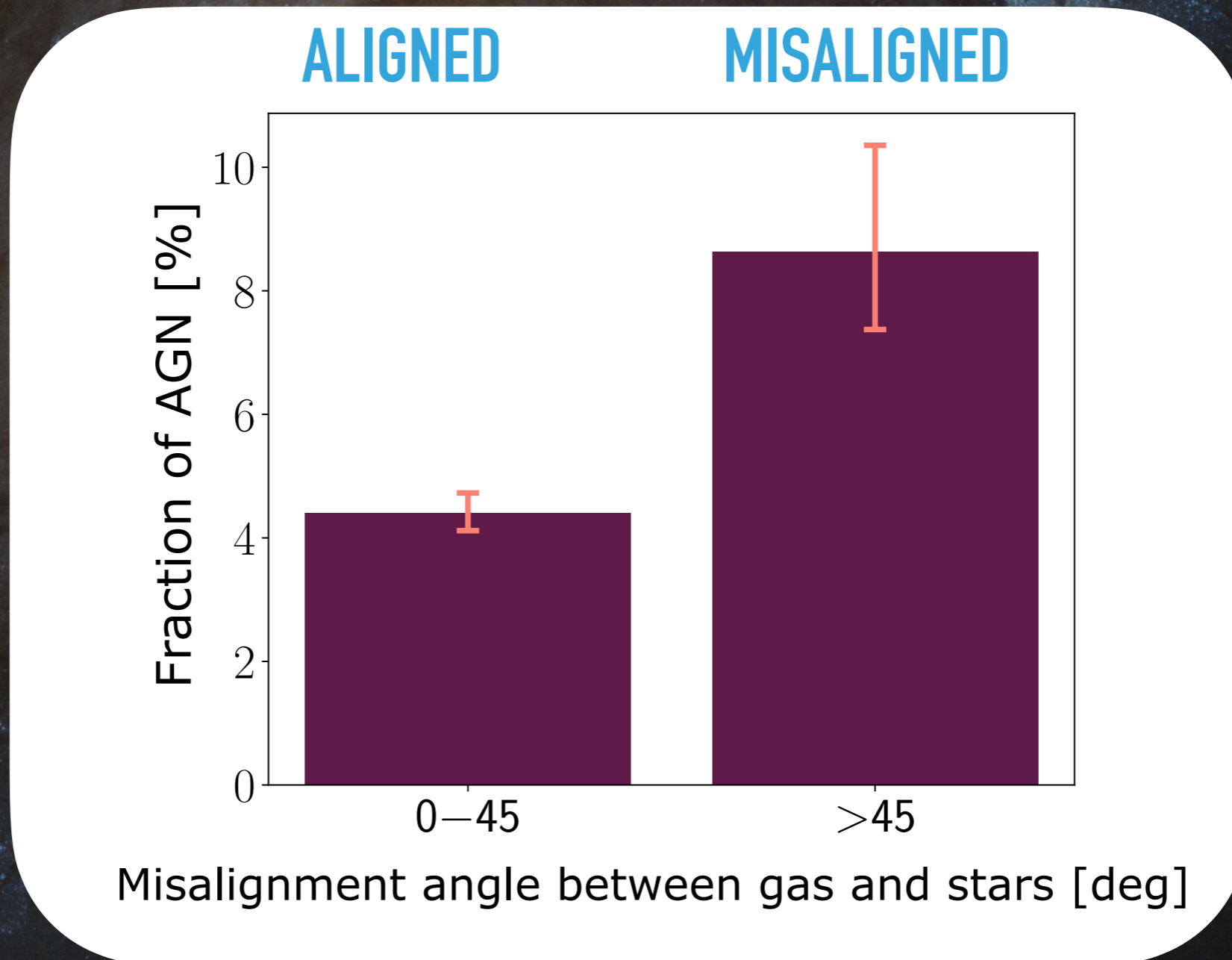
MANGA SURVEY – 10 000 GALAXIES



Different AGN selection mechanism (Rembold et al. 2017, Riffel et al 2023)

Same trend found.

MANGA SURVEY – 10 000 GALAXIES



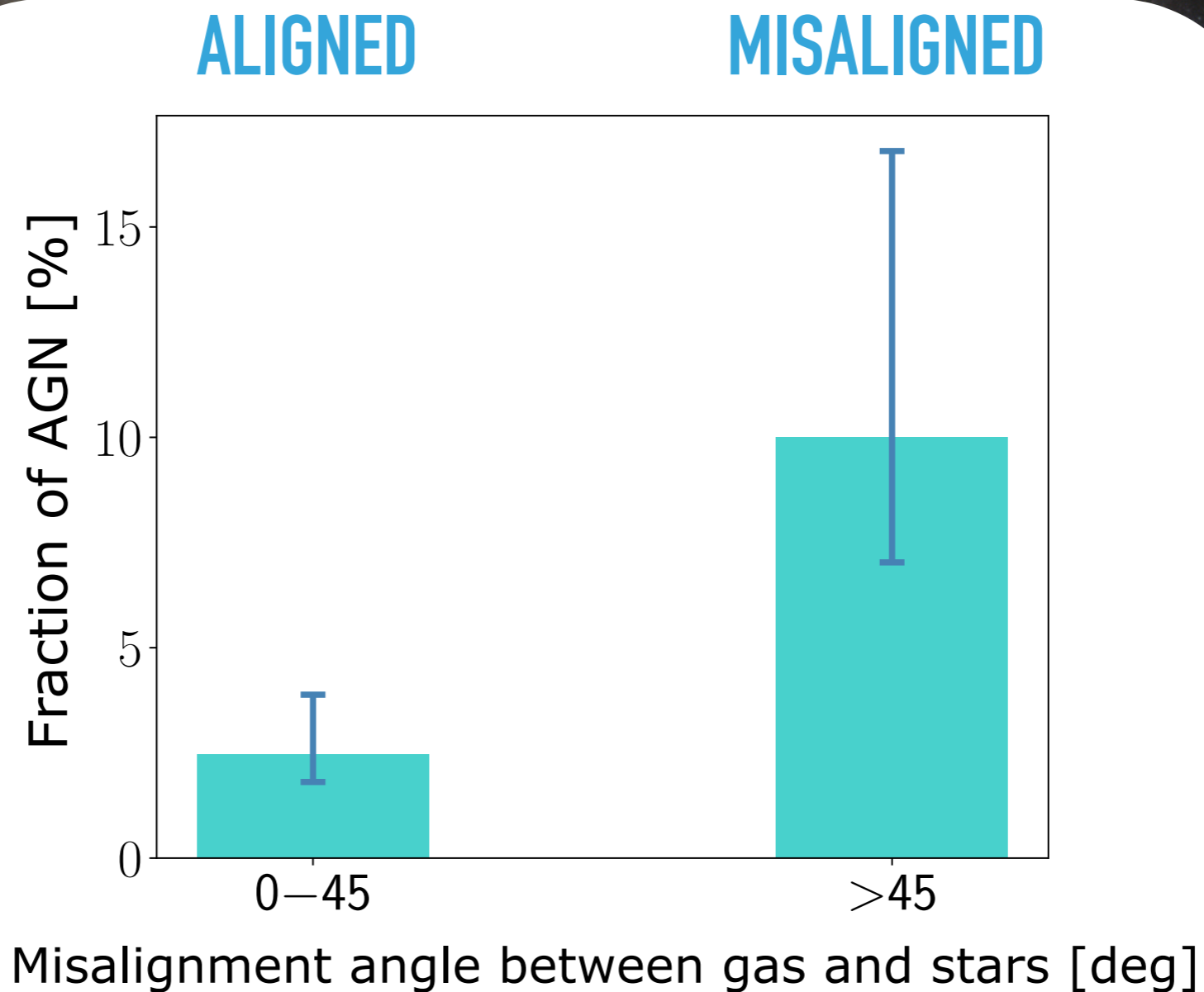
Kinematic misalignment not caused by AGN outflows

MAIN DRIVER: INTERACTIONS OR MISALIGNMENT?

Sample of MaNGA galaxies with visual signatures of mergers/interactions (Li et al 2021)

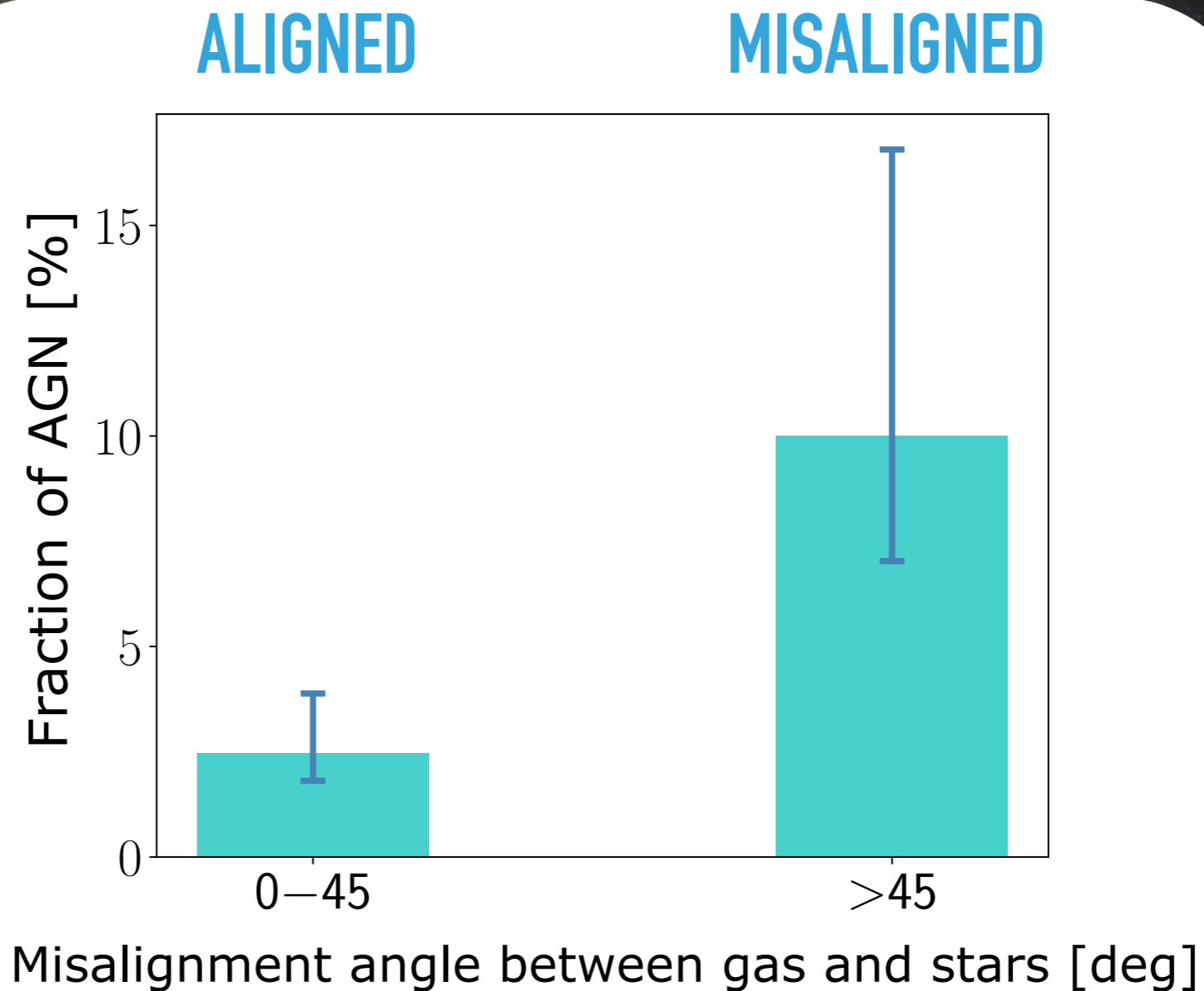
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MAIN DRIVER: INTERACTIONS OR MISALIGNMENT?

The driver is misalignment



CONCLUSIONS

- ▶ External gas accretion can build or replenish the galaxy gas reservoir
- ▶ The presence of a stellar to gas kinematic misalignment is connected with a higher fraction of active black holes.
- ▶ Important mechanism to fuel black holes, in particular in early-type galaxies
- ▶ Stronger effect at high redshift (due to higher fraction of galaxy interactions, e.g. Conselice et al. 2022).

