Title: Growing in the Wind: Emission-Line Imaging of OVI in the Circumgalactic Medium

Speakers: David Rupke

Collection/Series: Cosmic Ecosystems

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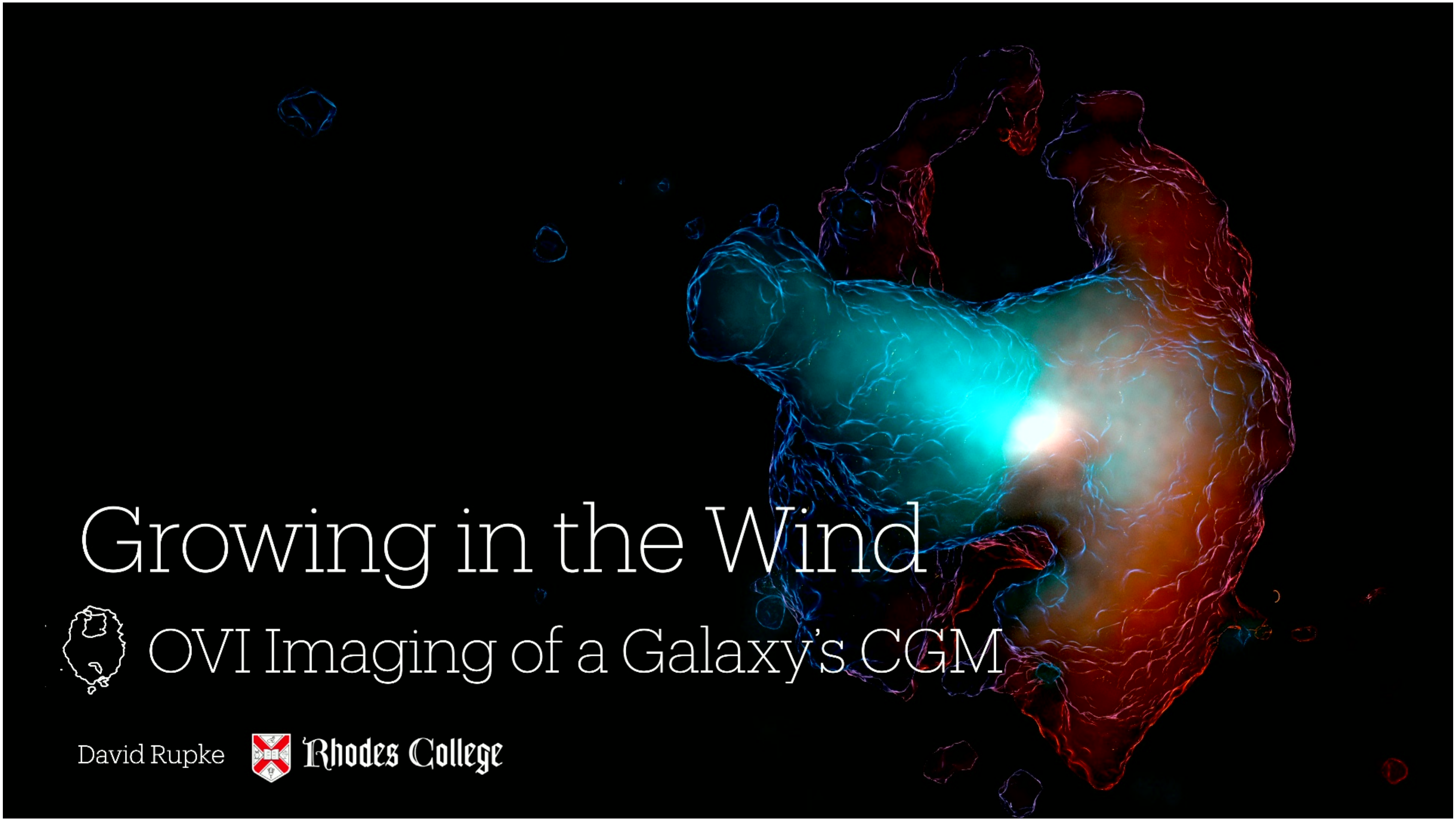
Abstract:

The baryon cycle of a galaxy involves a dynamic interplay between its star-forming disk and the environment of its virial halo, or circumgalatic medium. Simulations and observations agree that winds are a key seeding mechanism for the CGM, which serves as a reservoir for metals produced in disks. Cool clouds are predicted to form in the CGM from cooling halo gas, and are observed in absorbing sightlines to background quasars. This cloud growth may be accelerated by the action of winds. However, directly imaging the cold-hot interaction is extremely challenging, as most of the cooling channels lie in the UV and X-ray. I will present a deep image of OVI 1032, 1038 A and Lyman-alpha in the footprint of a prominent galactic wind. The OVI-emitting gas follows the morphology observed in lines at optical wavelengths. This represents only the second image of OVI in the halo or CGM of a galaxy, and is a signpost of cloud growth at large radii as the wind and CGM interact. This detection will help motivate further attempts to image the CGM-in-formation with existing or future facilities. It will also help inform models and simulations of the wind-CGM interaction.


Growing in the Wind
OVI Imaging of a Galaxy's CGM
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Collaborators

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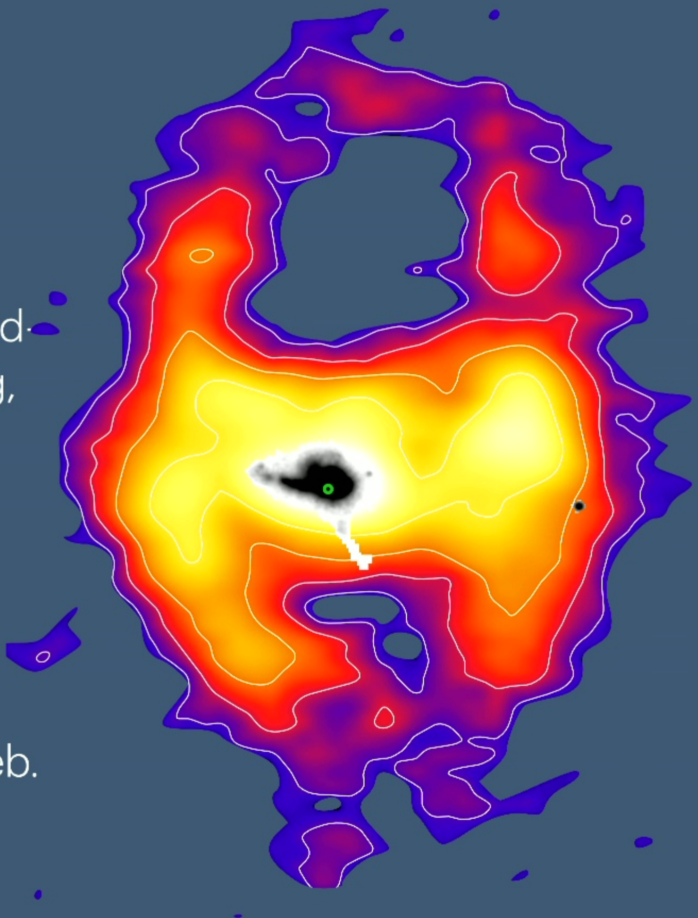
Sylvain Veilleux, Steven Shockley, Marcio Melendez

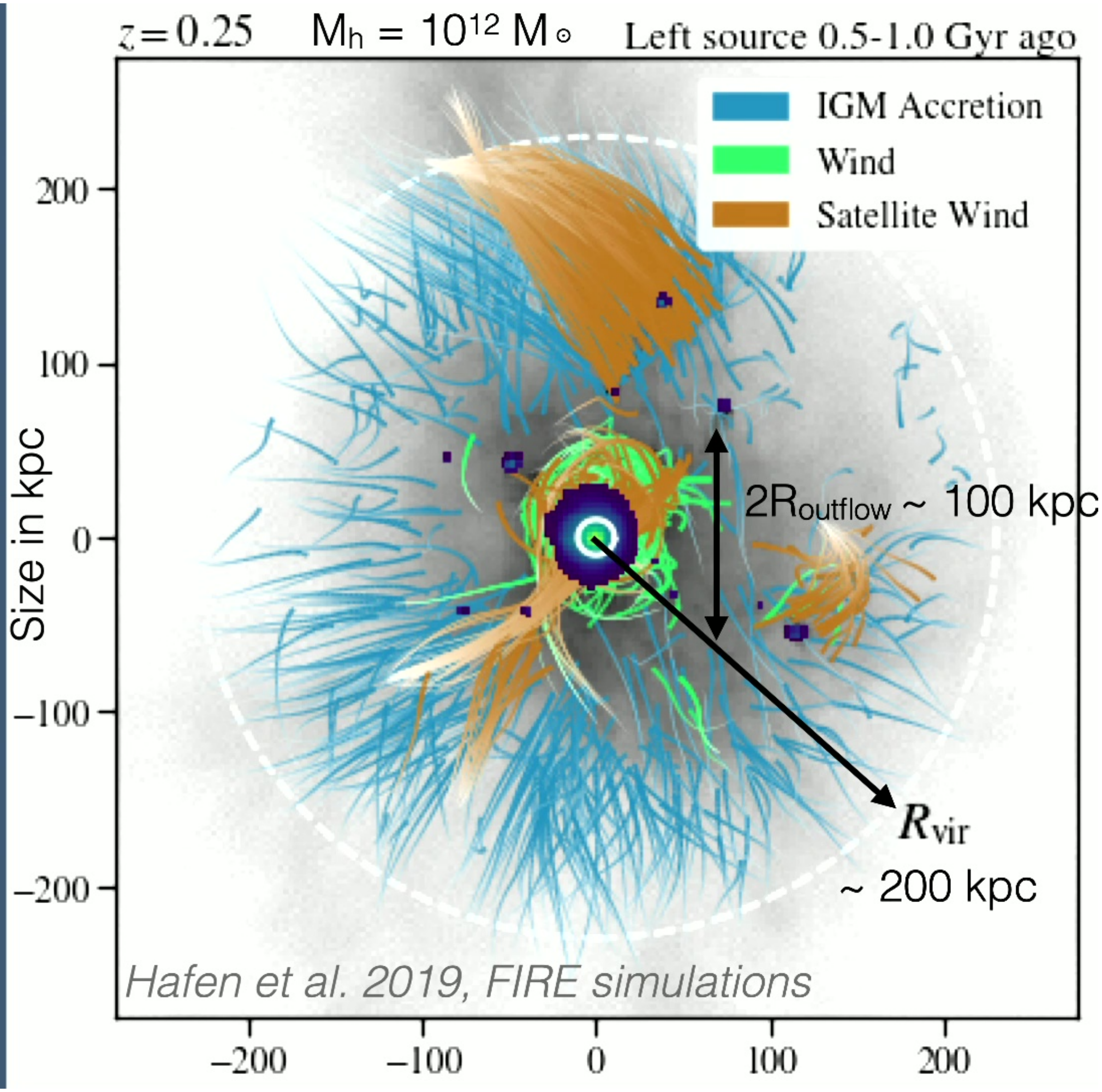
Thanks to Sally Heap for the original idea for this project (Feb. 2020)

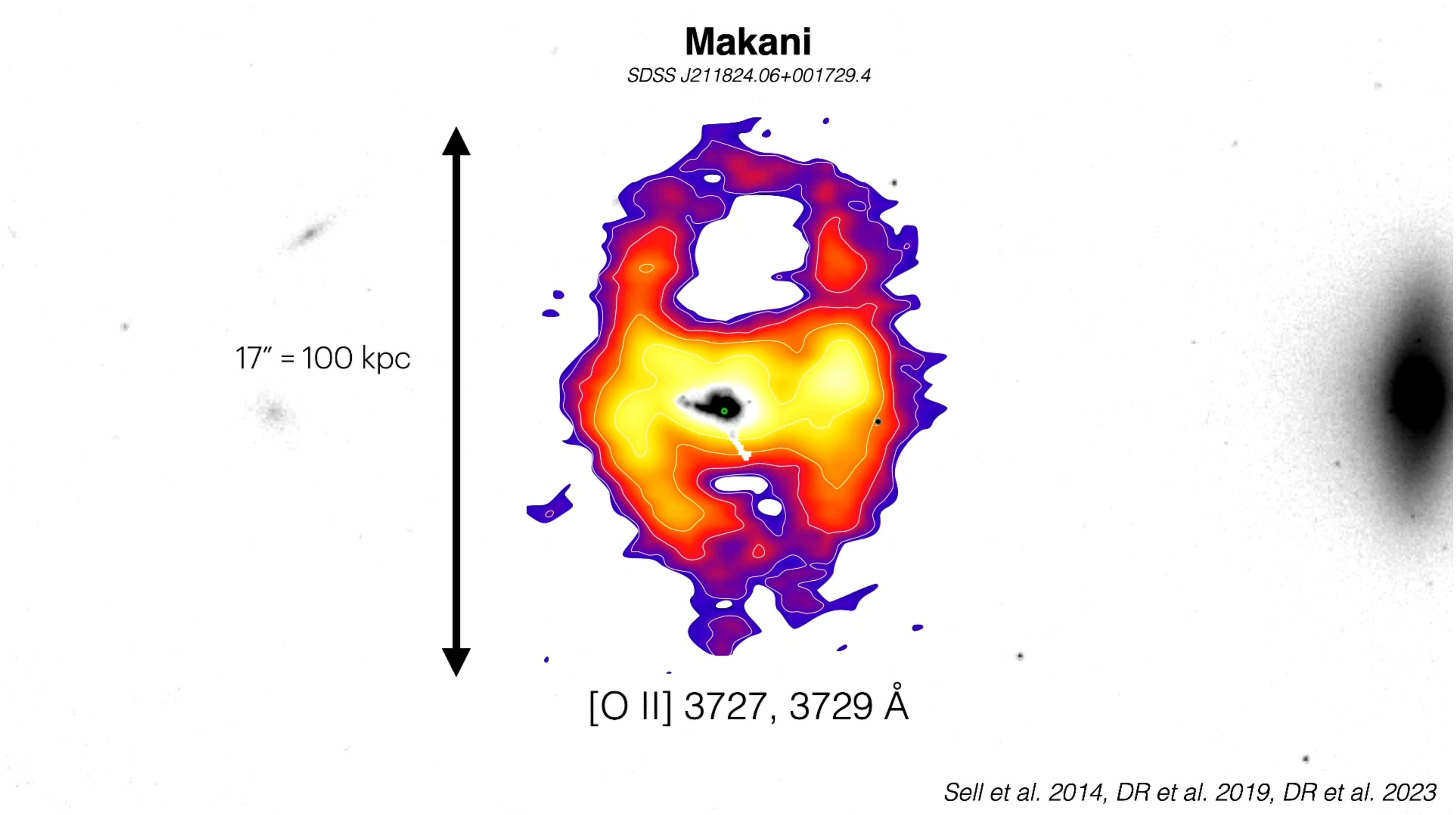


Moving metals

Winds move metals from production sites (galaxies) into the local (CGM) and global (ICM/IGM) environments

Regions surrounding galaxies contain 3/4 of all metals (Peeples et al. 2014)




Makani
SDSS J211824.06+001729.4
17″ = 100 kpc
[O II] 3727, 3729 Å
Sell et al. 2014, DR et al. 2019, DR et al. 2023

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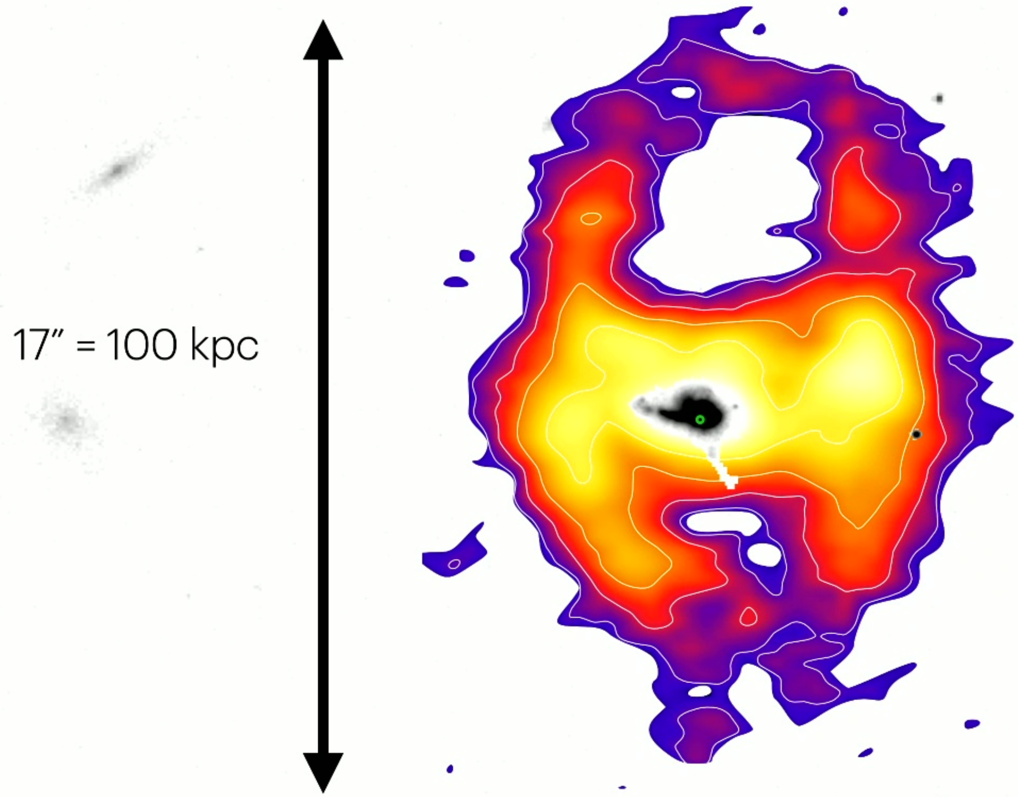


[O II] 3727, 3729 Å

Vital statistics

z = 0.459

$M_* = 10^{11.1}\ M_{sun}$

$M(H_2) = 10^{10}\ M_{sun}$

SFR = 250 M_{sun}/yr

SFH: 7 Myr, 400 Myr

Scales

R_e(stars) = 2.5 kpc

R_e([OII]) = 17 kpc

Warm Ionized Gas

L([OII]) = 3×10^{42} erg/s

shock-ionized, 2-stage wind

dM/dt ~ SFR (inner wind)

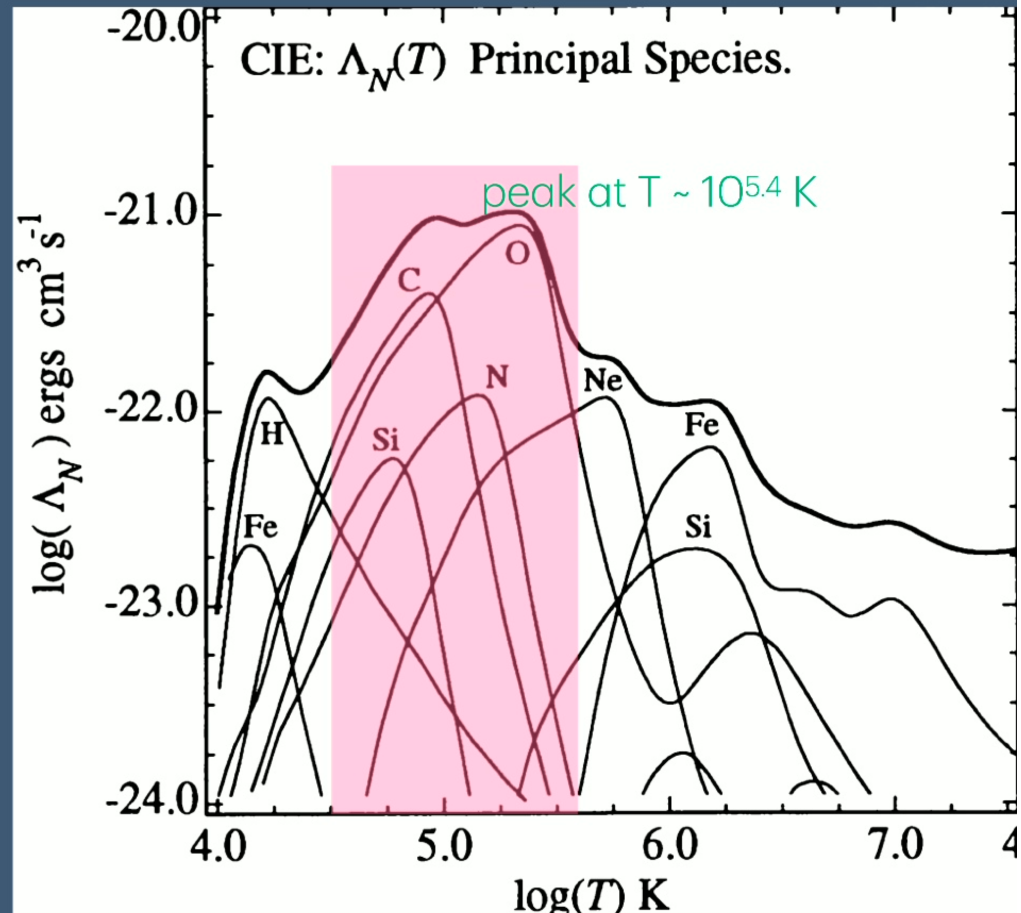
M(H II) ~ $M(H_2)$

Sell et al. 2014, DR et al. 2019, DR et al. 2023

Oxygen in the CGM

Tracing gas mixing and cooling

O is a major coolant of hot gas, whether in or out of equilibrium



Cooling Function: Sutherland & Dopita 1993

Oxygen in the CGM

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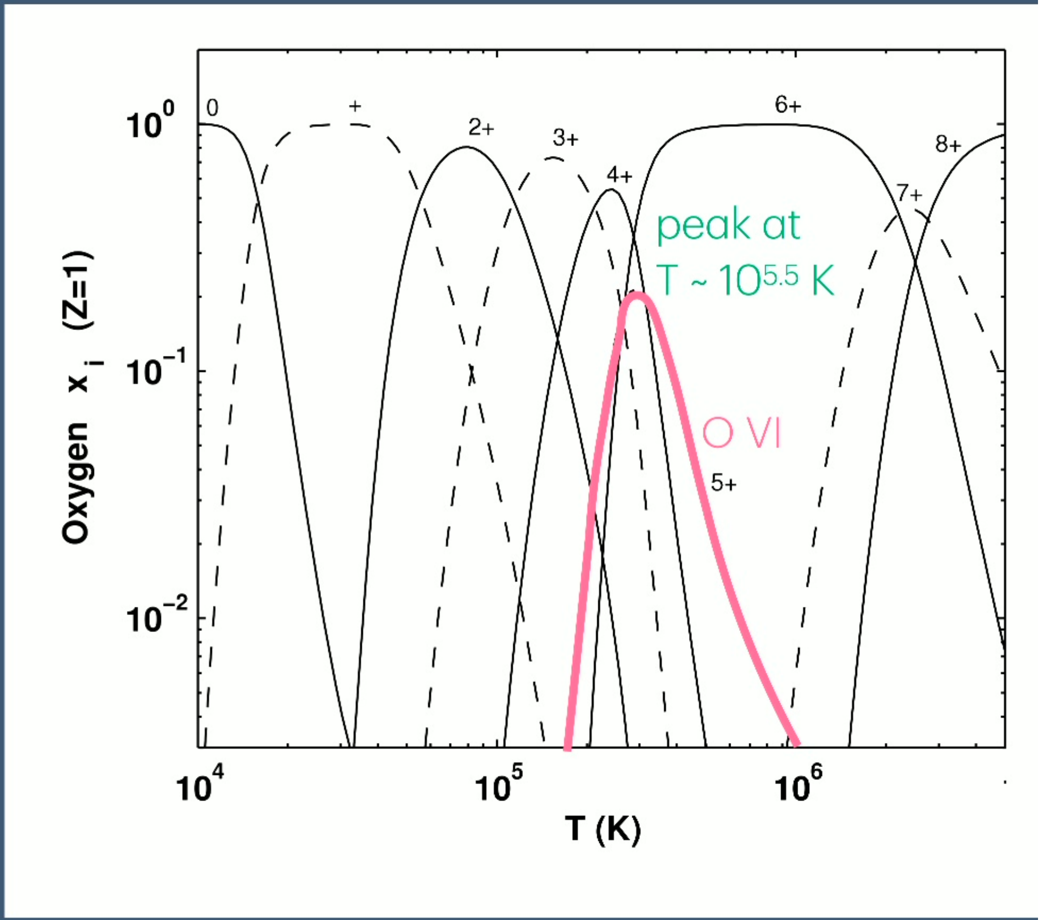
OVI ionization fraction peaks at T ~ $10^{5.5}$ K

OVI 1032, 1038 A in absorption is a key observable of the CGM (Tumlinson et al. 2011)



O Ion Fractions: Gnat & Sternberg 2007

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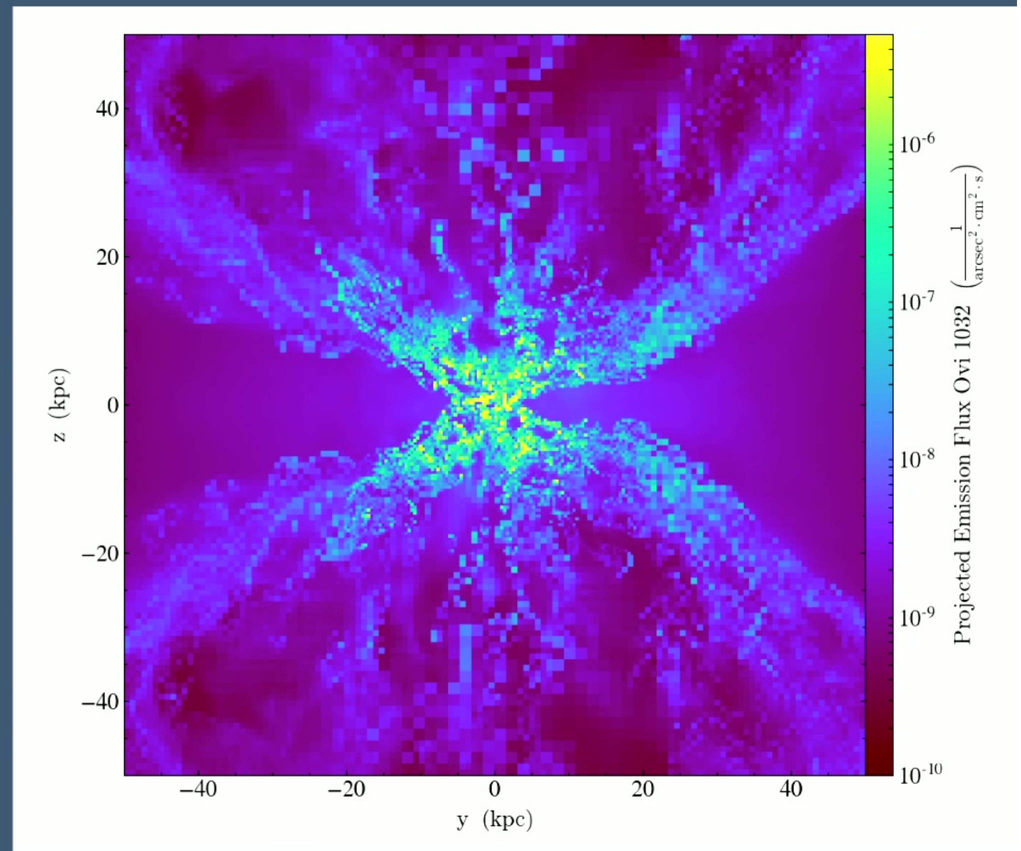
Cool clouds in a wind interact with the hot, diffuse CGM and hot wind fluid in turbulent mixing layers (Slavin et al. 1993, Heckman et al. 2001)

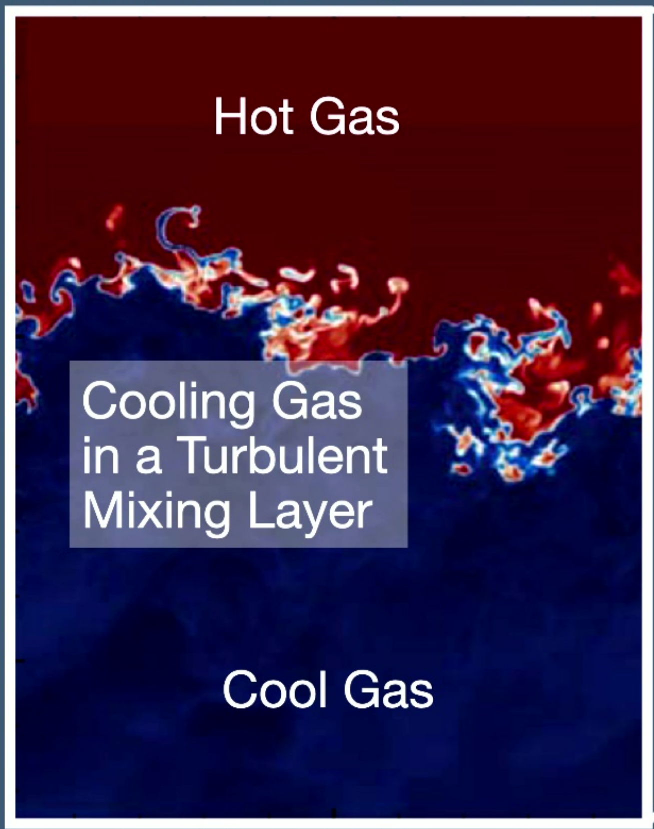
Cloud growth via cooling across this interface (Gronke & Oh 2018)



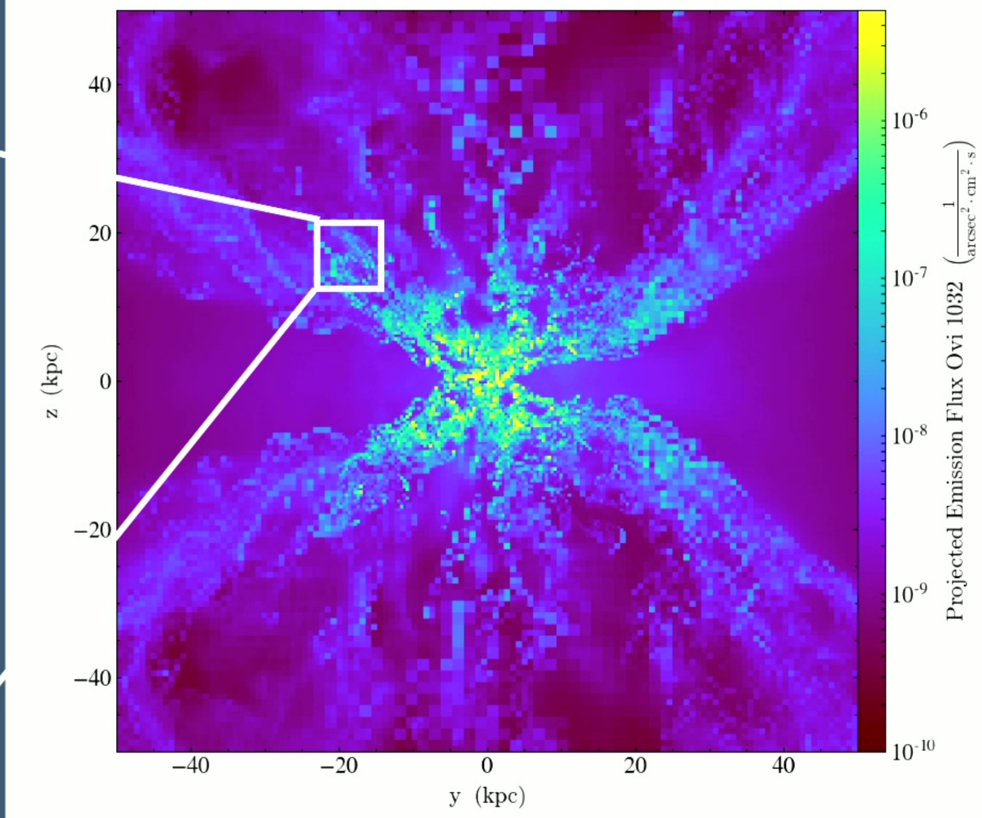
OVI emission from a cooling hot wind: Li et al. 2017, Li & Tonnesen 2020

Oxygen in the CGM

Tracing gas mixing and cooling



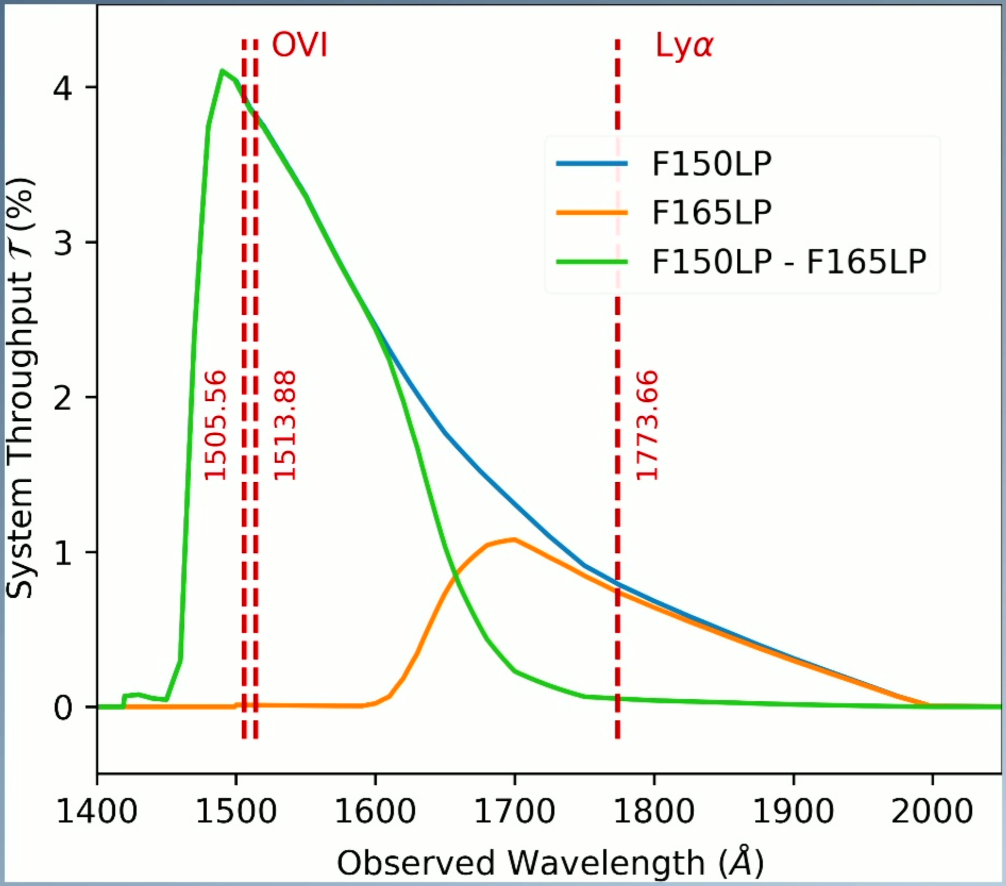
Fielding et al. 2020



OVI emission from a cooling hot wind:
Li et al. 2017, Li & Tonnesen 2020

The experiment

Ha, DR, et al. 2025



Differential narrowband imaging inspired by Hayes et al. 2016

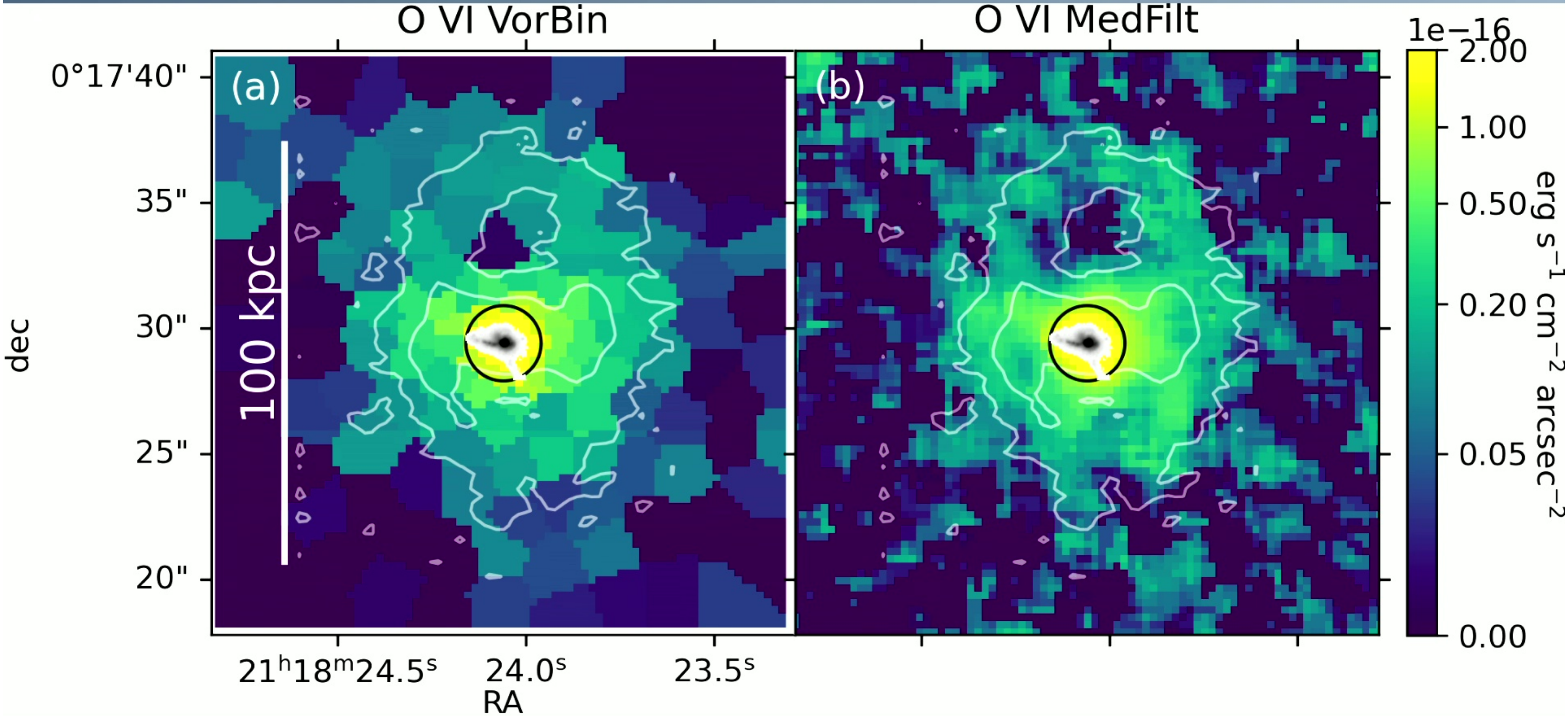
20 orbits with HST/ACS Solar Blind Channel

F150LP contains OVI + Lyα
F165LP contains only Lyα

Fluxed OVI Images

Ha, DR, et al. 2025

Strong connection between T ~ 10^4 K wind and T ~ $10^{5.5}$ K gas



Wind-CGM interaction

Shocked clouds in a hot medium

L(O VI) ~ L([OII]) = 3x10^{42} erg/s

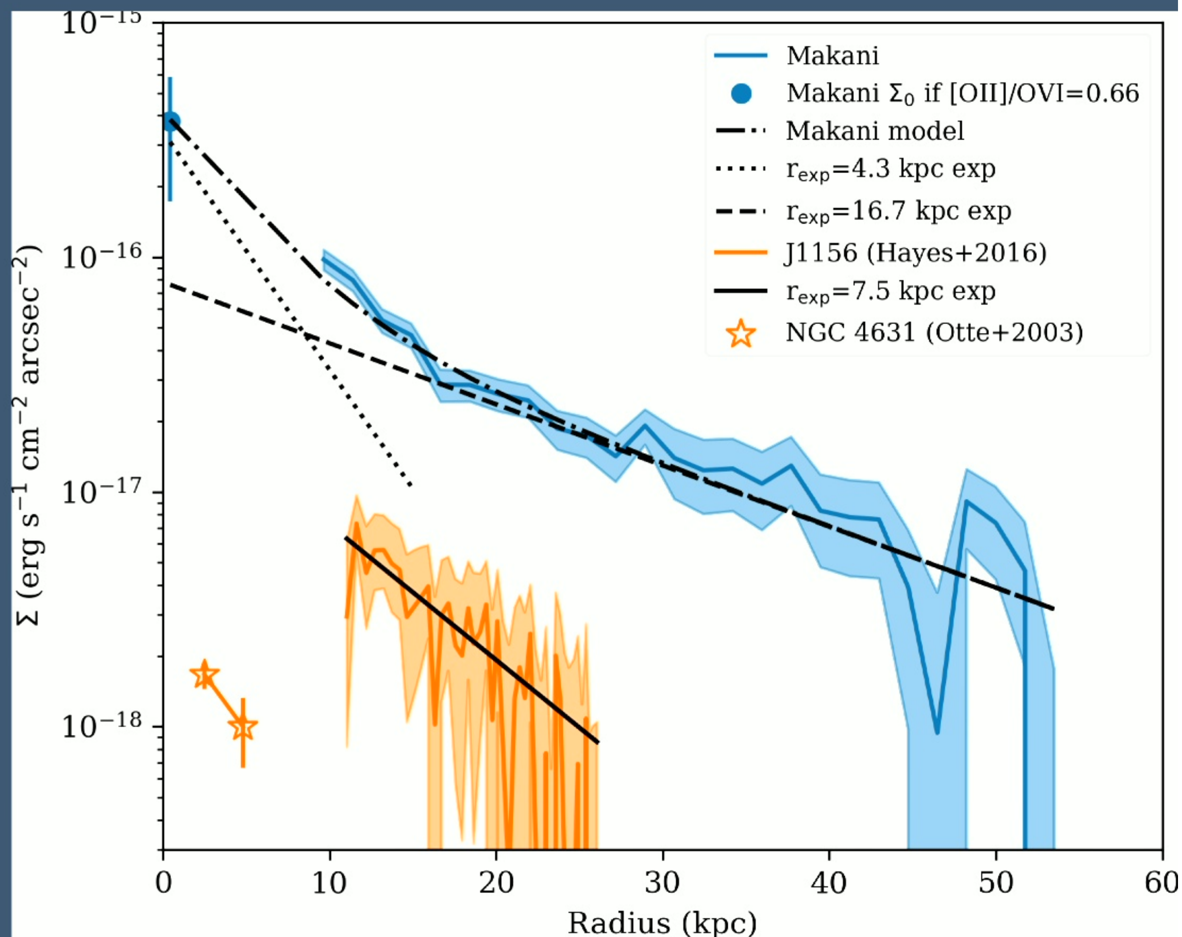
20x more luminous than J1156 at z = 0.235 (Hayes et al. 2016)

consistent with SFR scalings (Li et al. 2017, Tchneryshyov et al. 2023)

Strong connection between T ~ 10^4 K wind and T ~ 10$^{5.5}$ K gas

⇒ Coupling between hot and cool gas

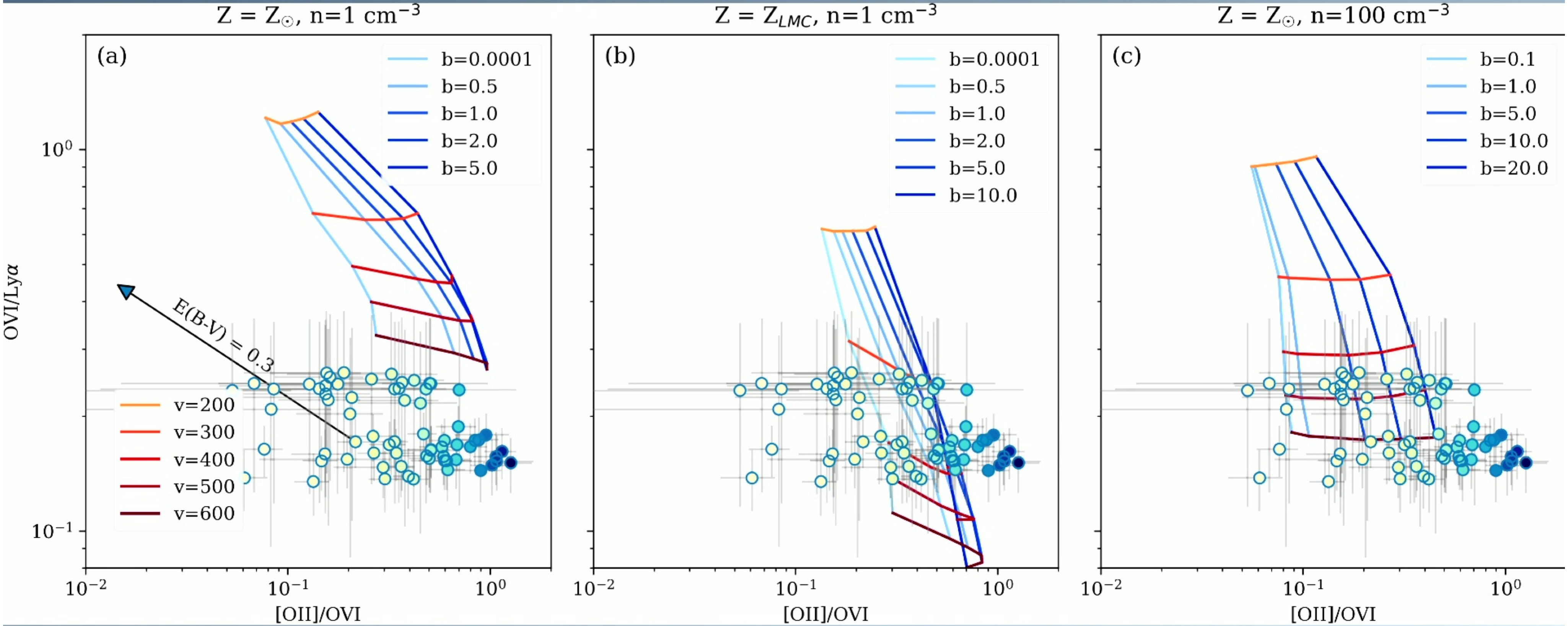
via mixing, radiative cooling, and condensation (Gronke & Oh 2018)



Still shocking?

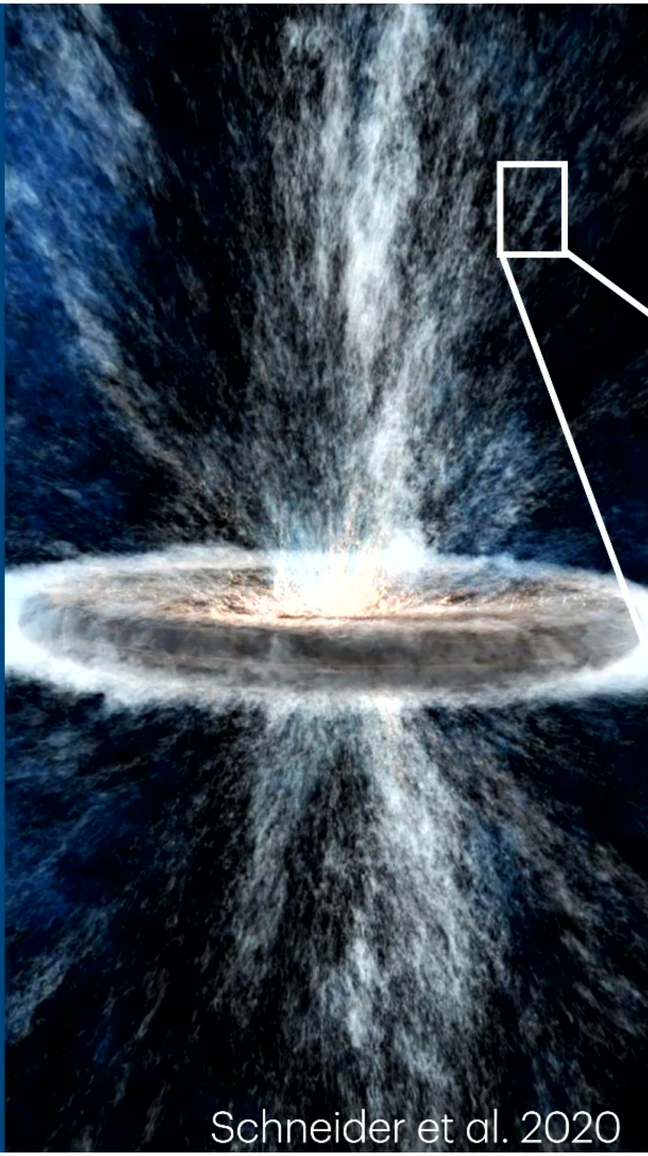
Ha, DR, et al. 2025

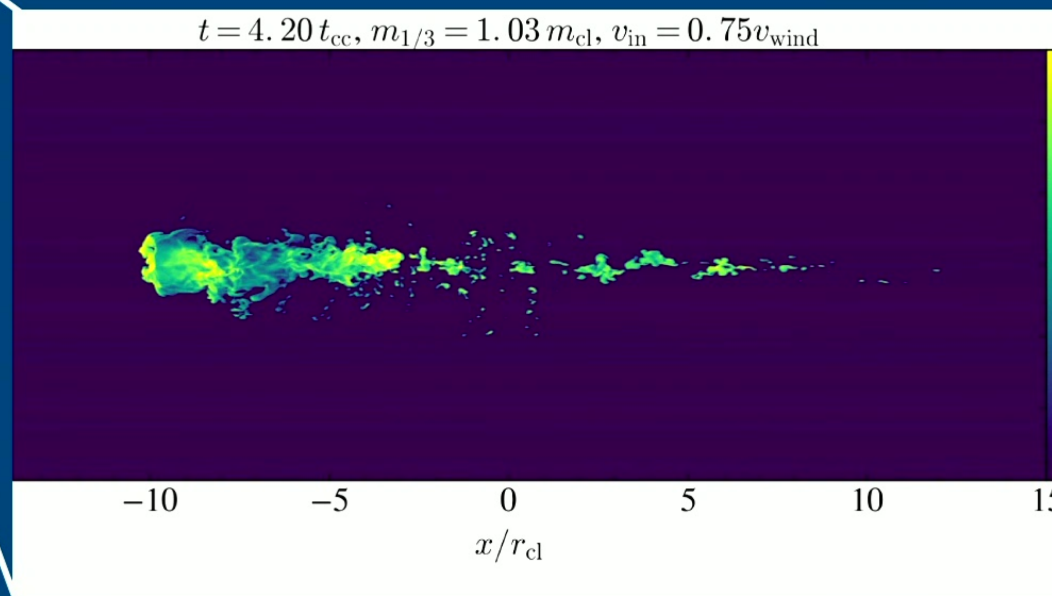
Warm ionized gas consistent with shock ionization (DR et al. 2023). What about FUV lines?



Models from Allen et al. 2008. Attenuation and radiative transfer effects complicate things.

Cool Clouds: Shredding and Growing in a Hot Wind?



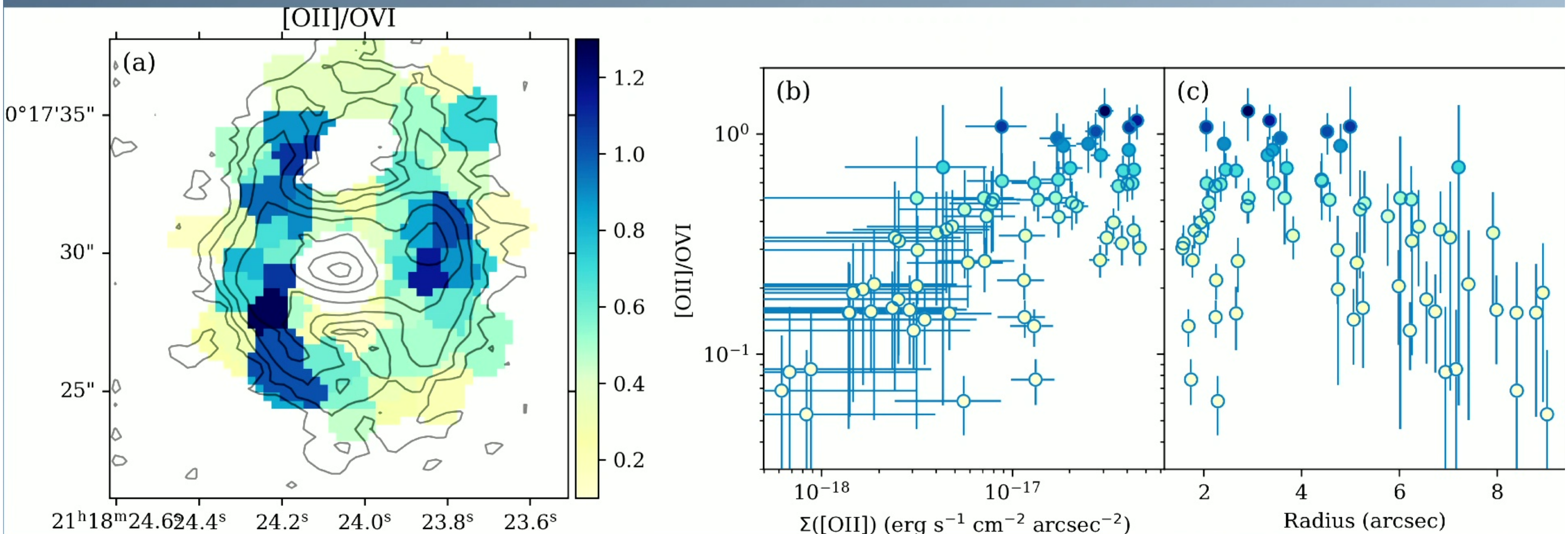


Gronke et al. 2018

Line Ratios

Ha, DR, et al. 2025

[OII]/OVI higher in hourglass "lobes", larger radius for given S.B.



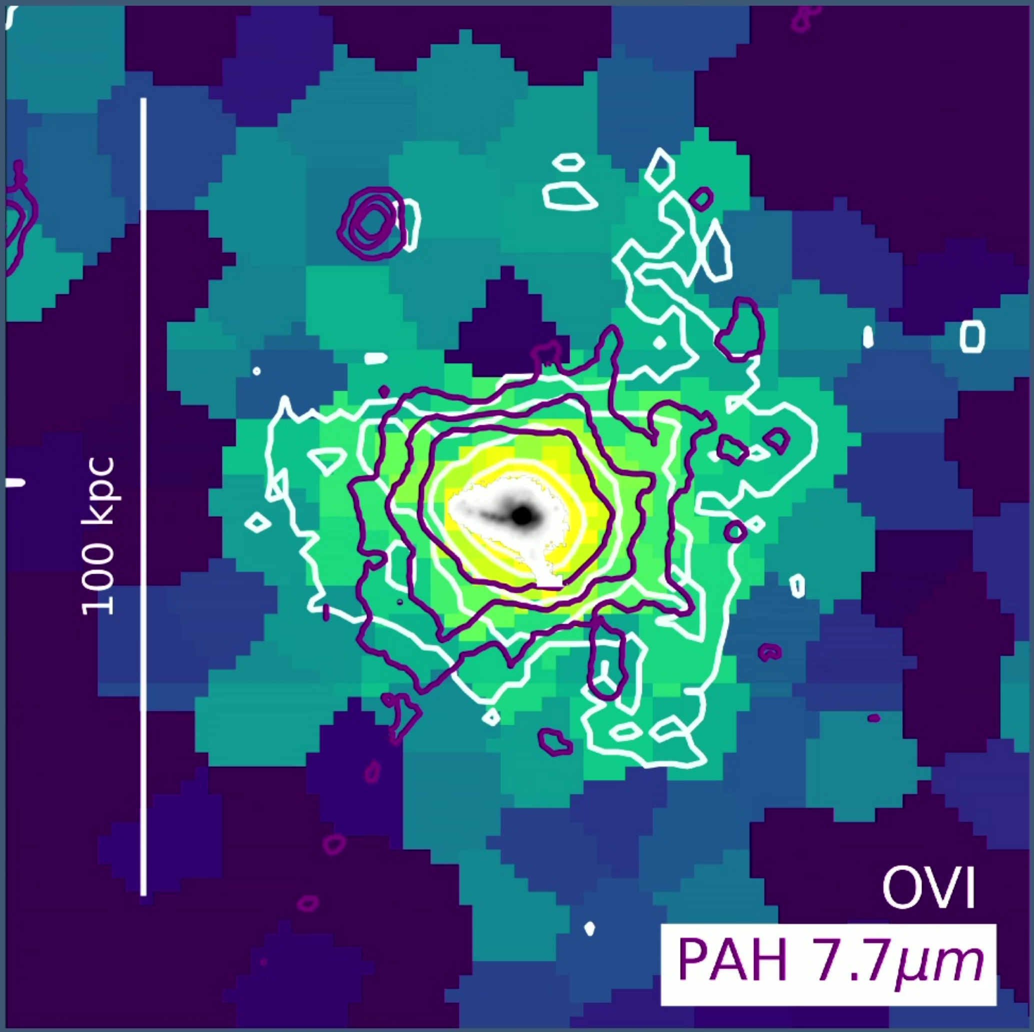
Dust in the Wind

JWST MIRI imaging at 5—25 μm

Warm dust + PAH molecules

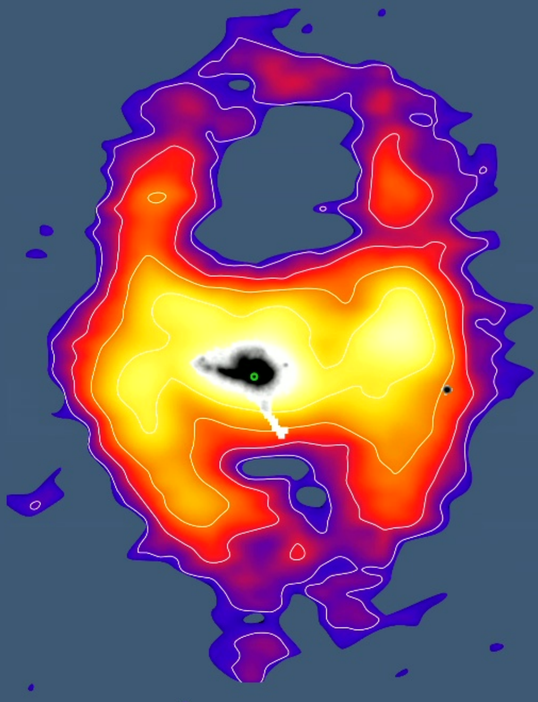
Emission extends to 30+ kpc, but evidence for erosion of grains

Dust survival may be enabled by cloud growth



Veilleux et al. 2025, in press

The Answer my Friend, is Growing in the Wind



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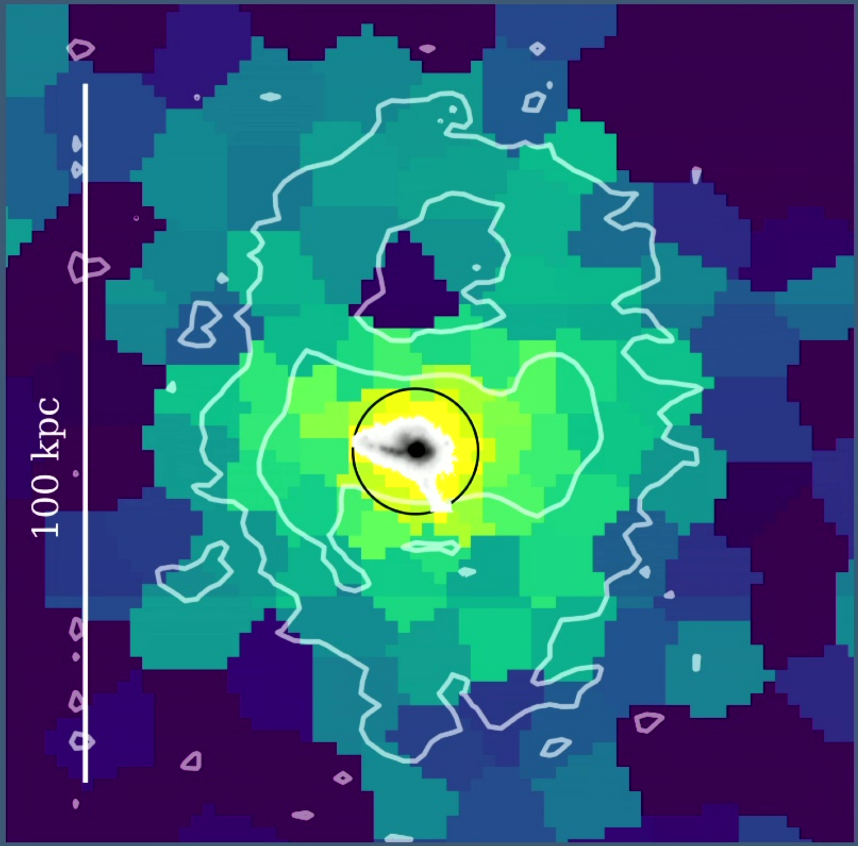

O VI 1032, 1038

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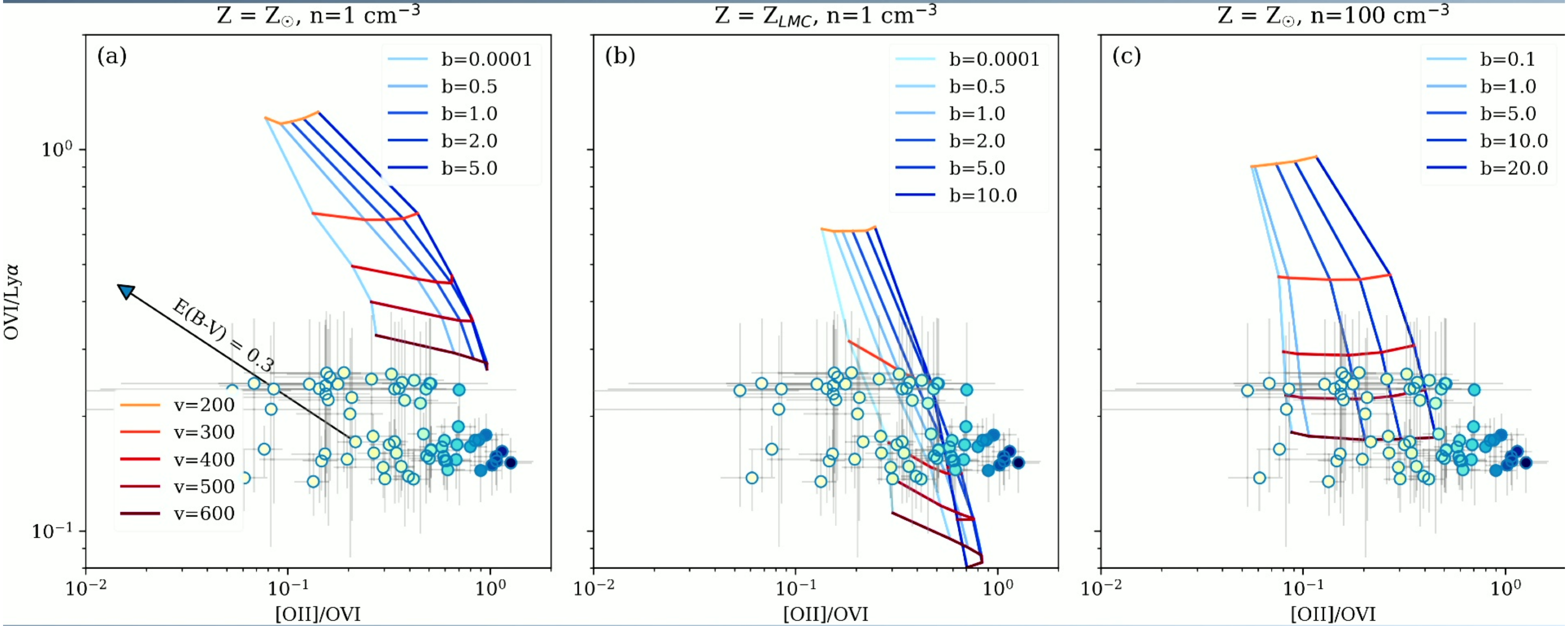

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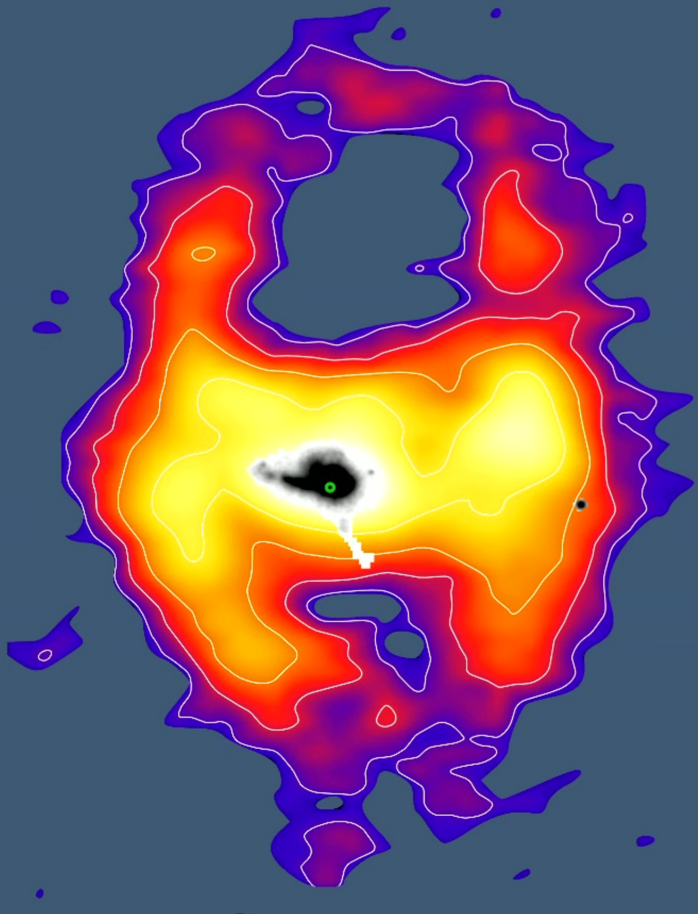
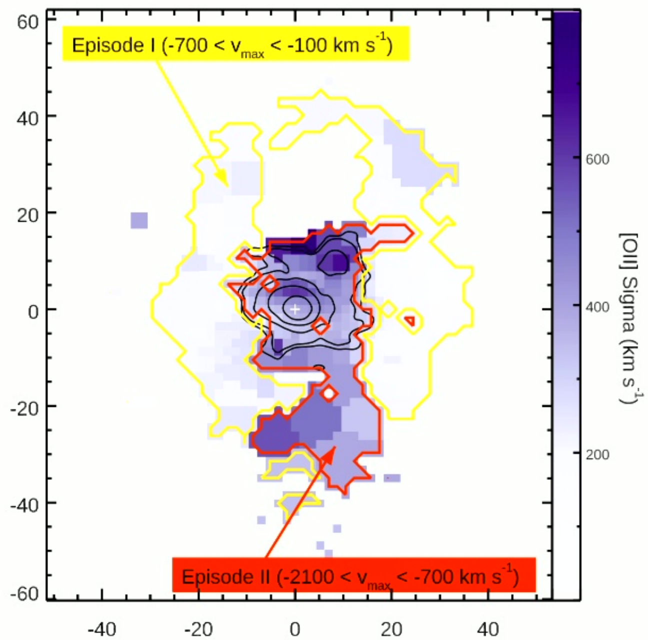
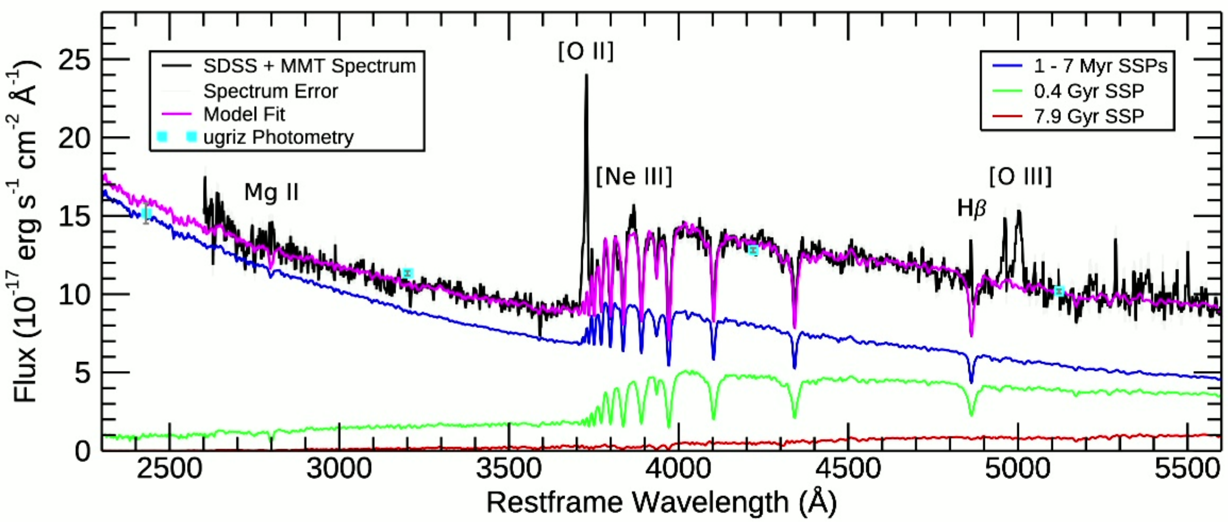
Extremes in compact, starburst mergers



$\Sigma_\star$	$10^{11}\ M_\odot\ kpc^{-2}$
Σ_{SFR}	$10^{3}\ M_\odot\ yr^{-1}\ kpc^{-2}$
$R_{outflow}$	50 kpc
$V_{outflow}$	$3000\ km\ s^{-1}$
dM/dt	$2000\ M_\odot\ yr^{-1}$
η	20

Connecting Wind Kinematics and Star Formation History





DR et al. 2019