Characterizing obscured AGN in powerful outflow hosts using mid-IR spectral diagnostics

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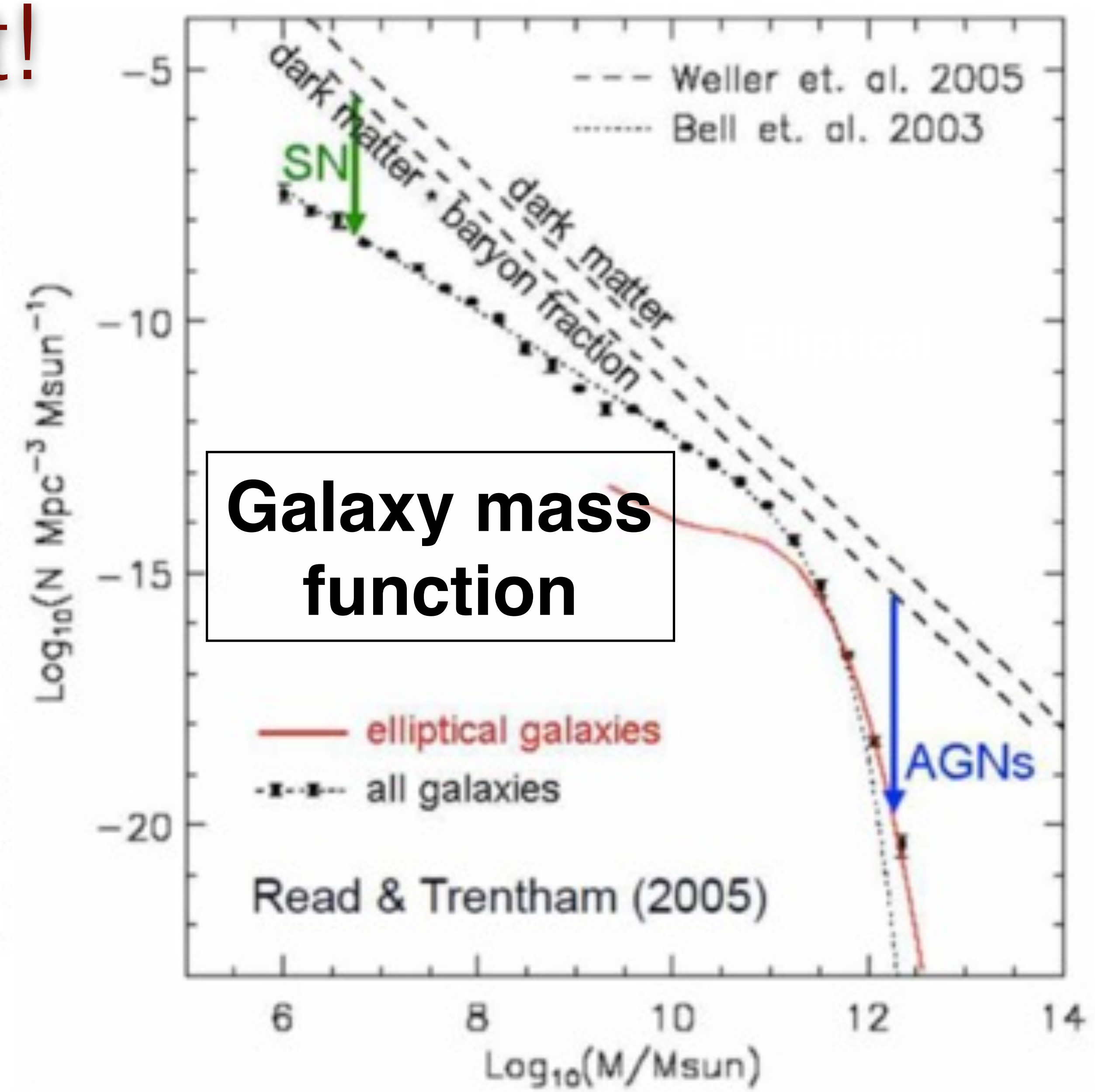
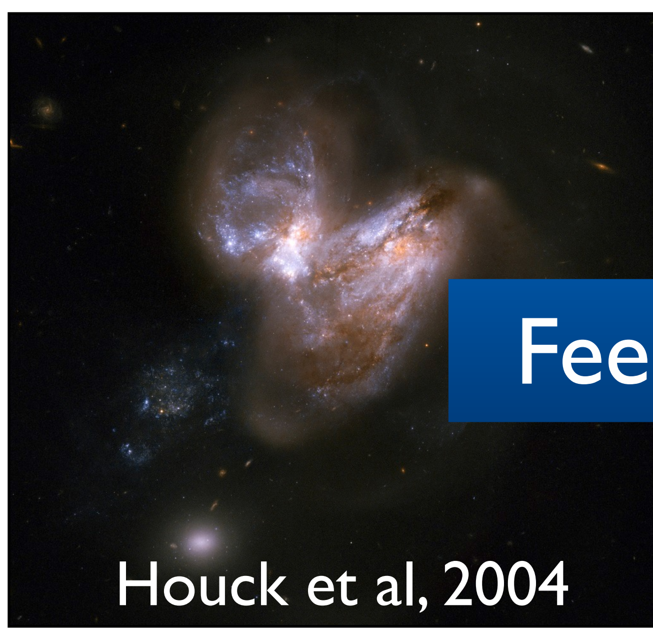
AGN feedback is important!

AGN-driven feedback in massive galaxies is invoked to explain observations like the:

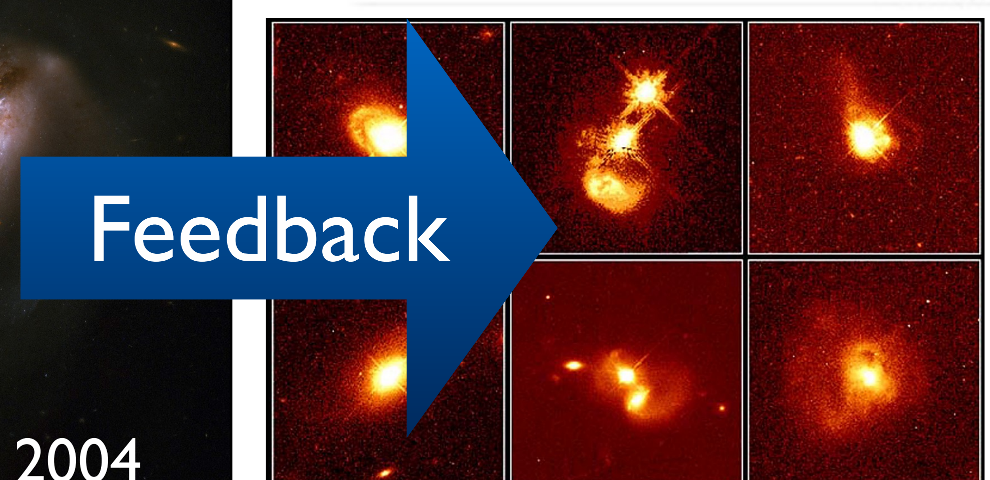
- Black-hole bulge co-evolution
  see Kormendy & Ho, 2013
- Downturn of the galaxy mass function



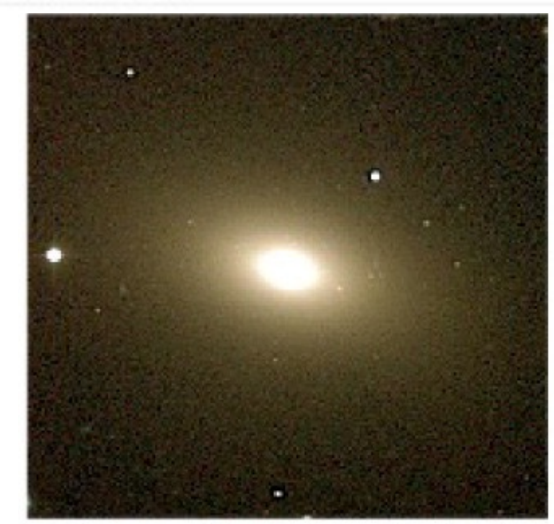
Merger



Dust-rich, IR-luminous ULIRGs



Optically luminous, unobscured quasar

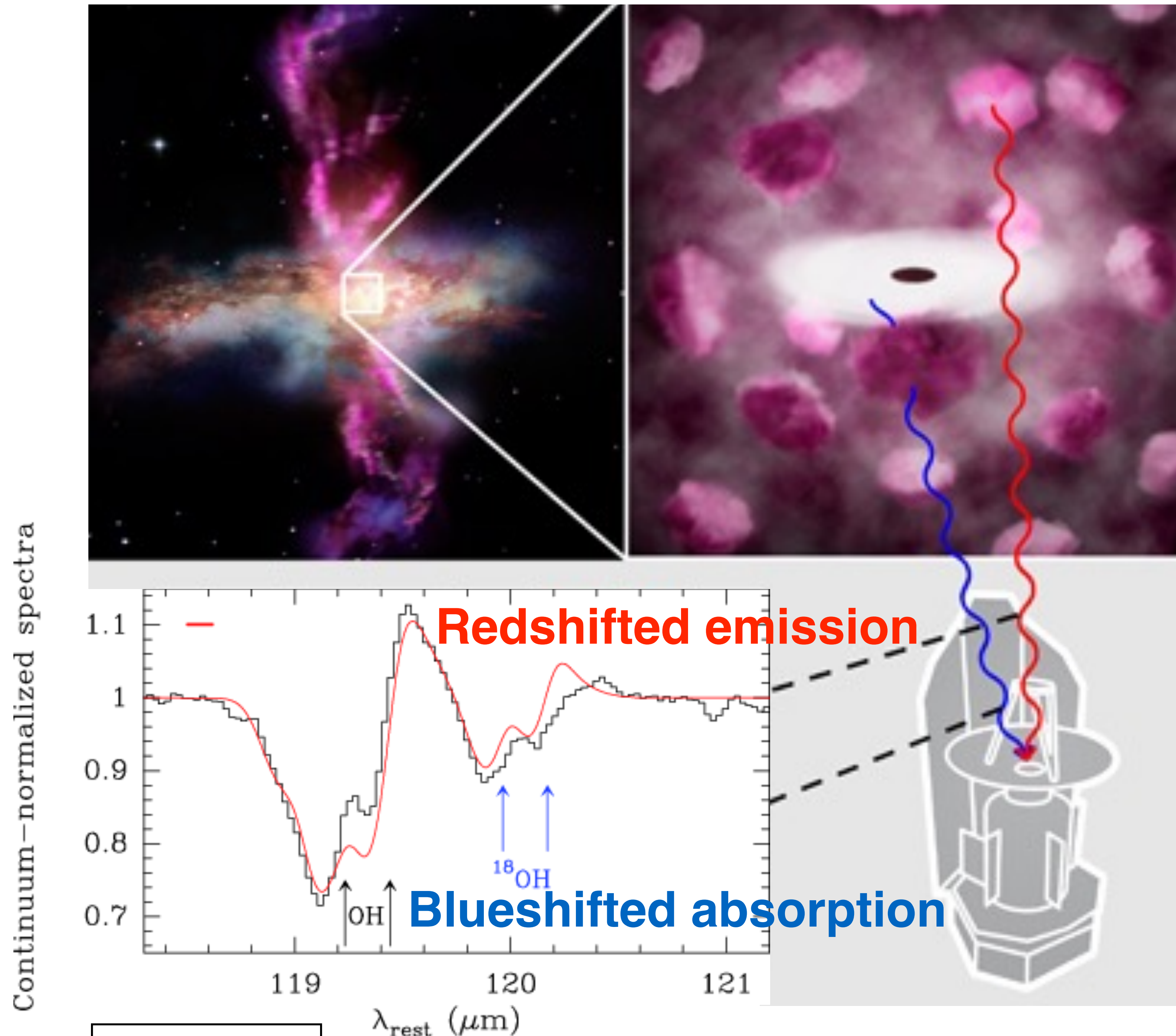


Dead elliptical

AGN feedback via *outflows*

Neutral, ionized and molecular gas outflows known

Galaxy-wide, molecular gas outflows — long-term impact on SF by quenching



Mrk 231

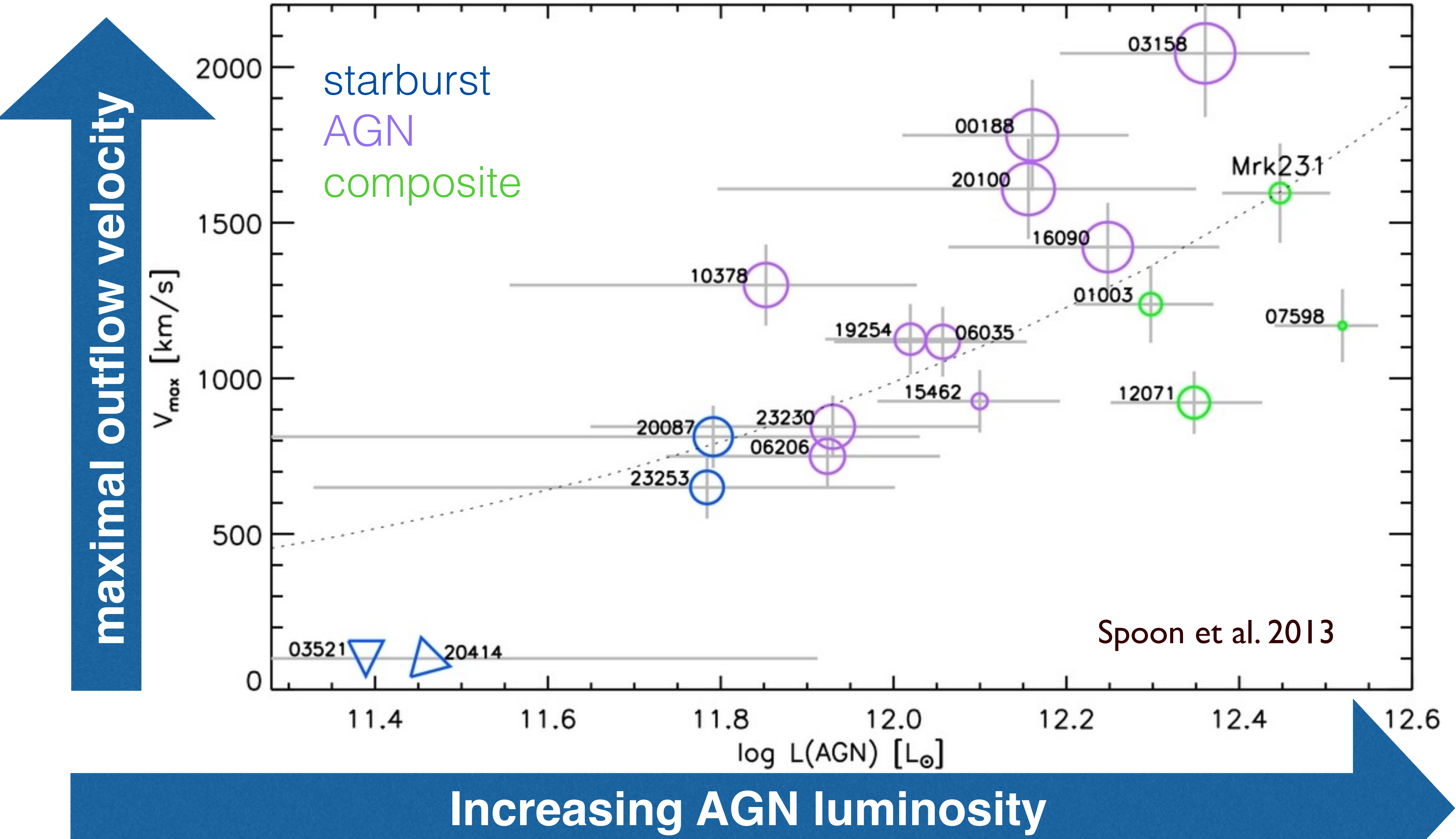
OH 119 µm doublet P-cygni profiles are an outflow signature!

Credits: ESA/AOES Medialab

e.g Rupke et al. 2005, Fischer et al 2010

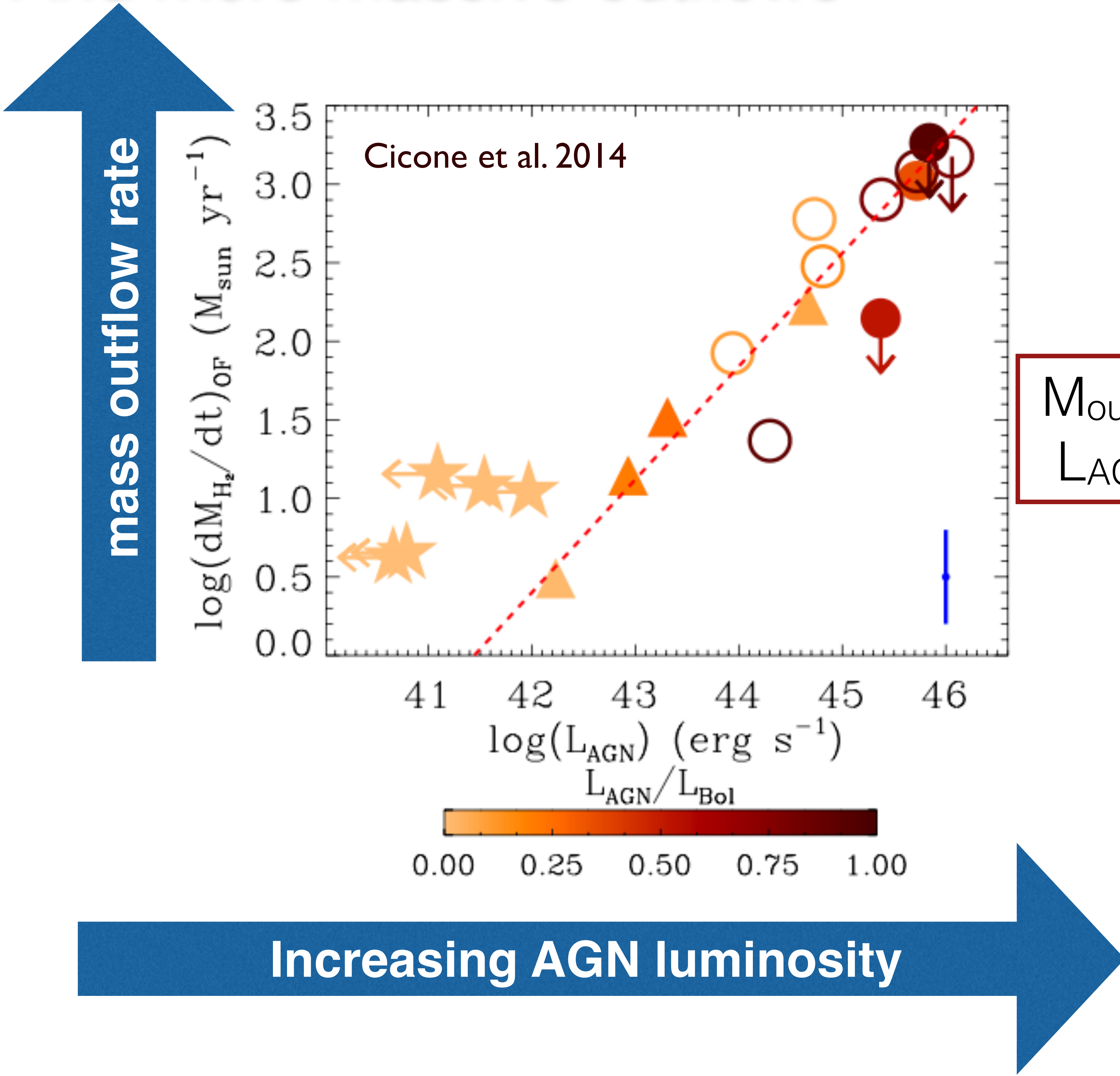
AGN drive *faster* molecular outflows

v_{max} increases with L_{AGN}



e.g. Sturm et al., 2011, Spoon et al. 2013

And more massive outflows

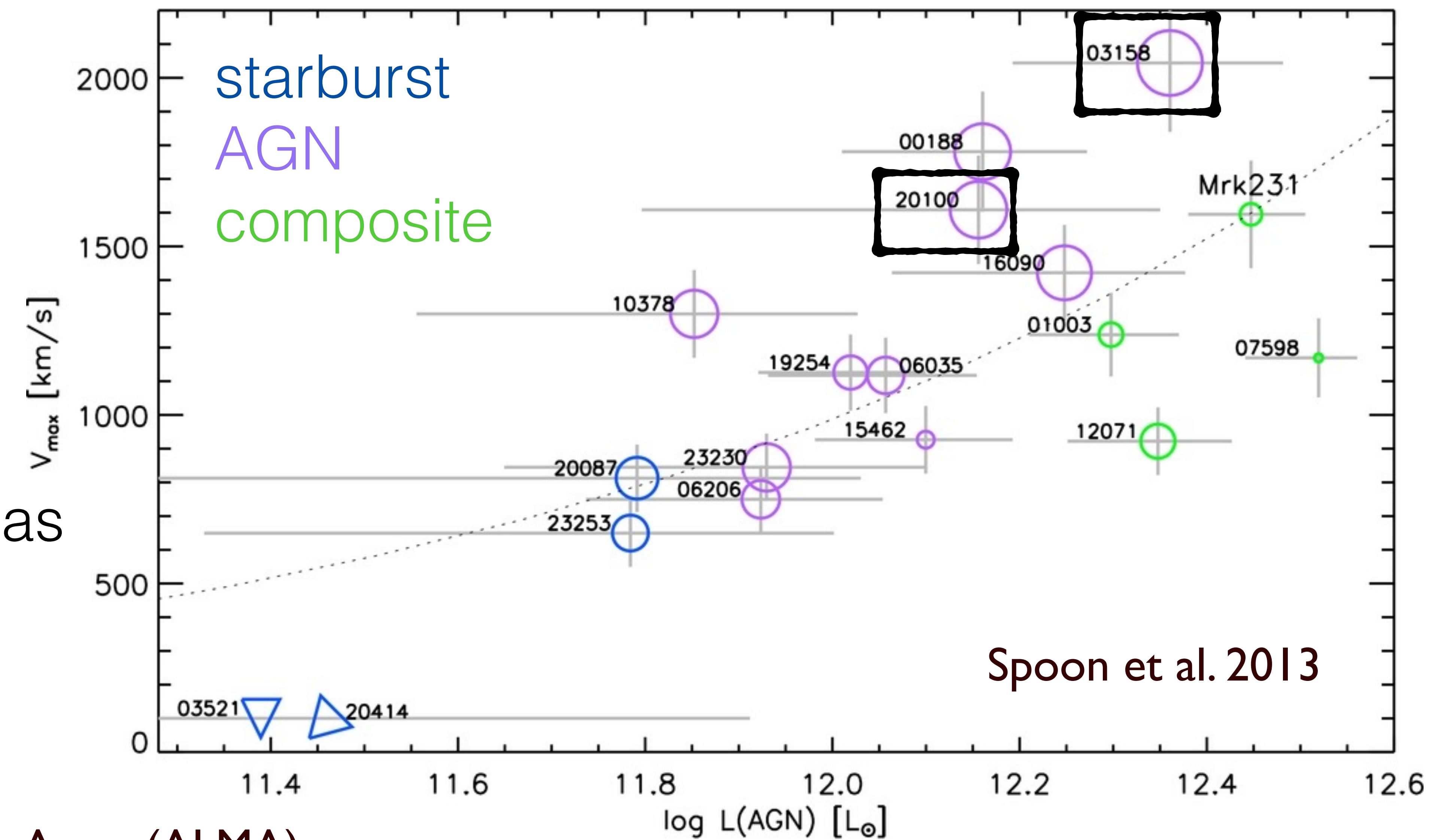


$\dot{M}_{out}$ increases with L_{AGN} and L_{AGN}/L_{bol}

The most extreme outflows in the local universe

Follow up in CO(1-0)!

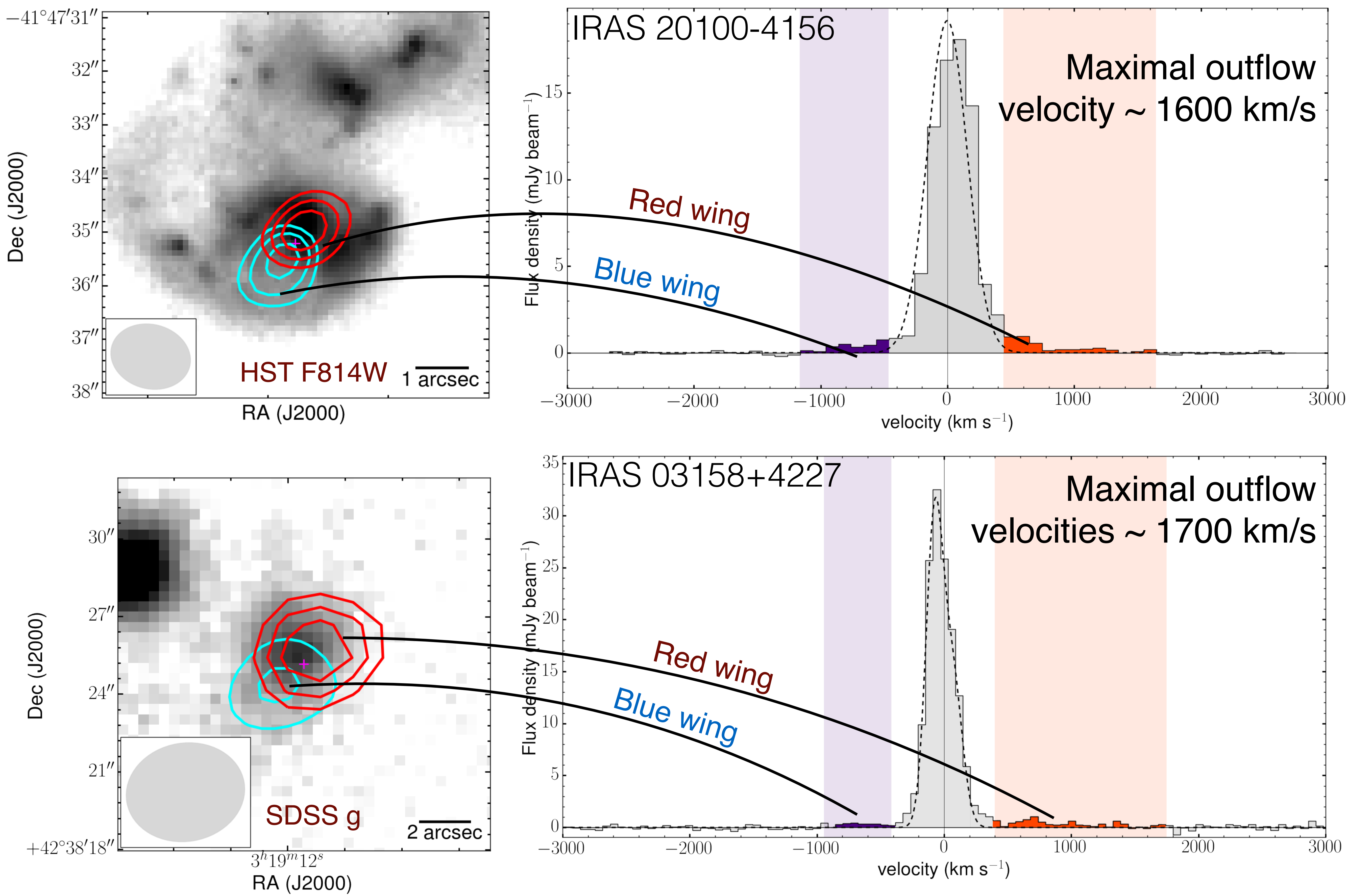
- Bulk of molecular gas
- Not line-of-sight
- Spatial Resolution



Atacama Large (sub)millimeter Array (ALMA)

Plateau de Bure Interferometer (PdBI)

High-velocity outflow wings seen in CO(1-0)



Gowardhan et al 2017 in prep

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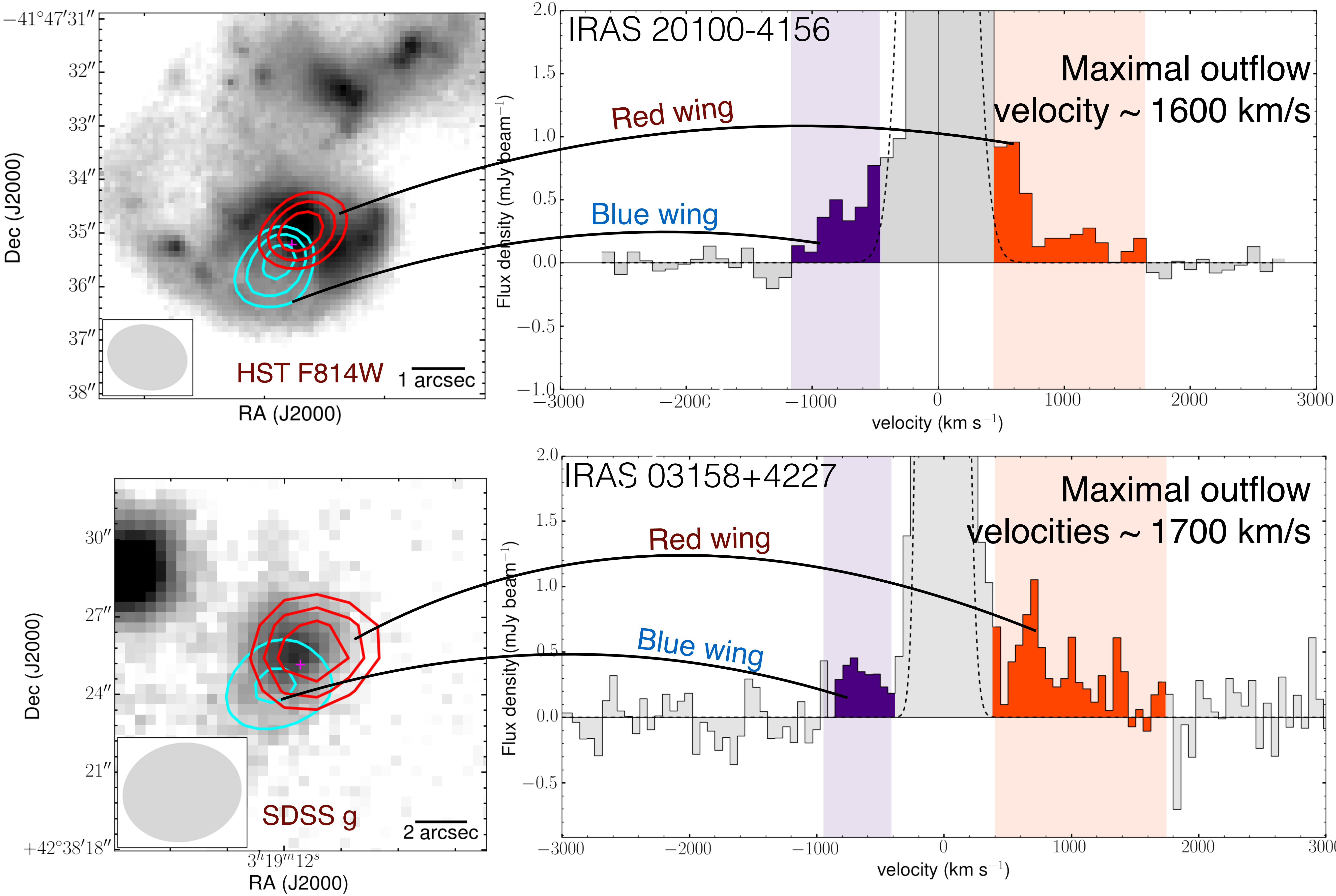

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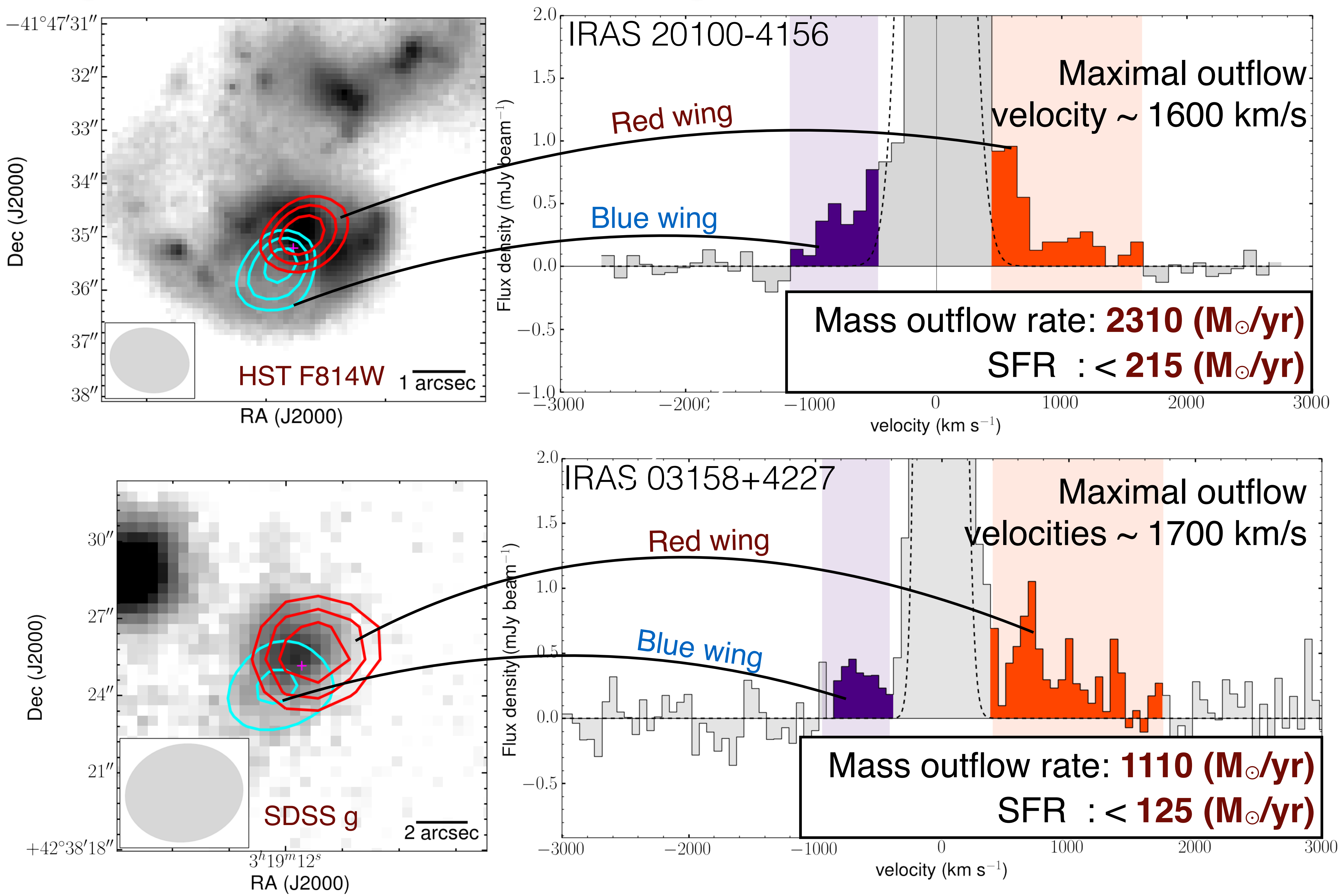

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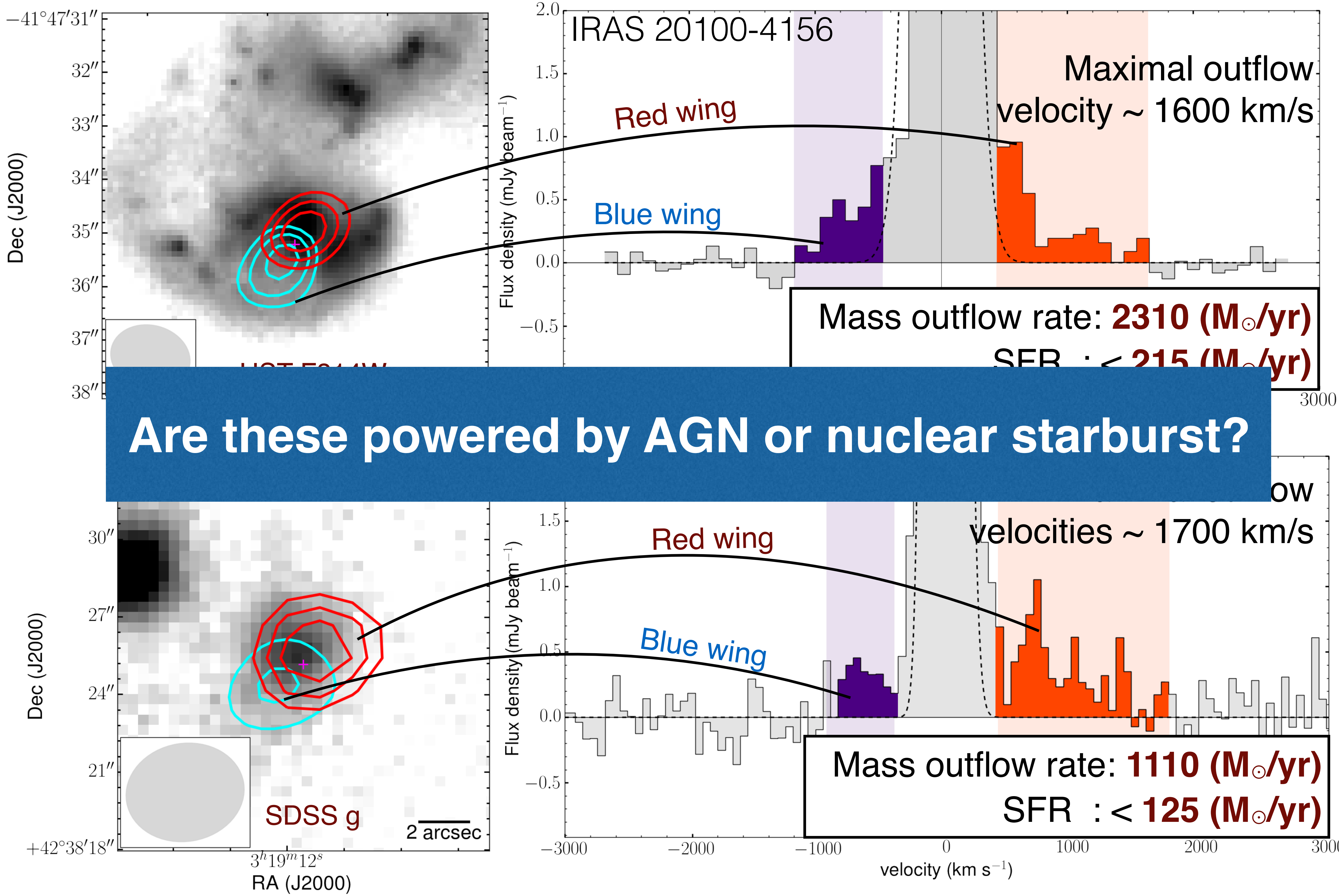

Are these powered by AGN or nuclear starburst?

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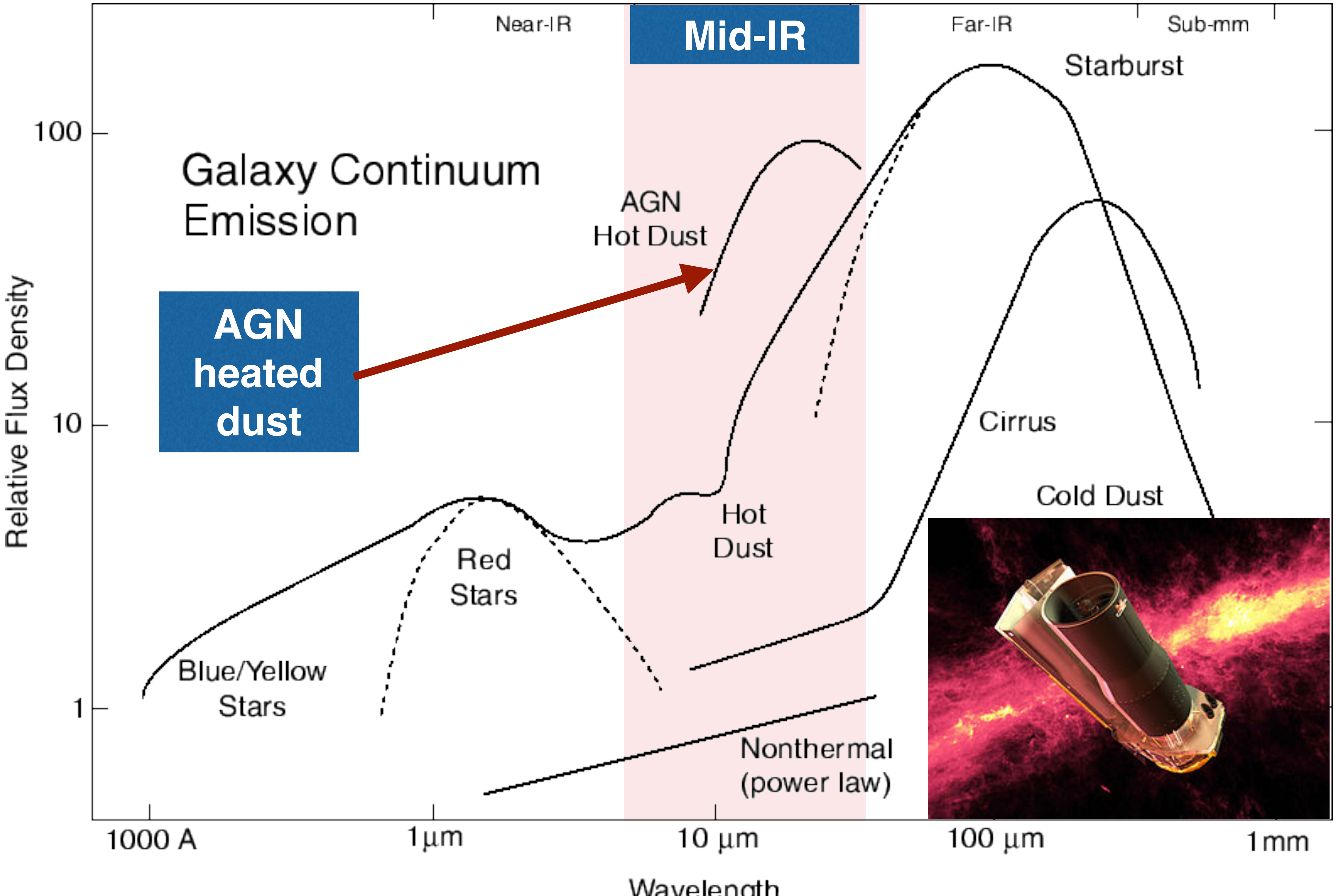
Mid-IR spectroscopy offers numerous ways to get the AGN fraction in dust-obscured nuclei.



Vaccari, 2004

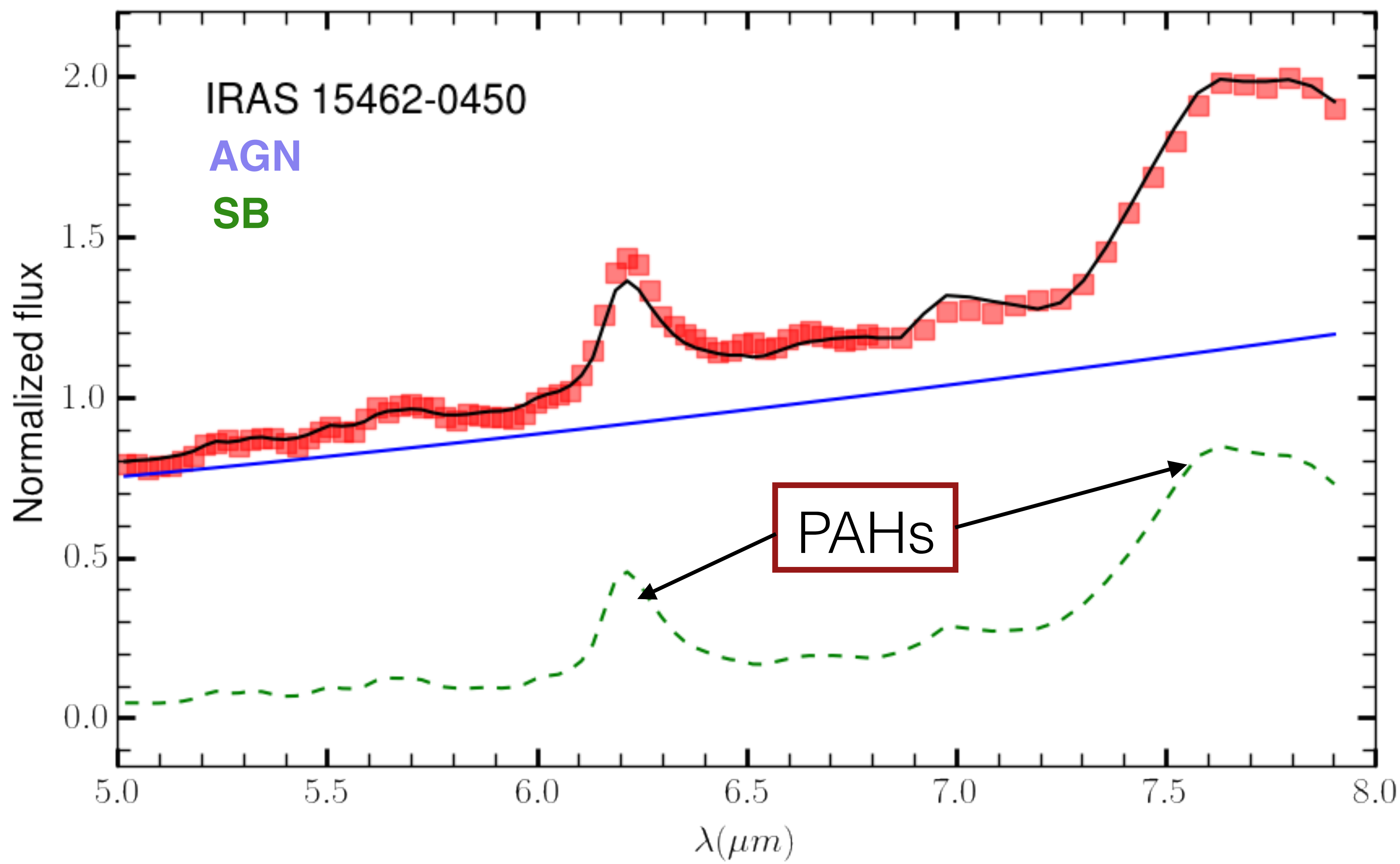
Mid-IR diagnostics for AGN fraction

- AGN-heated dust —> flatter mid-IR slope —> f_{15}/f_{30}

Veilleux et. al. 2009

- Decomposition of 5-8 µm mid-IR spectra into starburst and AGN templates

Nardini+09, 10; pvt comm.

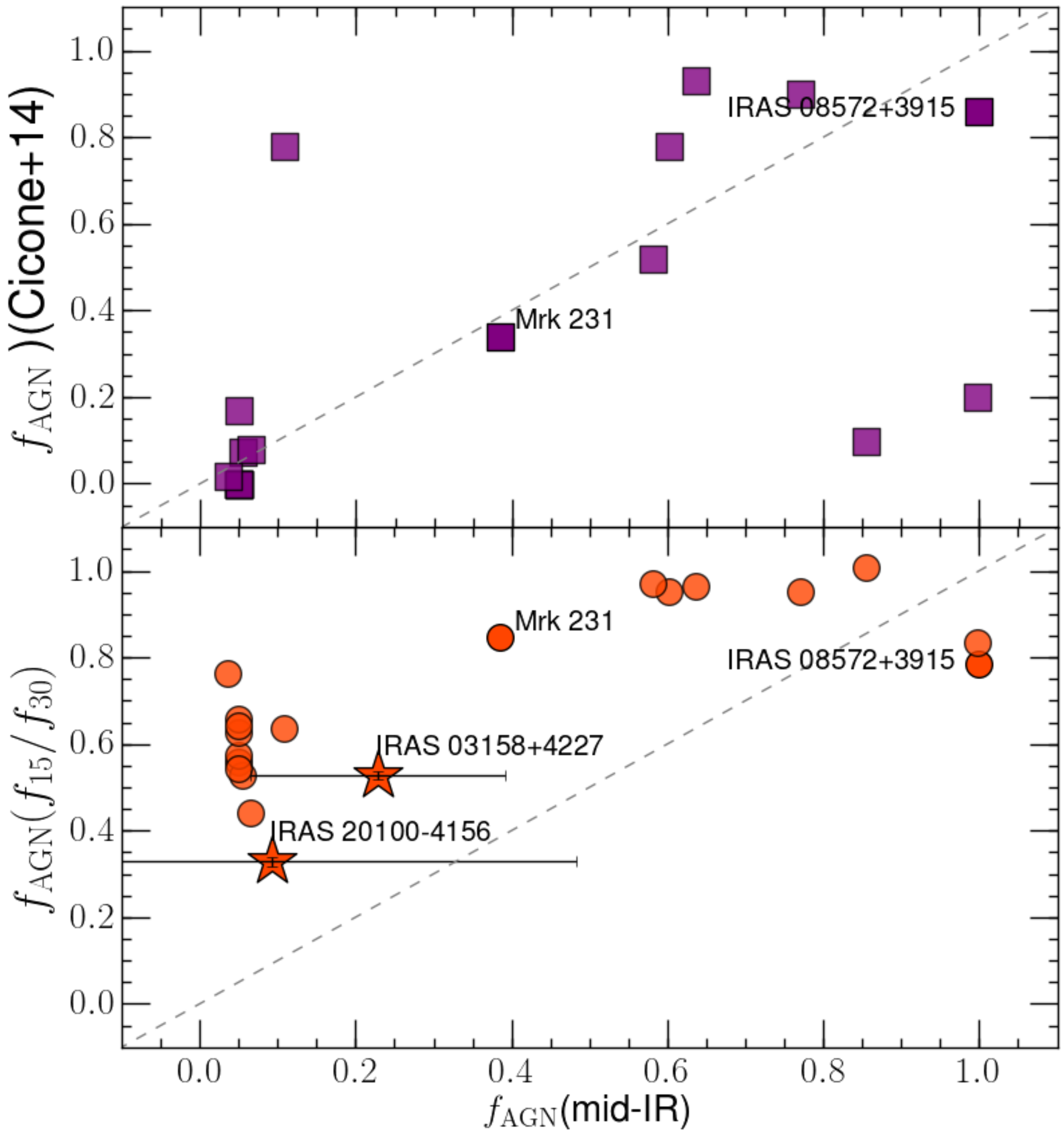


Comparing different AGN estimators

f_{15}/f_{30} **method systematically overestimates f_{AGN}**

Mid-IR decomposition works better

Our two sources are NOT AGN-dominated



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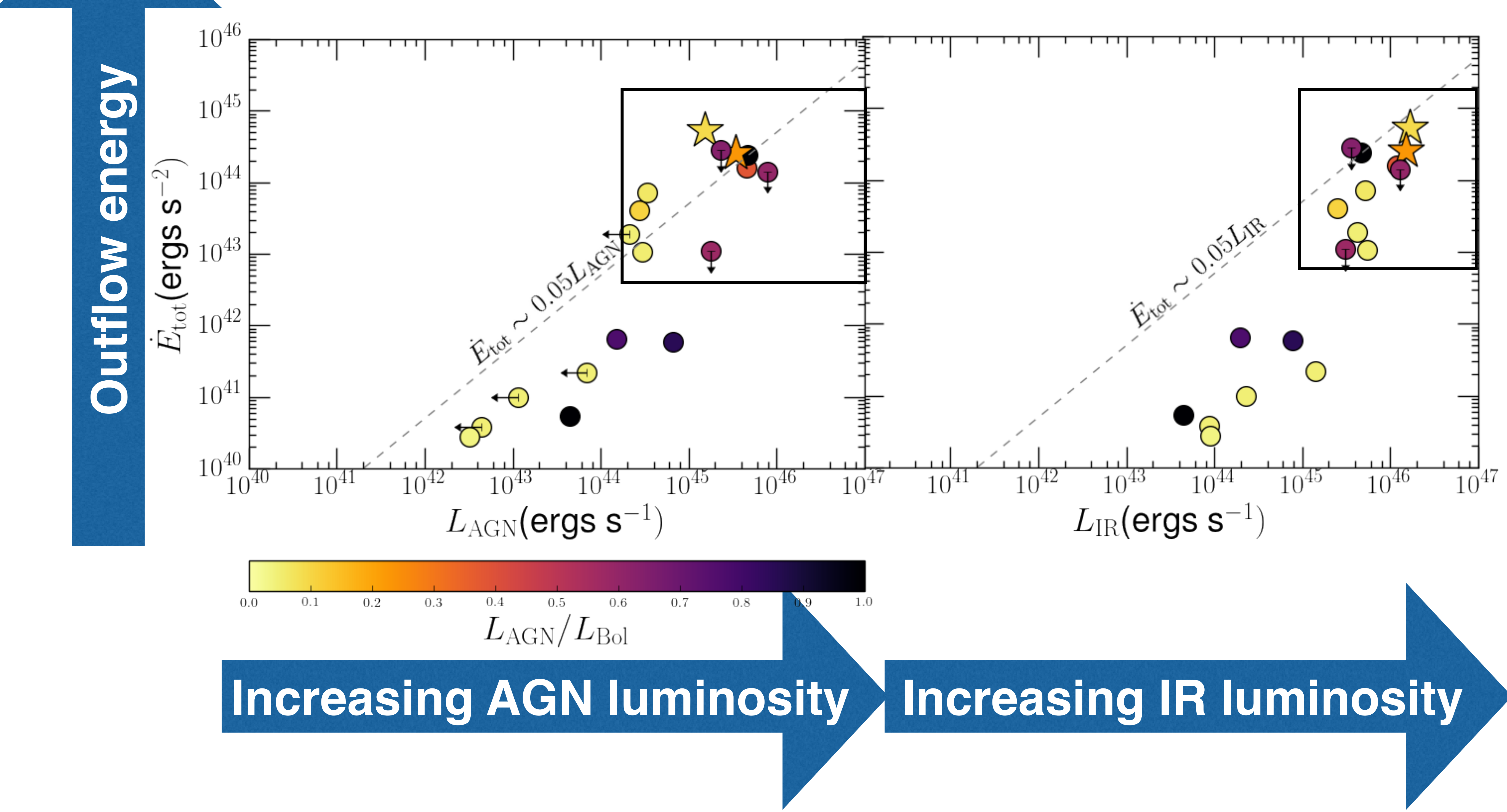
Outflow energetics

L_{AGN} insufficient to power outflows, need L_{SFR}



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Conclusions and future work

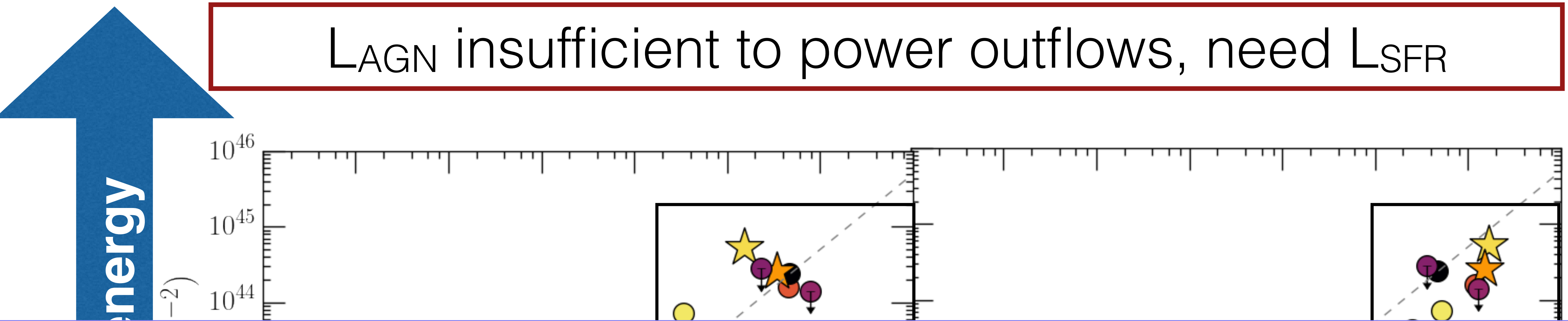
- We have spatially resolved the 2 most massive galaxy wide (~kpc) scale outflows (~x 1000 $M_{\odot}$/yr) in the local universe
- No dominant AGN contribution; powered by powerful nuclear starbursts, based on mid-IR diagnostics.

Next steps:

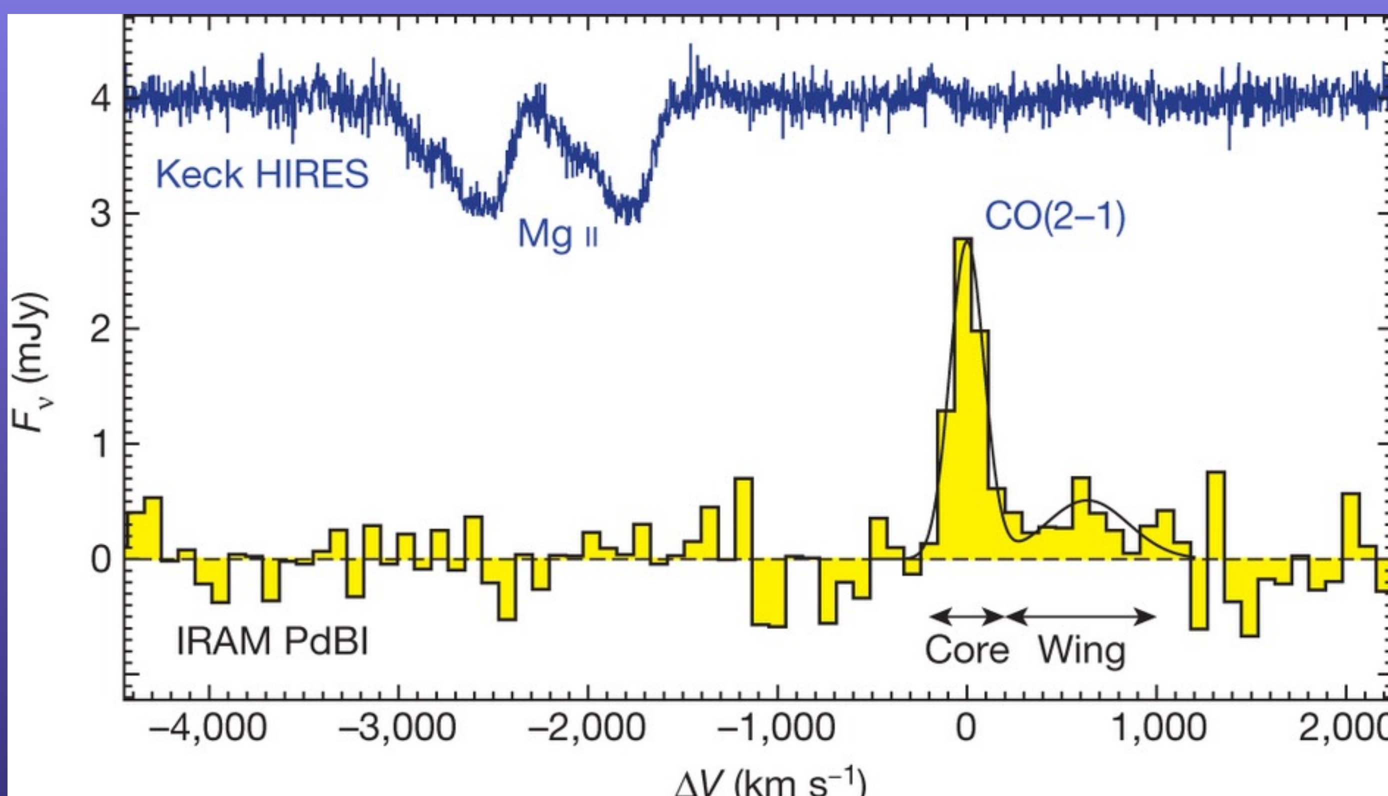
- JWST (MIRI and NIRSPEC) for H_2 ro-vibrational lines, Ne[V], Ne[VI] lines, and spatially resolved outflow mapping on ~pc scales

Outflow energetics

L_{AGN} insufficient to power outflows, need L_{SFR}



SDSS J0905157, z ~ 0.7



Compact nuclear starburst driving an outflow, v ~ 1000 km/s , mass outflow ~ 250 $M_\odot$/yr

Gowardhan et al 2017 in prep

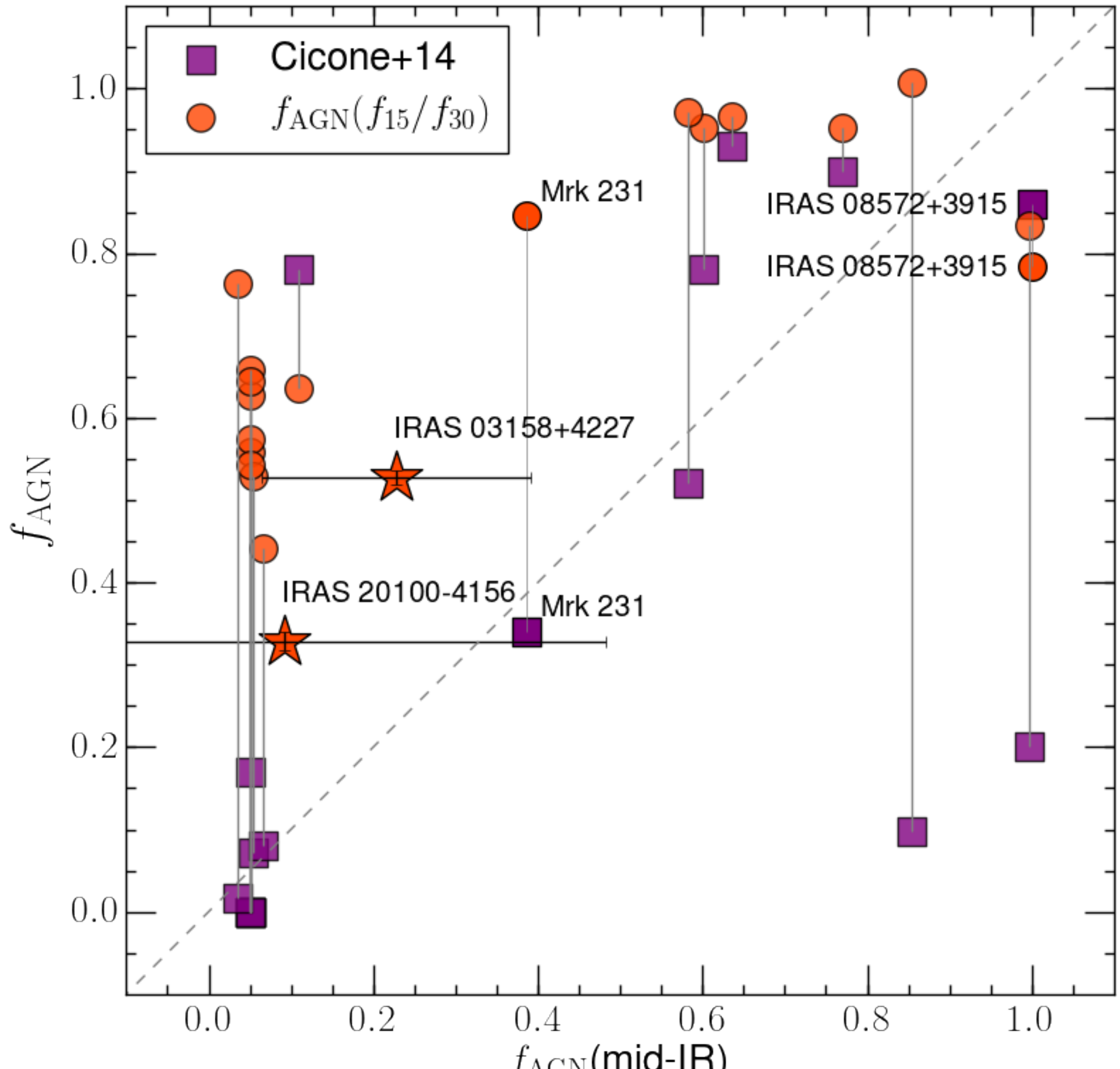
Geach et al. 2014

Comparing different AGN estimators

f_{15}/f_{30} method systematically overestimates f_{AGN}

Mid-IR decomposition works better

Our two sources are NOT AGN-dominated



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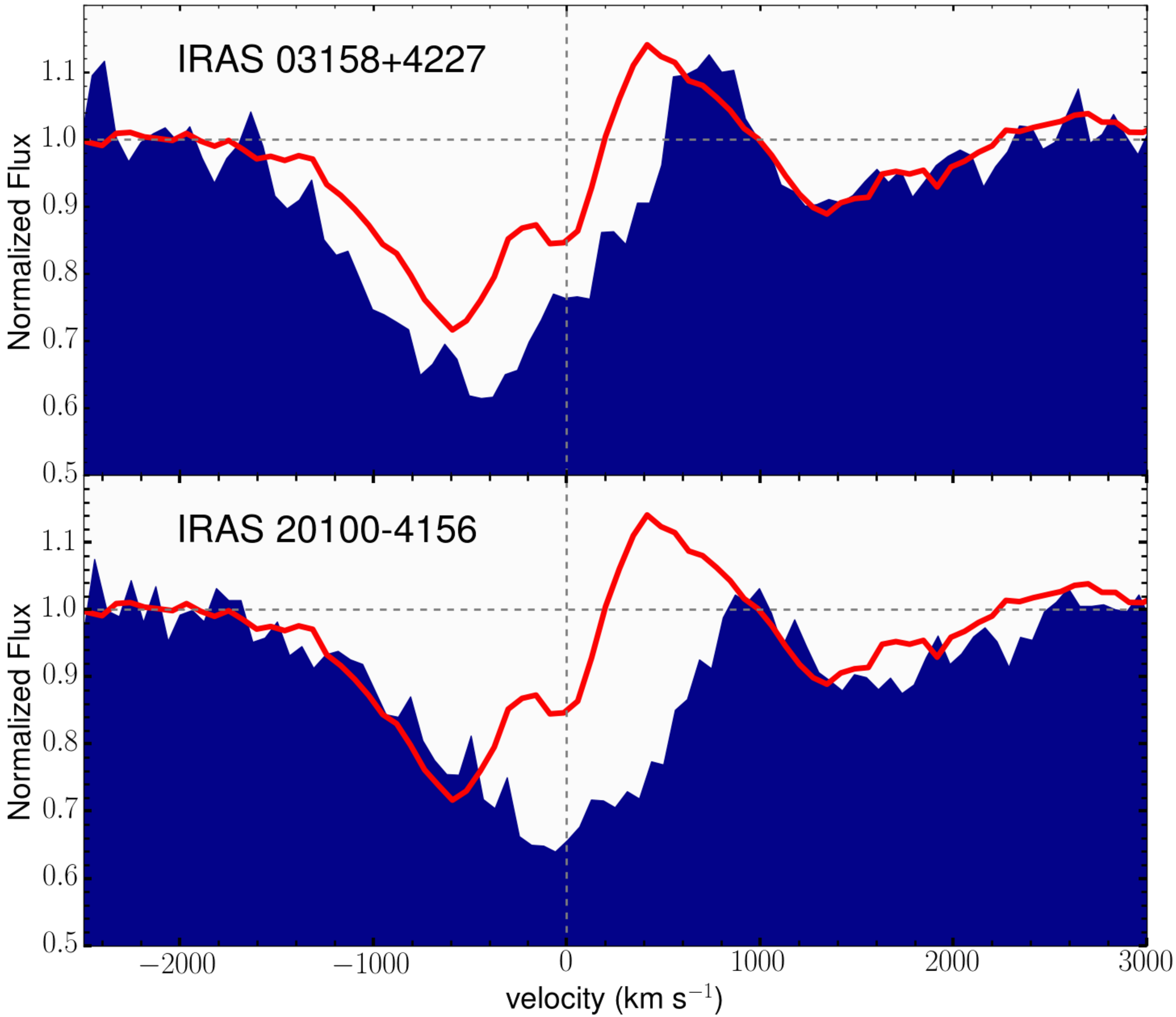
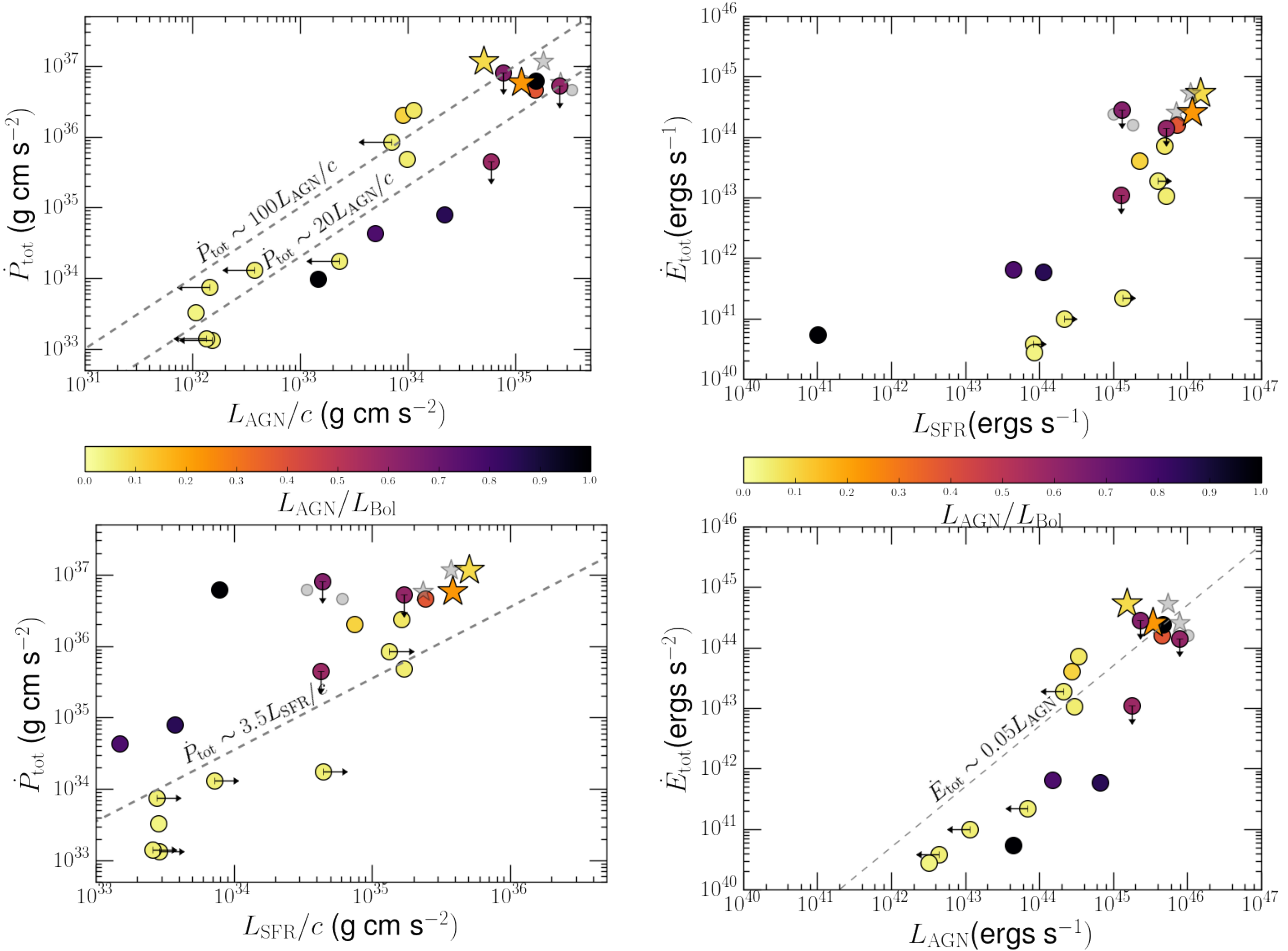
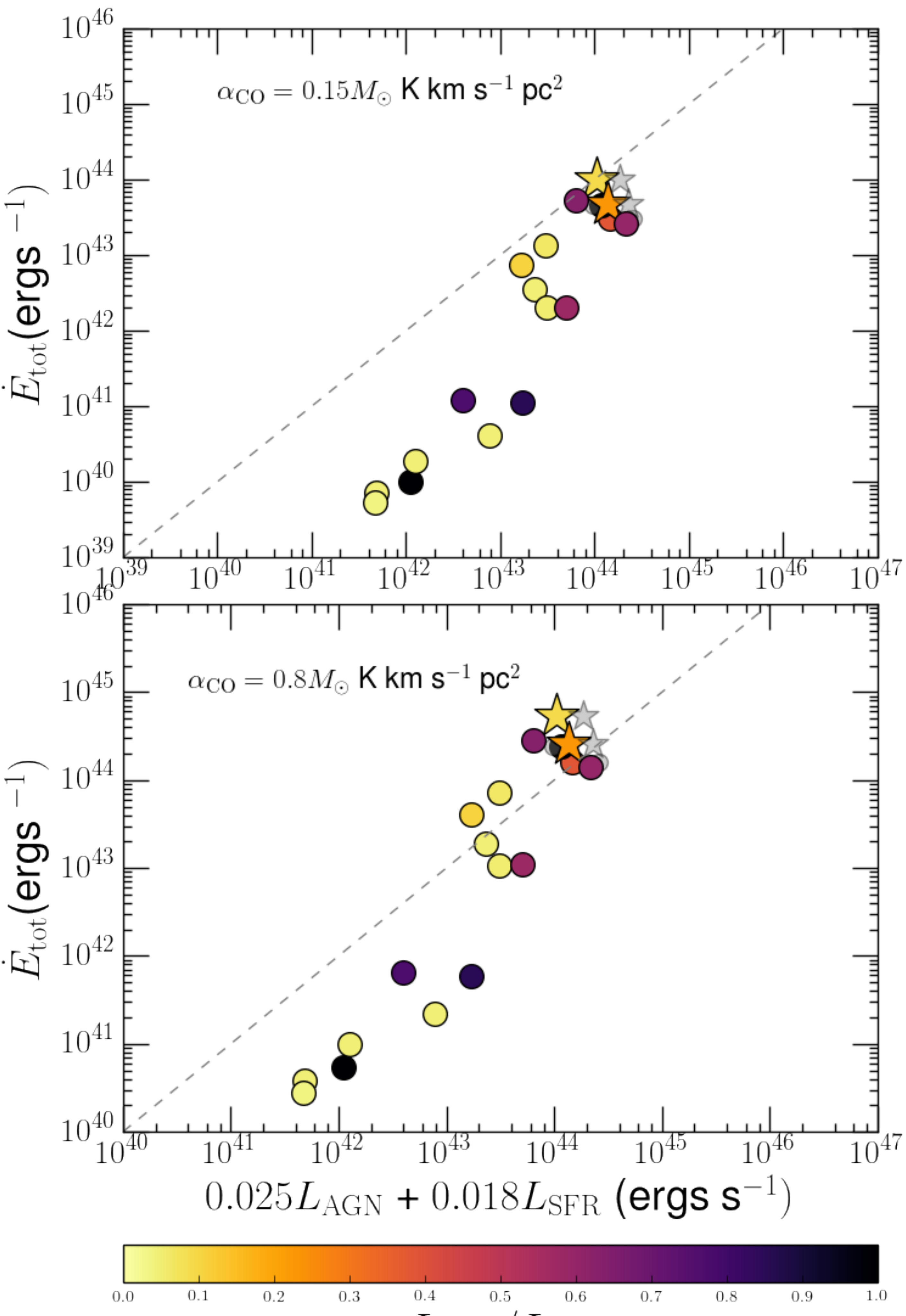
P-cygni profiles



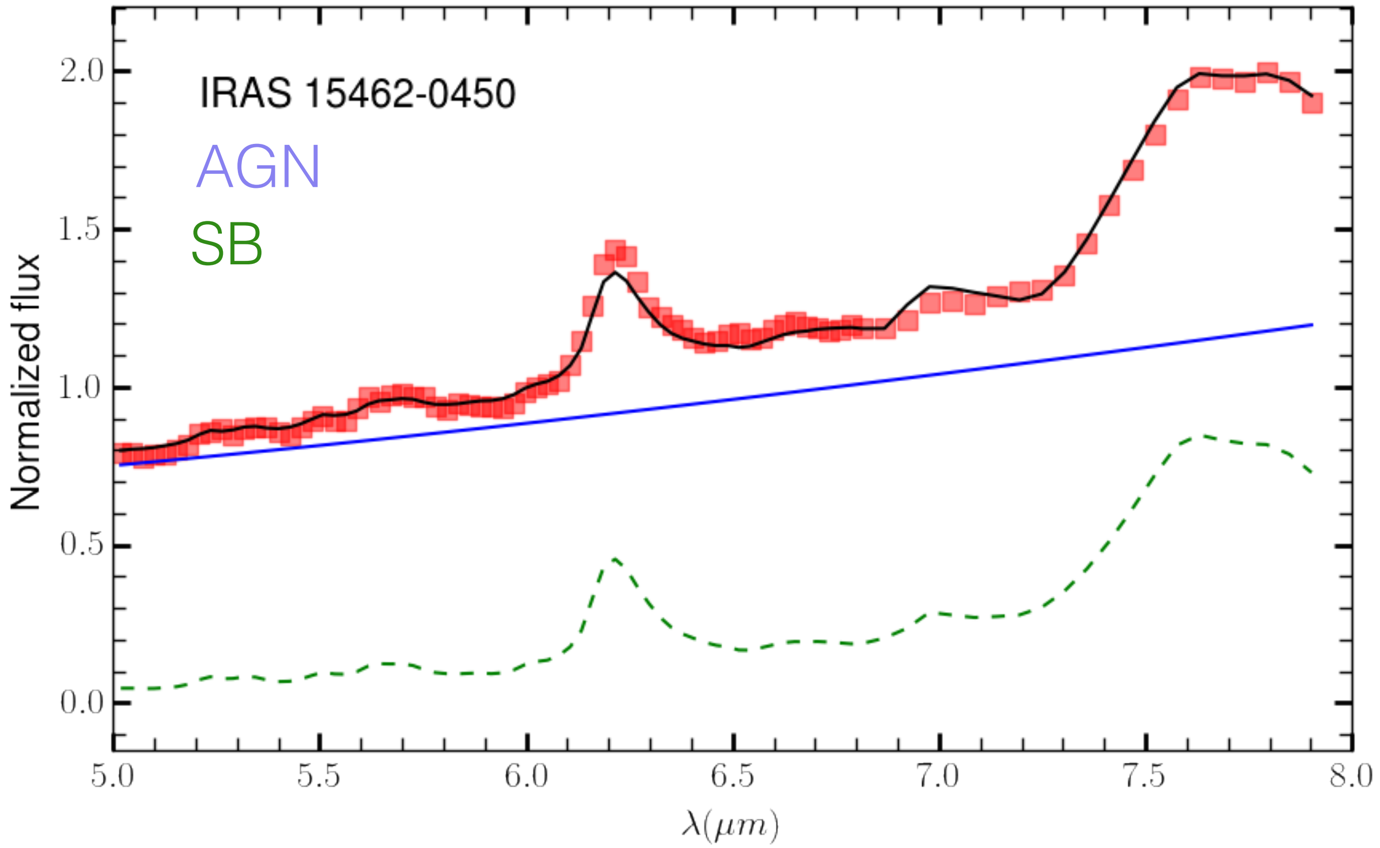
OH 119 μm profiles show deeper absorption/higher v_{max} than Mrk 231 (red)

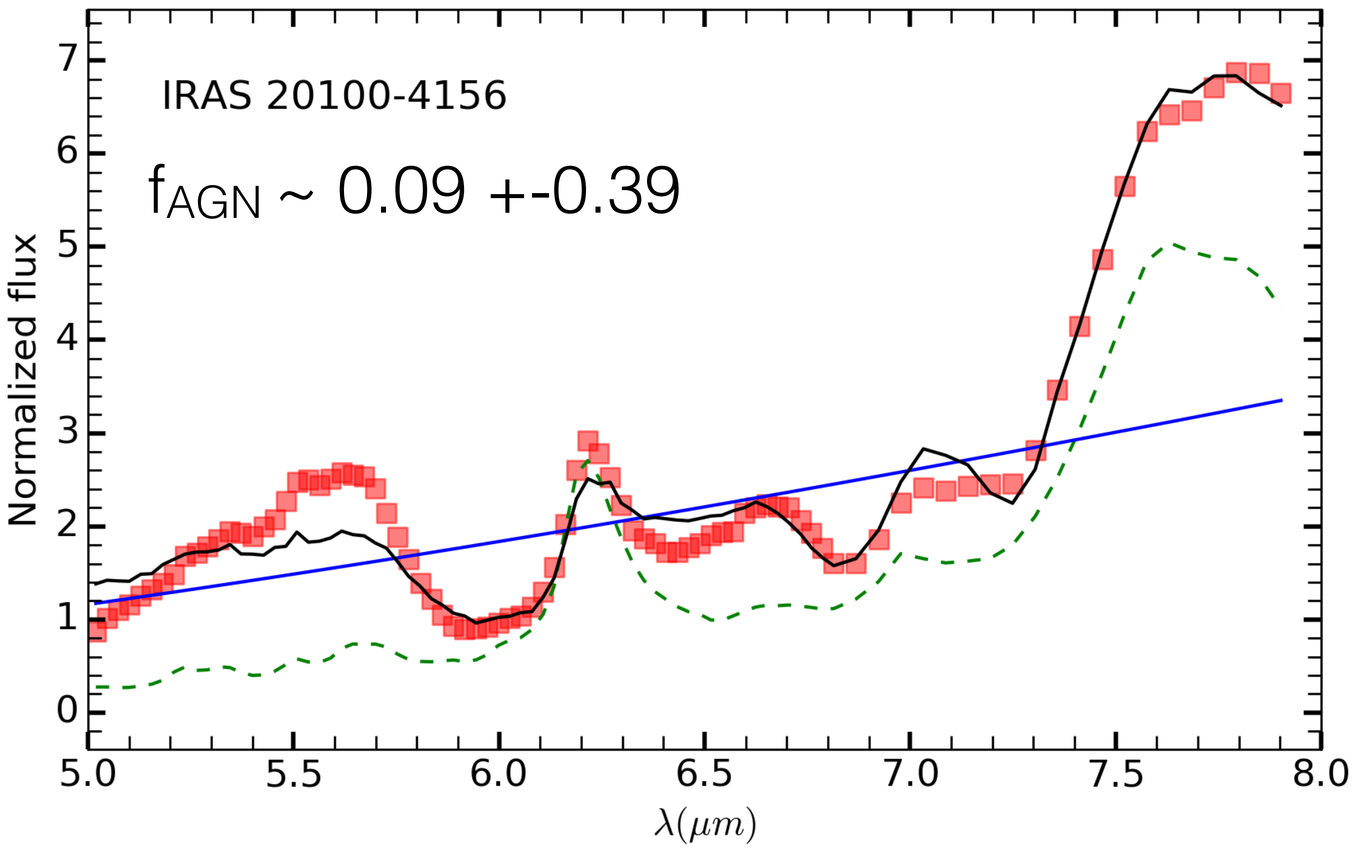

$\dot{P}_{\rm tot}$ (g cm s^{-2})
$L_{\rm AGN}/c$ (g cm s^{-2})
$\dot{P}_{\rm tot} \sim 100 L_{\rm AGN}/c$
$\dot{P}_{\rm tot} \sim 20 L_{\rm AGN}/c$
$\dot{E}_{\rm tot}$(ergs s^{-1})
$L_{\rm SFR}$(ergs s^{-1})
$L_{\rm AGN}/L_{\rm Bol}$
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0
$L_{\rm AGN}/L_{\rm Bol}$
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0
$\dot{P}_{\rm tot}$ (g cm s^{-2})
$L_{\rm SFR}/c$ (g cm s^{-2})
$\dot{P}_{\rm tot} \sim 3.5 L_{\rm SFR}/c$
$\dot{E}_{\rm tot}$(ergs s^{-2})
$L_{\rm AGN}$(ergs s^{-1})
$\dot{E}_{\rm tot} \sim 0.05 L_{\rm AGN}$

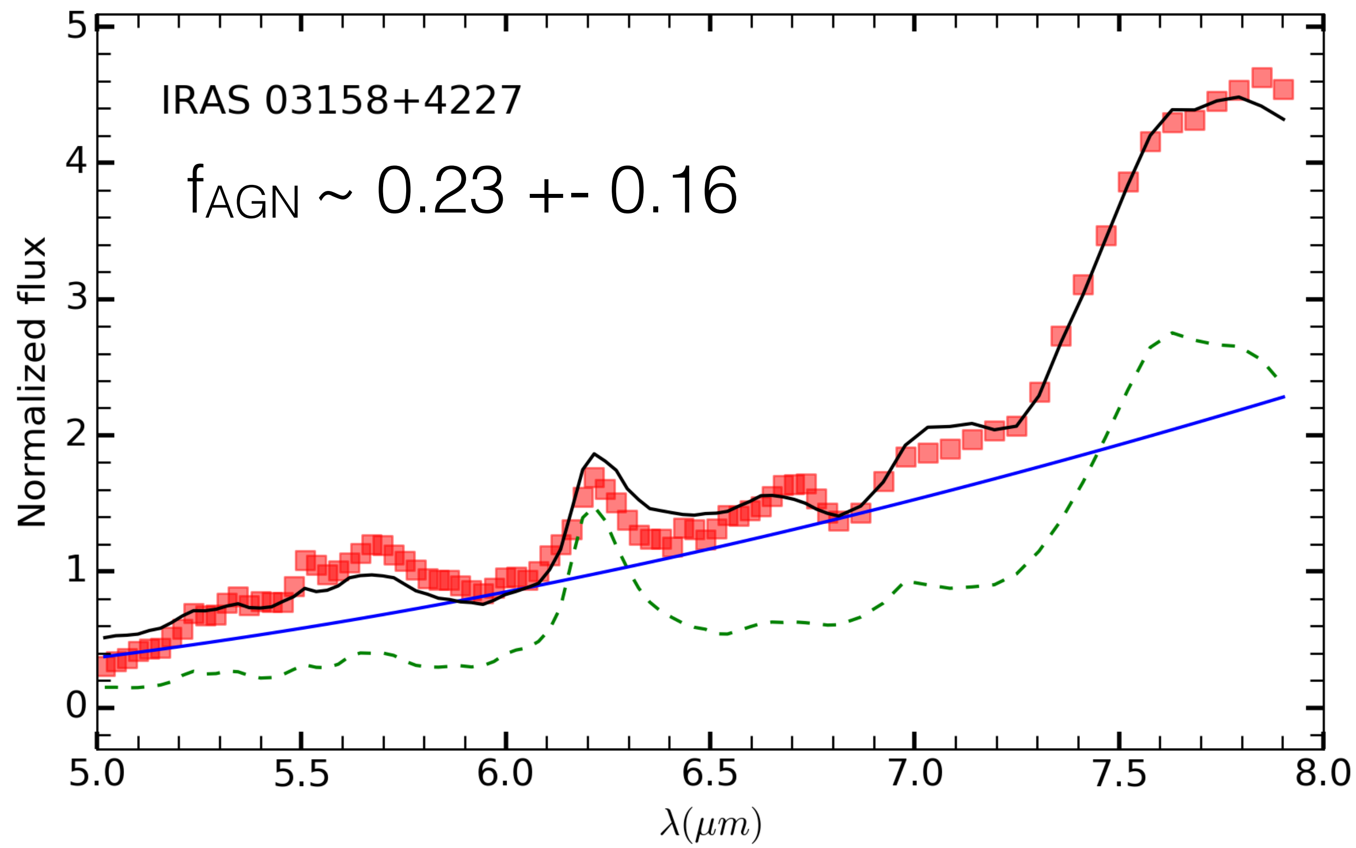


The energetics become more consistent with the modification of alpha to more reasonable numbers, as suggested by Richlings et al 2017.

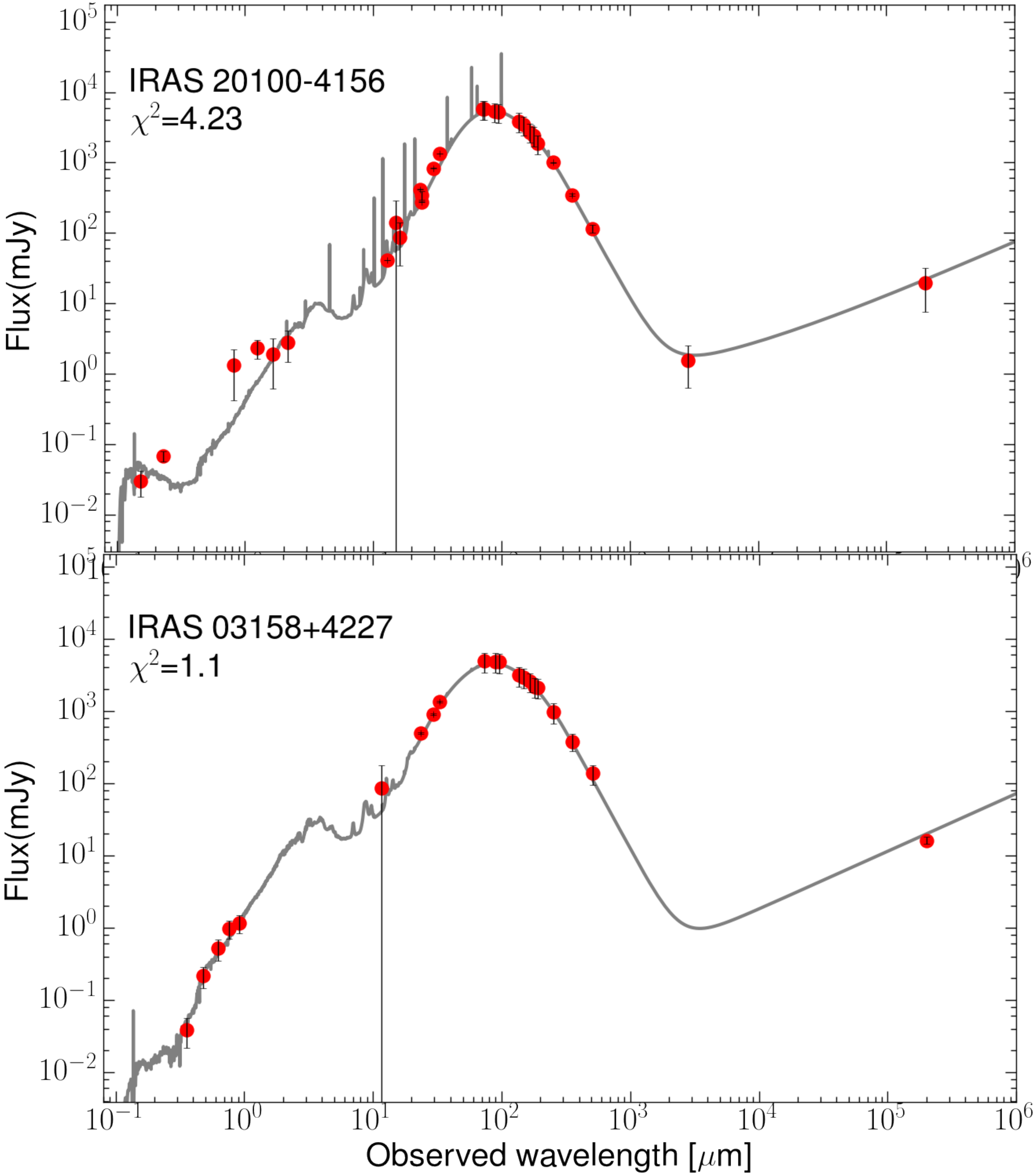
Mid-IR diagnostics for AGN fraction







Veilleux et al. 2013, Nardini+09, 10; pvt comm.



Spectral Energy Distribution (SED) fitting