# Properties of AGN in Dwarf Galaxies

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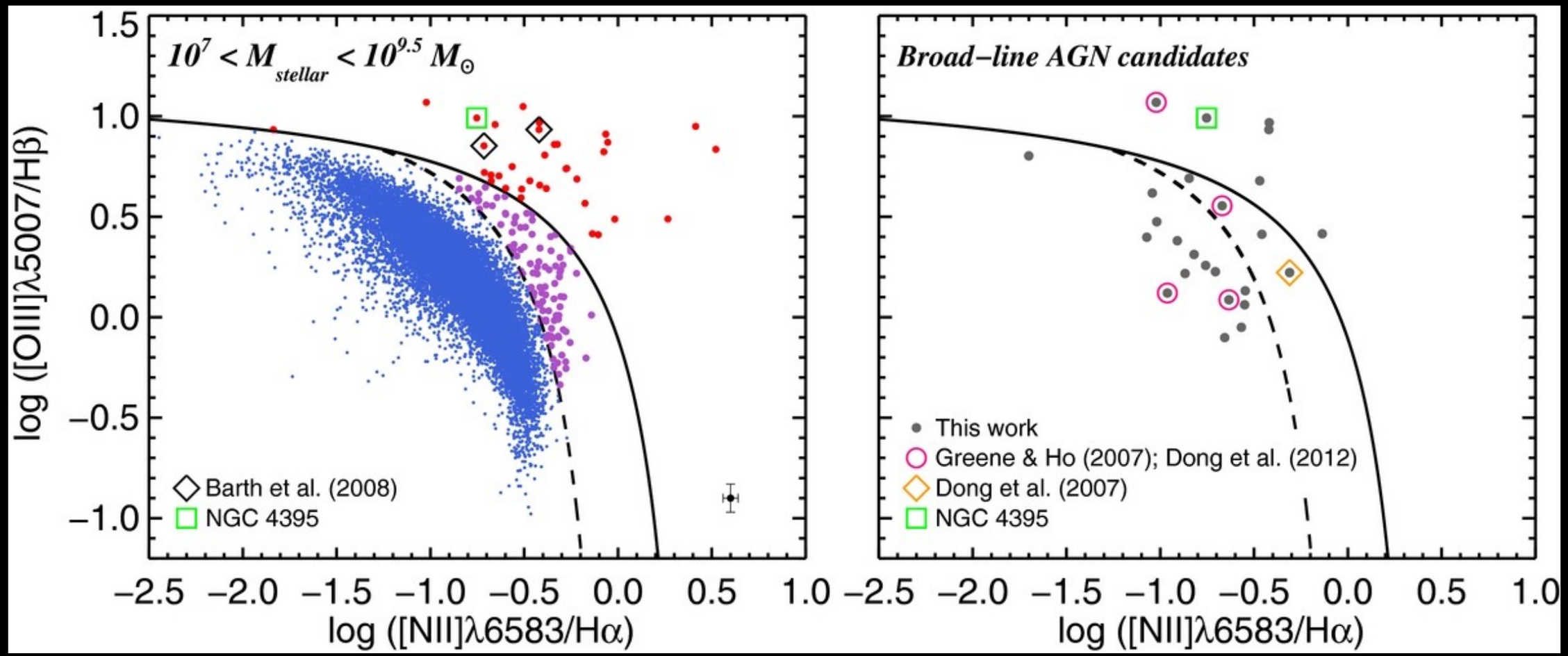
# Massive black holes in dwarf galaxies

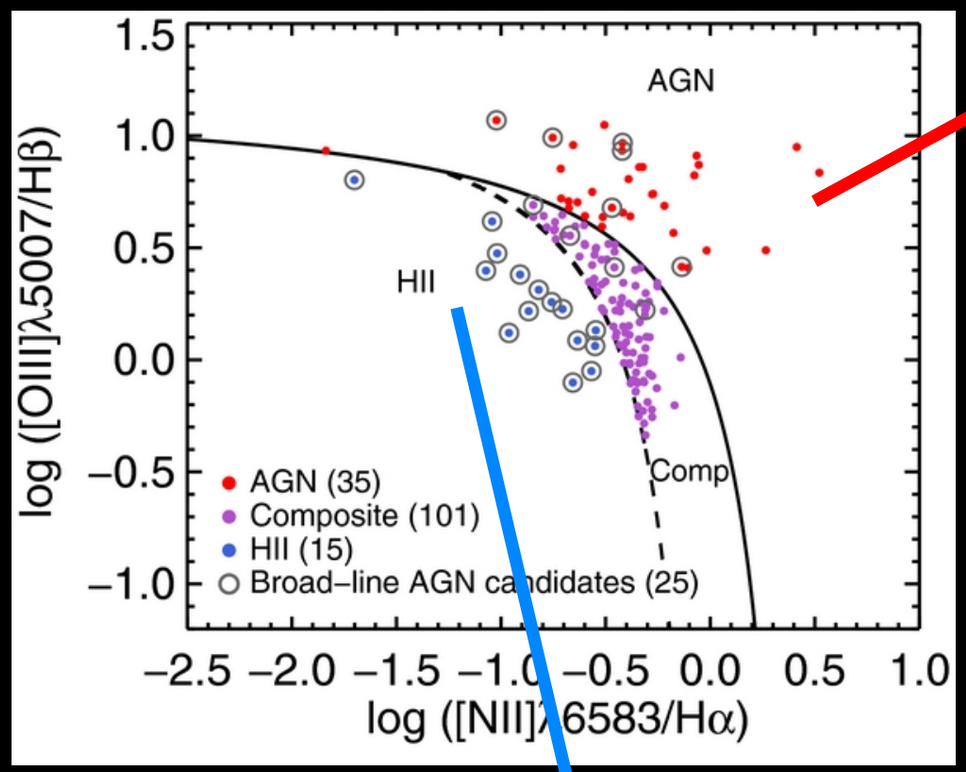
- Provide best constraints on masses of BH "seeds" in the early universe
- Difficult to find: sphere of influence of $10^5$ solar mass BH unresolvable with HST outside Local Group
- Solution: search for accreting BHs in dwarf galaxies

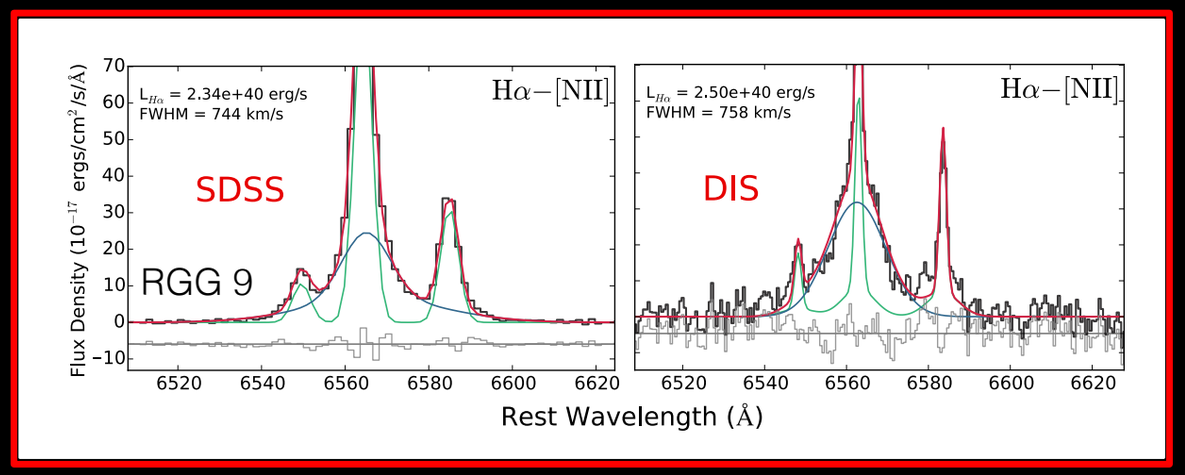
# Until recently, a handful of dwarf galaxies were known to contain AGN




- Reines et al. 2013: 136 narrow-line AGN in dwarf galaxies + 25 broad-line AGN candidates

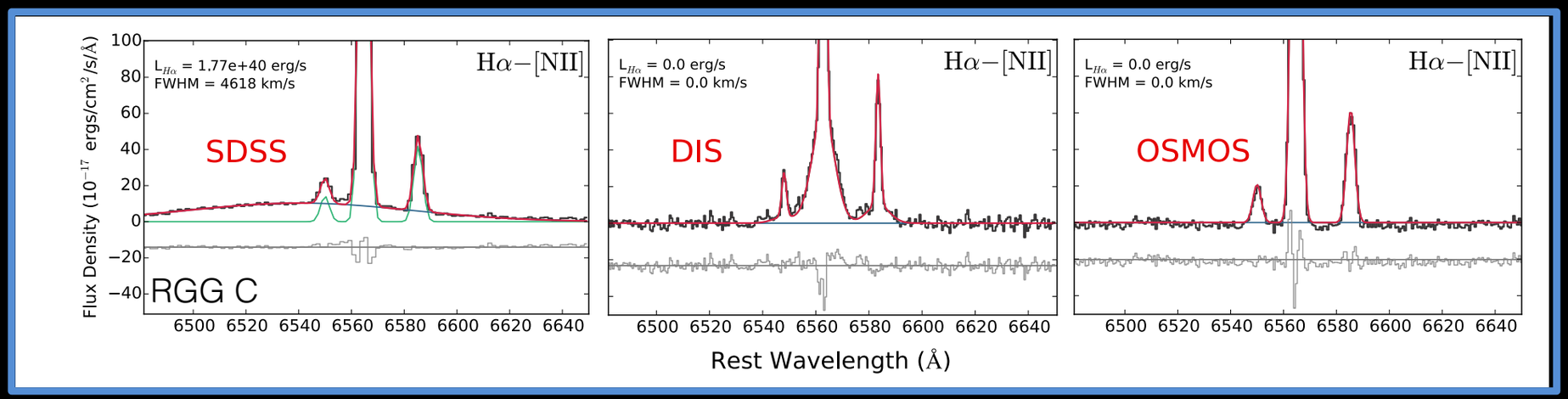
# AGN selection can be tricky at the low-mass end…



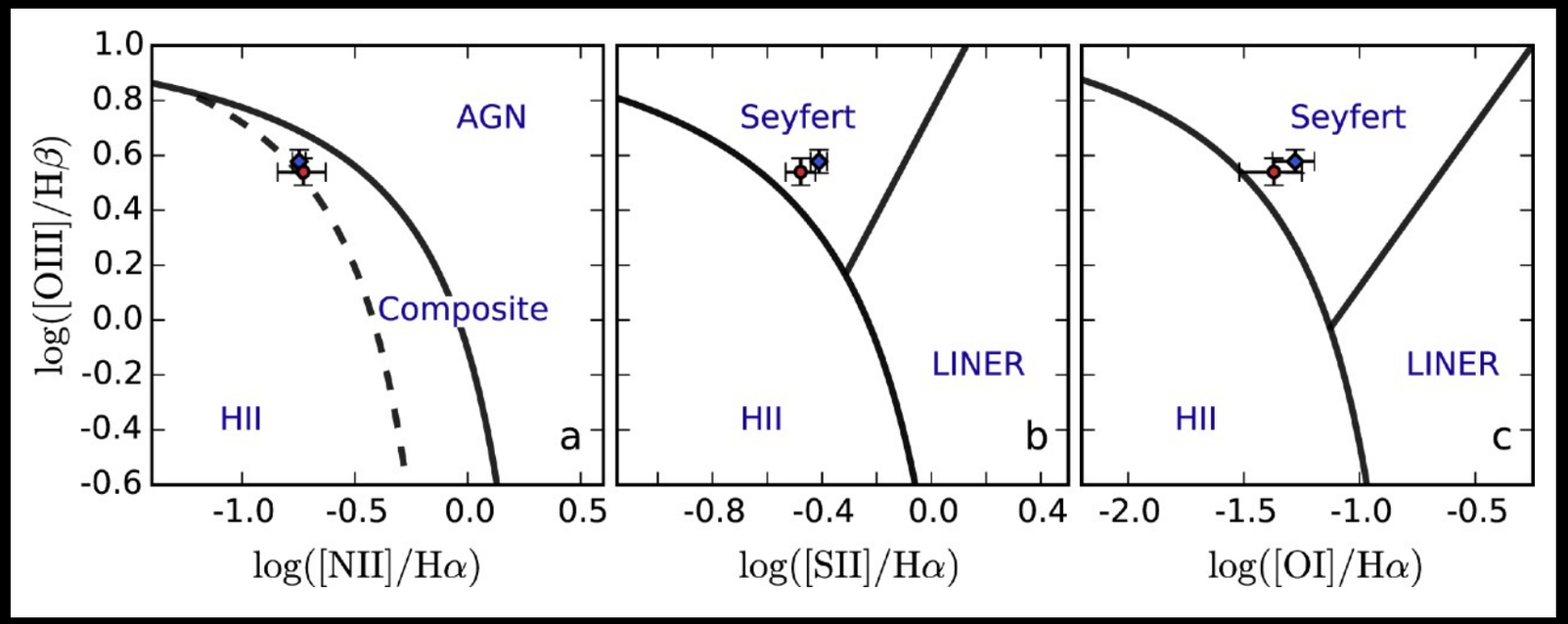

Broad emission from AGN

Broad emission from transient stellar processes




Baldassare et al. 2016

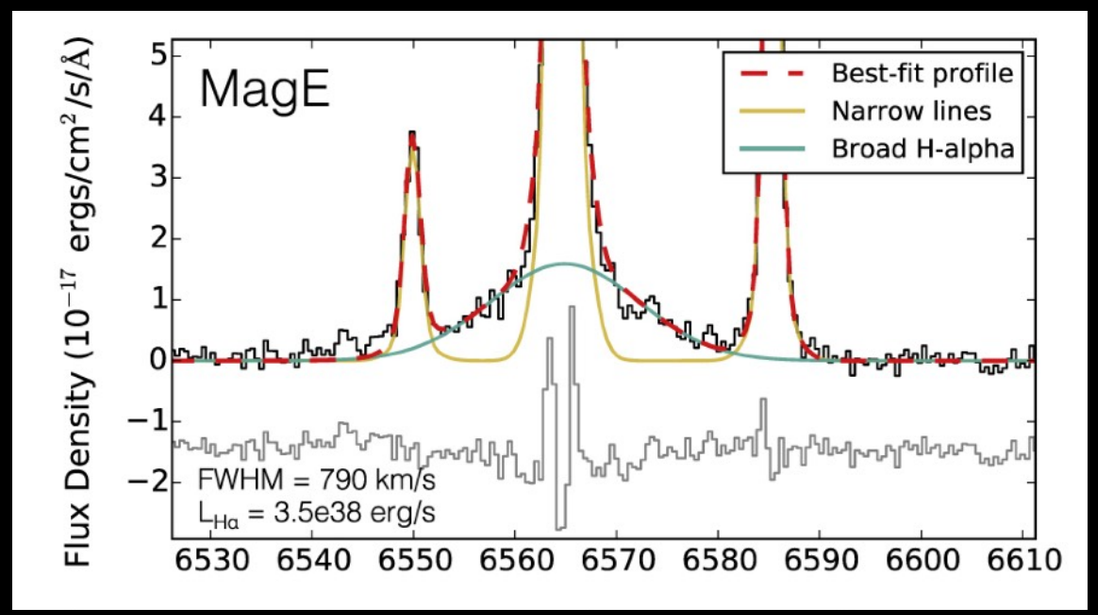
# RGG 118: a dwarf galaxy with a 50,000 solar mass BH




Narrow emission lines support presence of AGN

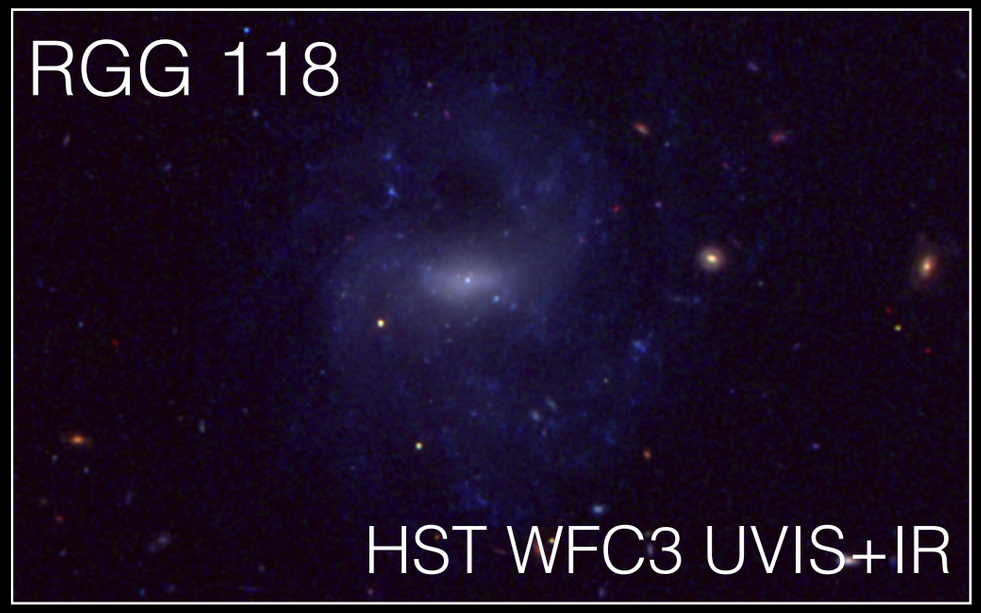
Spectroscopy with Magellan Echellette Spectrograph clearly reveals broad H-alpha

Using broad H-alpha emission, estimate $M_{BH}$ = 50,000 $M_{Sun}$

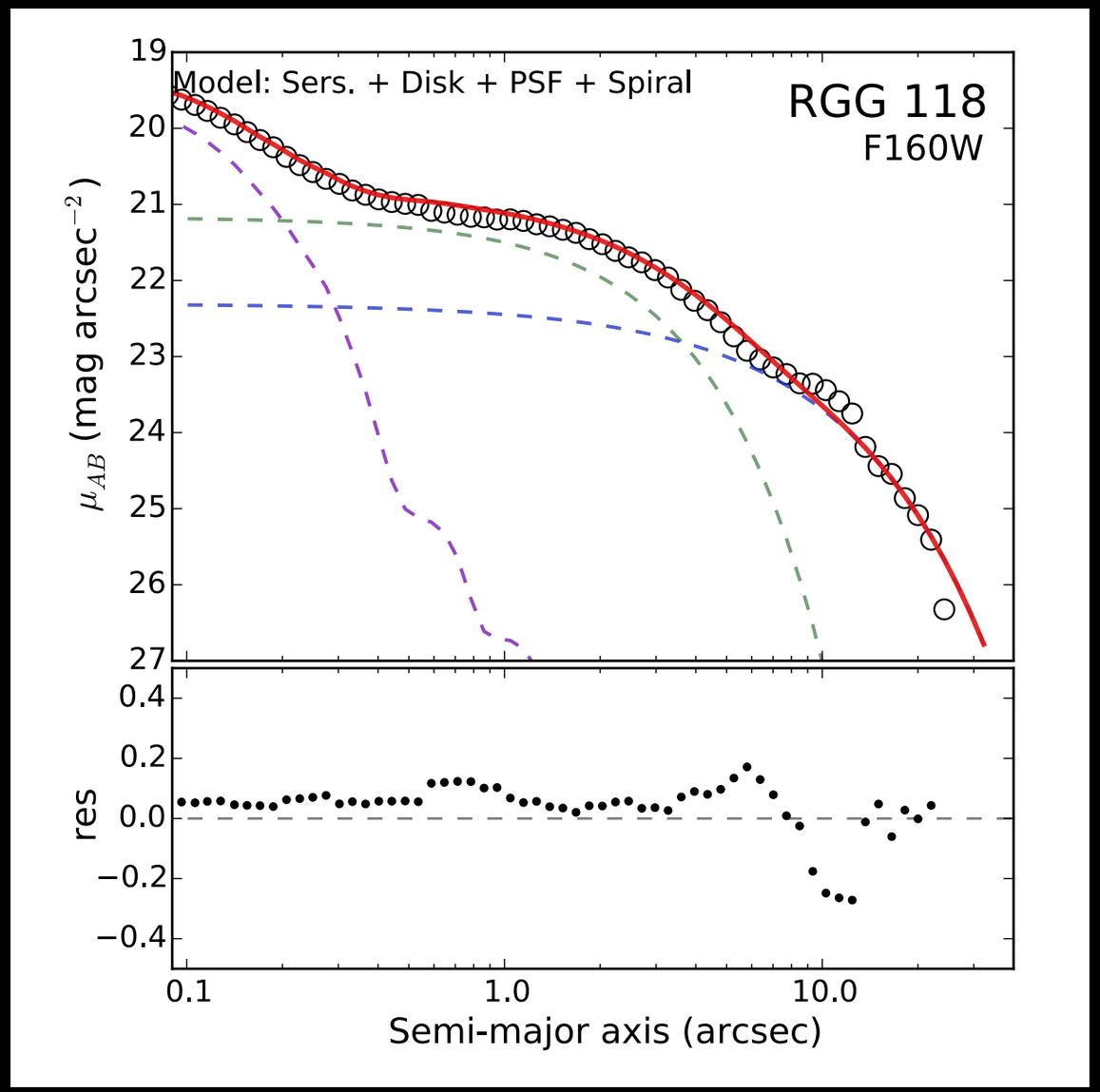



Baldassare et al. 2015

# Morphology of RGG 118

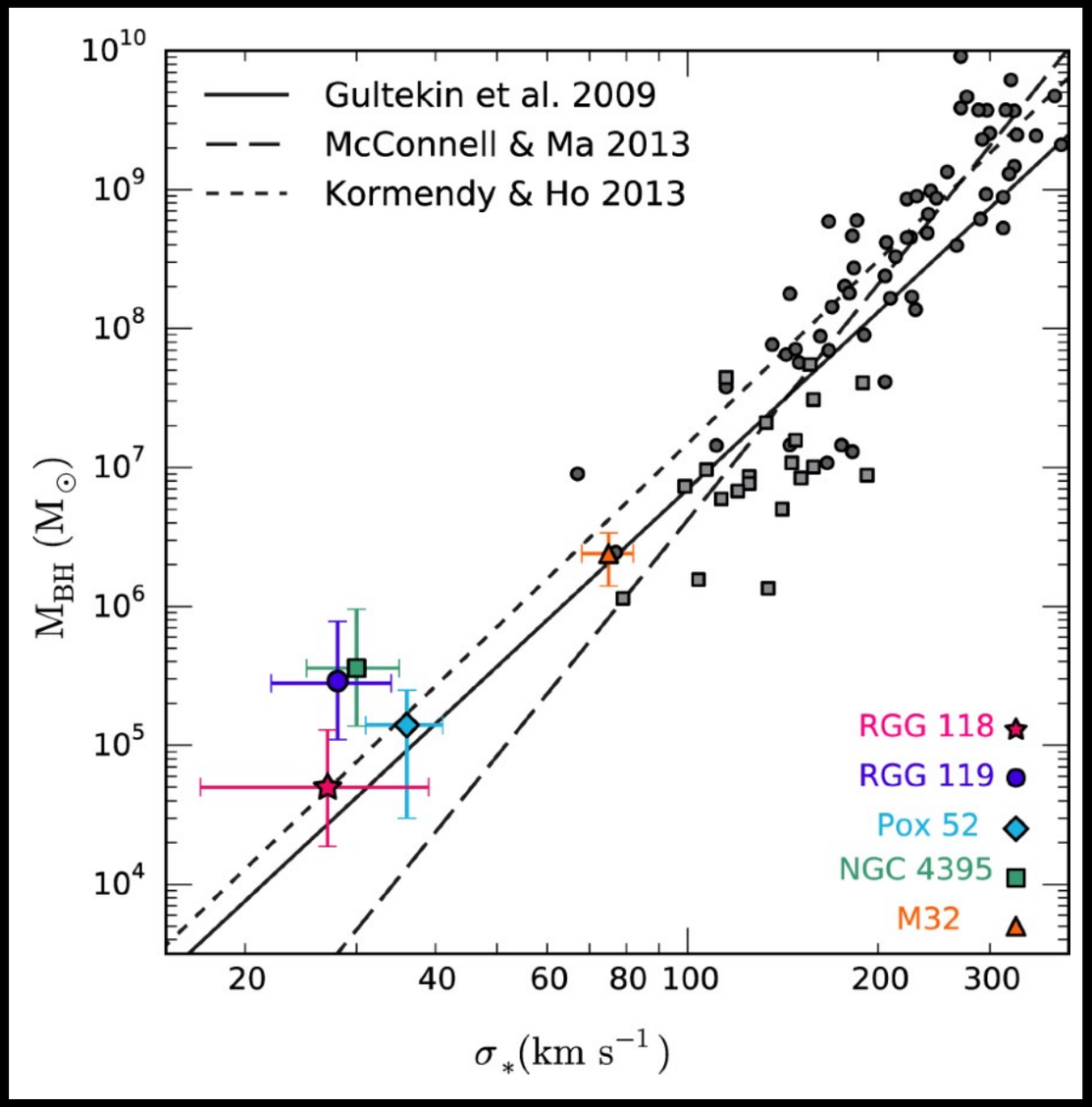


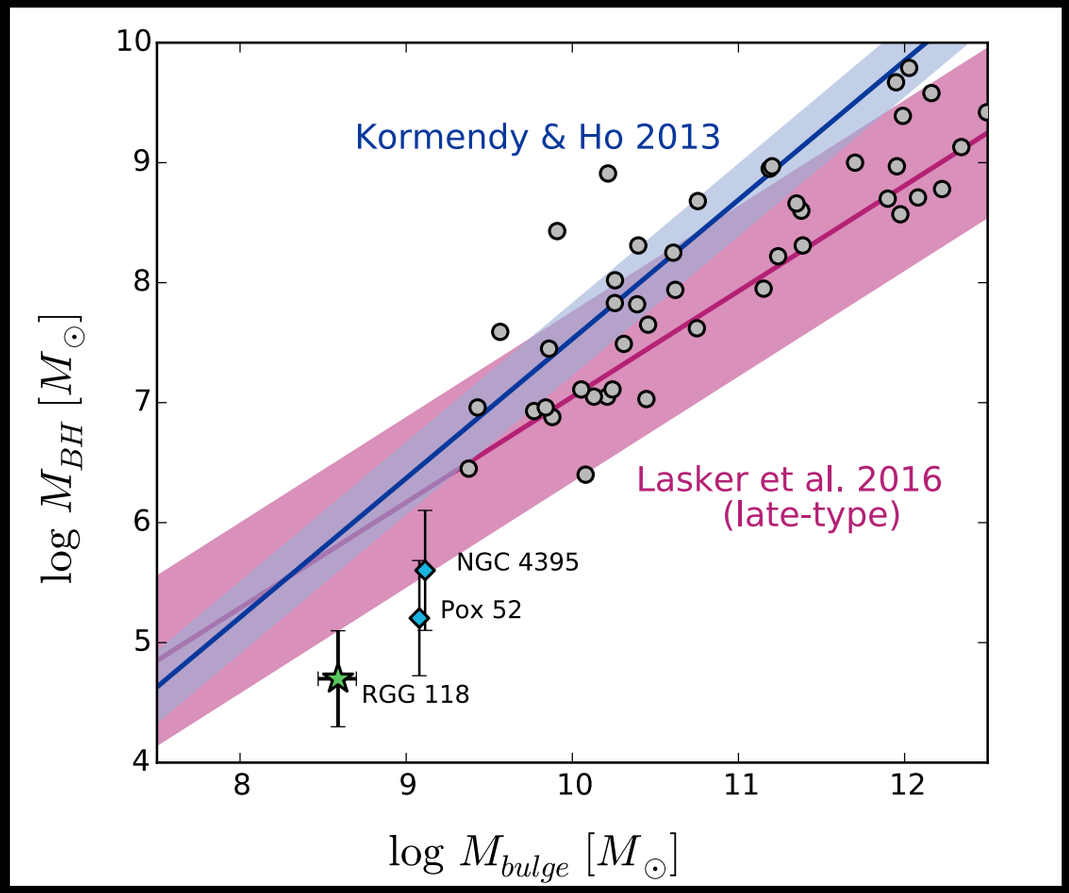

- Stellar mass = $2 \times 10^9$ $M_{Sun}$
- Best fit model: outer disk + inner bulge-like component + PSF




Baldassare et al. 2017b

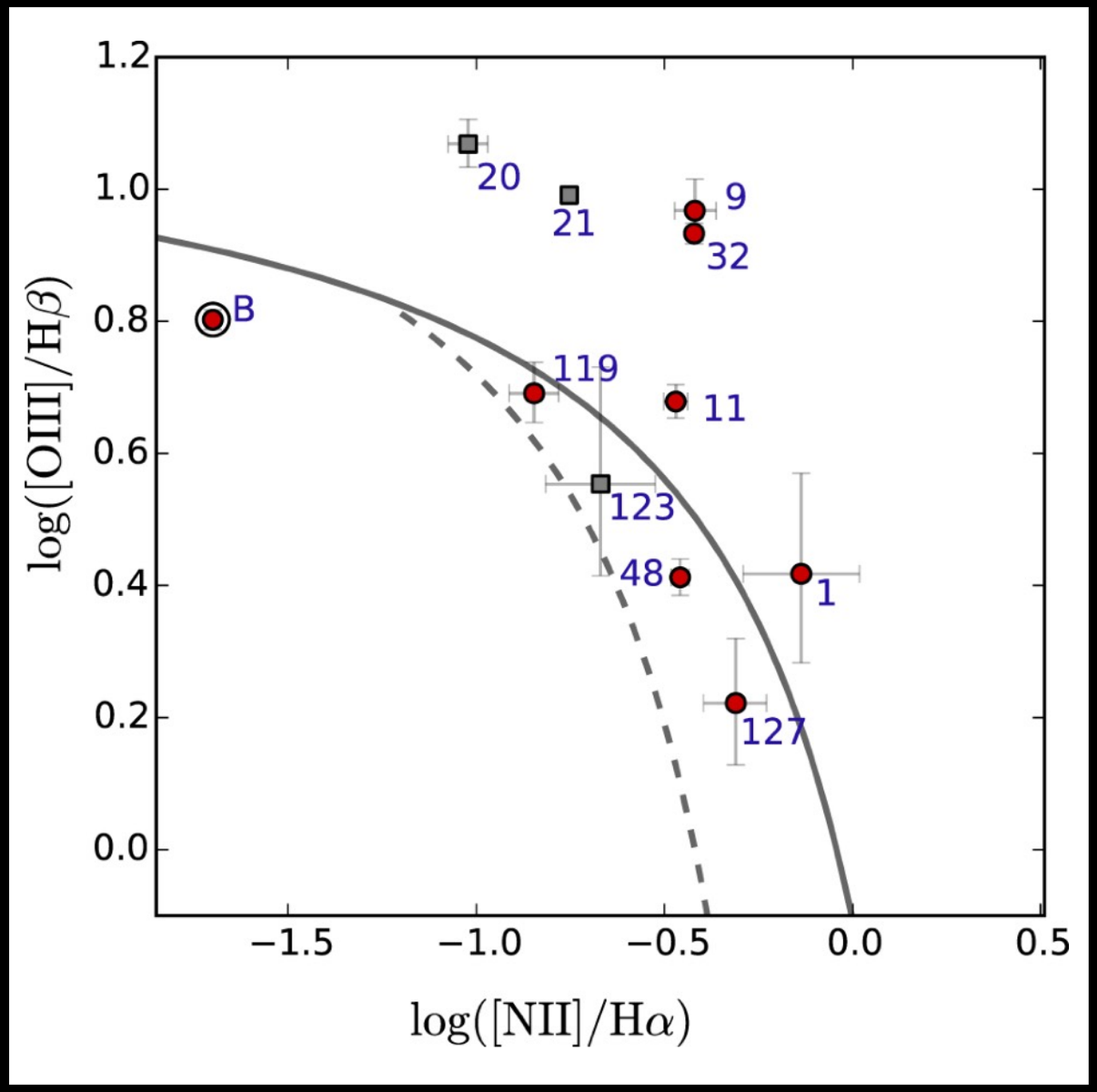
# Scaling relations at the low-mass end

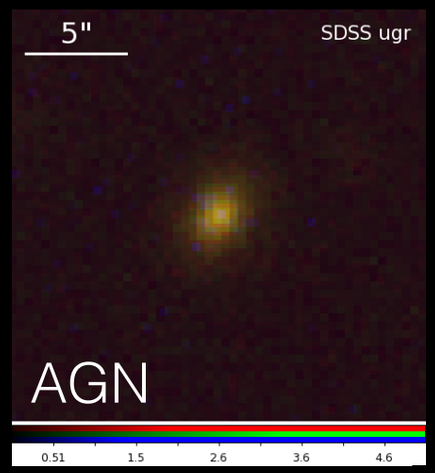


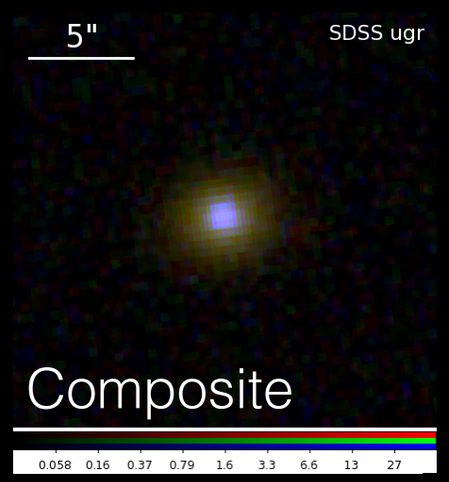




Baldassare et al. 2016, 2017b

# X-ray observations of broad-line AGN in dwarf galaxies



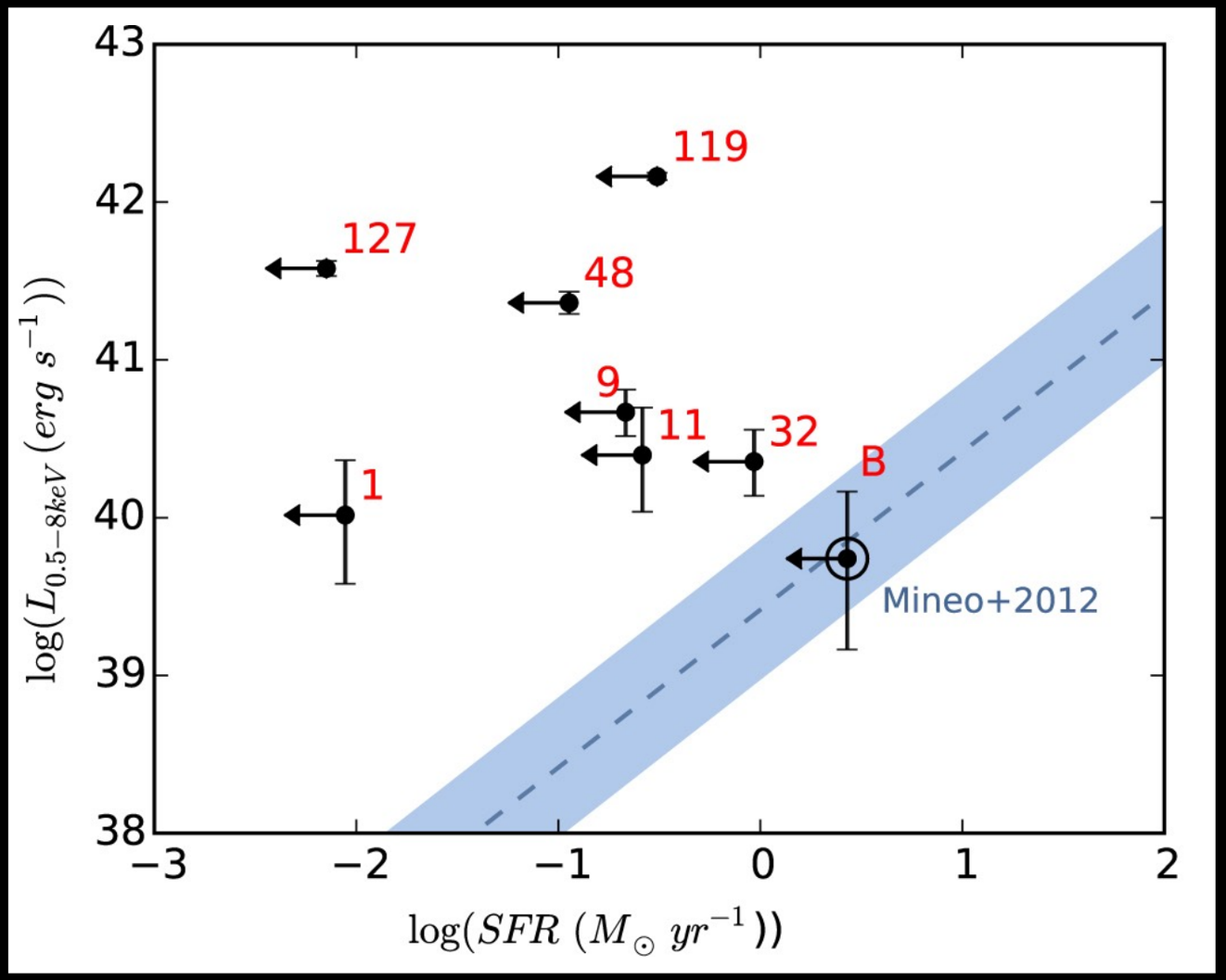





Baldassare et al. 2017a

# Optically selected broad-line AGN in dwarf galaxies are accreting rapidly




Baldassare et al. 2017a

- All dwarf galaxies with broad and narrow-line AGN signatures are X-ray detected
- X-rays are more luminous than expected from X-ray bianaries
- $L/L_{Edd}$ from 0.1-50%

# Future directions

- Build larger samples of AGN in dwarf galaxies
- Continue to populate the low-mass end of scaling relations
- Explore whether dwarf galaxies with AGN are “special”