Co-evolution of galaxies and central black holes: Extended emission-line region around quasars

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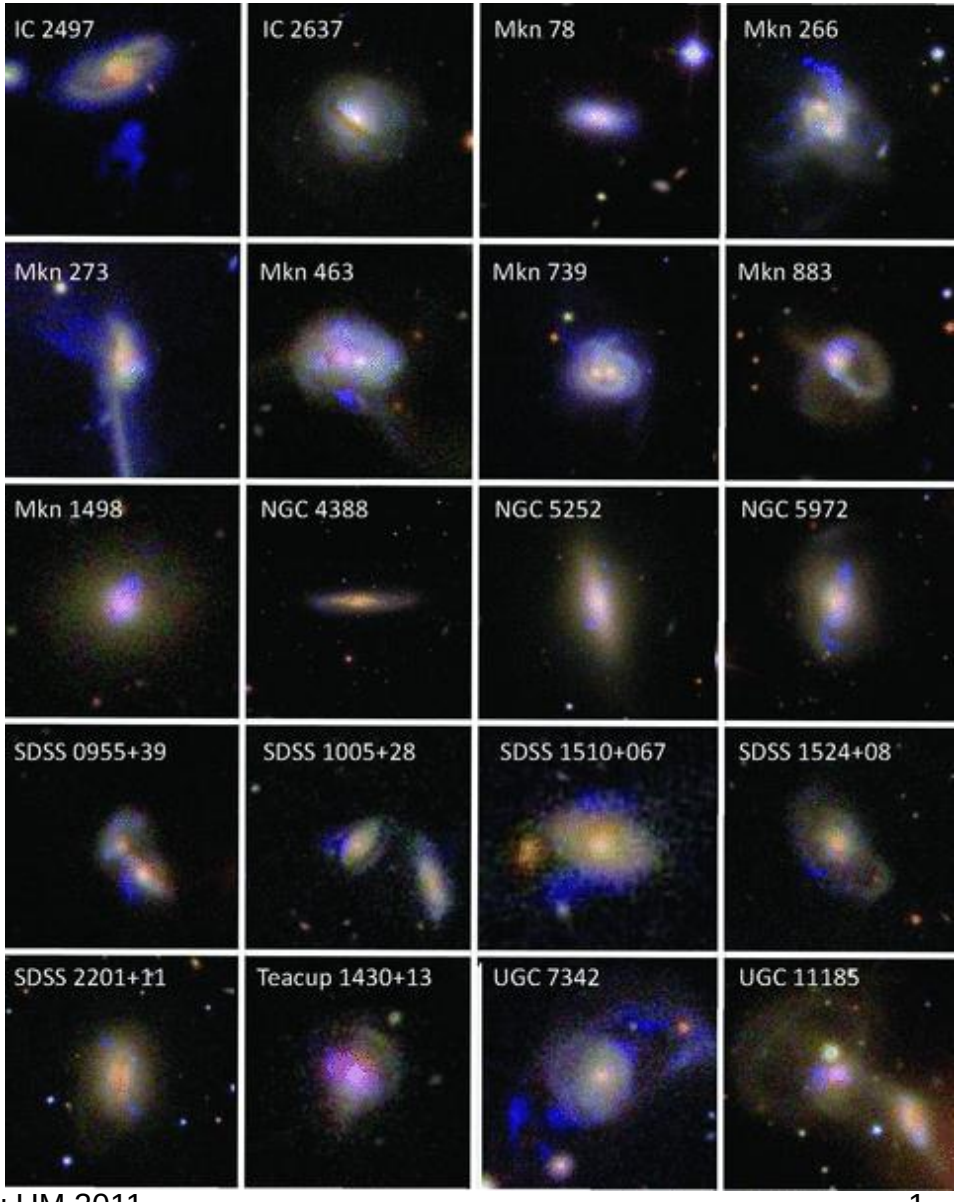
INTRODUCTION – ELR (or EELR)

Extended emission-line region

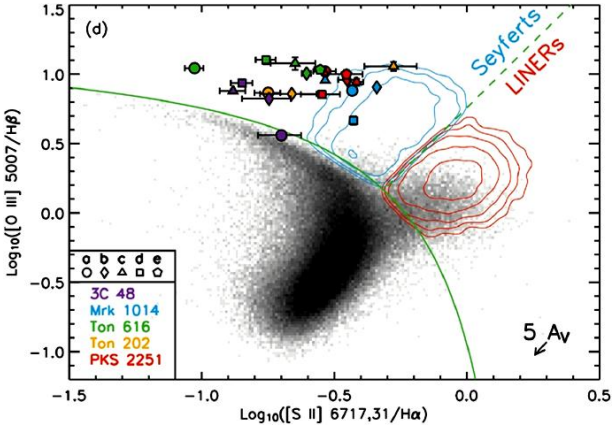
- Massive ionized nebulae observed around some AGNs (~a few x 10 kpc)
- Mostly detected in [O III] λ5007
- Not many observations to date
  - Long-slit spectroscopy
  (Boroson et al.1985; Villar-Martin et al. 2011)
  - NB-filter imaging
  (Stockton & MacKenty 1987)
  - IFU spectroscopy
  (Husemann et al. 2008; Fu & Stockton 2009)
- Preferentially found around radio quasars with
  - steep radio spectrum
  - strong NLR [O III] line
  - broad and bump Hβ profile
  - weak Fe II lines

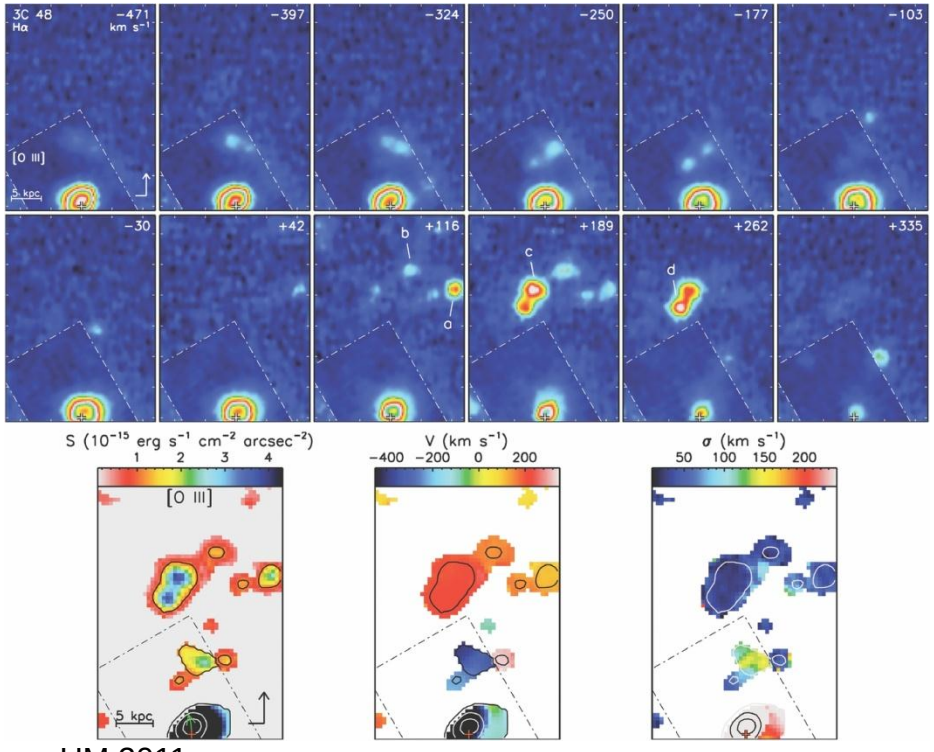


INTRODUCTION – Why do we care?

Extended emission-line region

- Ionization source:
  mostly AGN (based on the BPT diagram)
- Kinematics:
  - "locally ordered but globally disordered"
  - some high-velocity clouds leaving the host galaxies
  - minor-merger origin?





ELR phenomenon
= galaxy-wide energy injection into the ISM by AGN radiation

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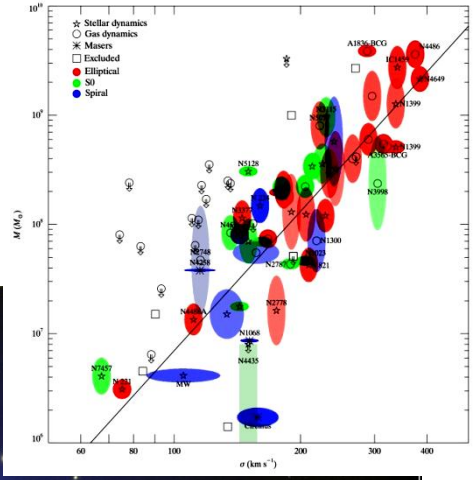
Reminiscent of
"AGN feedback"

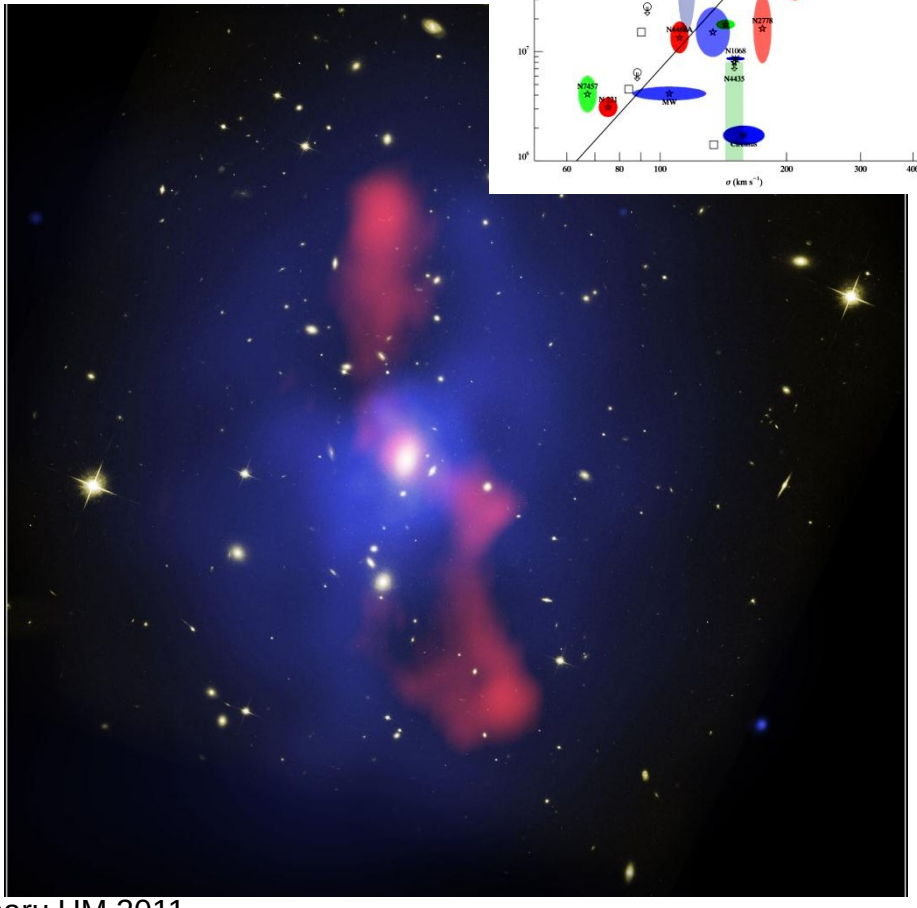
INTRODUCTION – AGN feedback

A compelling mechanism for driving the co-evolution of galaxies and SMBHs

- "Magorrian relation" (→)
  - tight correlation between galaxy-bulge mass and SMBH mass
- "Over-cooling" problem
  - much more massive galaxies are formed in the Λ CDM models than observed
- Color-mass-morphology relation
  - models predict the inverted relation to observations.

→ Regulate SF activity in massive galaxies by AGN



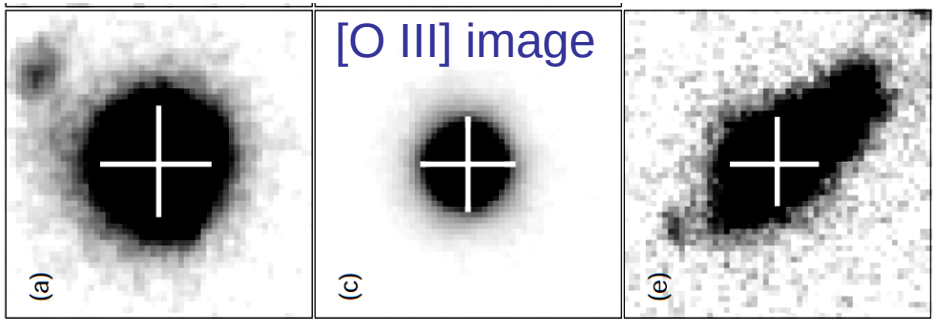


DATA – New observation and compilation

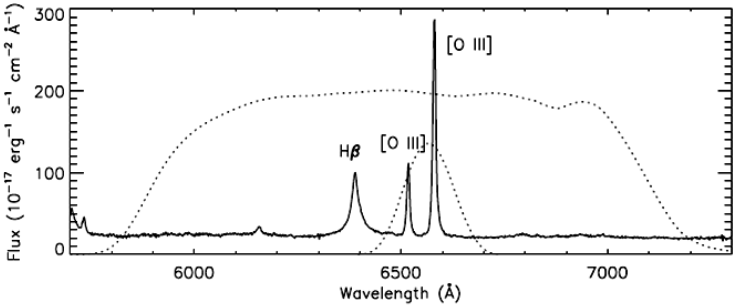
Subaru/Suprime-cam observation

- Open-use program S11A-028
  (2011 May 2-4; 1/3 clear nights)
- Targets: SDSS quasars at z ~ 0.3
- Filter: NA_{656} ([O III] λ5007), R_c (cont.)
- Exp time: 45 min (NA_{656}) + 15 min (R_c)

→ Detection of 2 ELR out of 5 targets



- Compilation of the past measurements
  - 61 type-1 quasars (27 ELR detection)
  - 20 type-2 quasars (10 ELR detection)



RESULTS – Origin of ELR - PC 1 correlation

Principal component 1 (PC1; eigenvector 1) of the AGN emission correlation
- steep-spec. radio emission
- strong NLR [O III] line
- broad and bump Hβ profile
- weak Fe II lines

- mainly driven by Eddington ratio

Clear correlation between the ELR fraction and Eddington ratio

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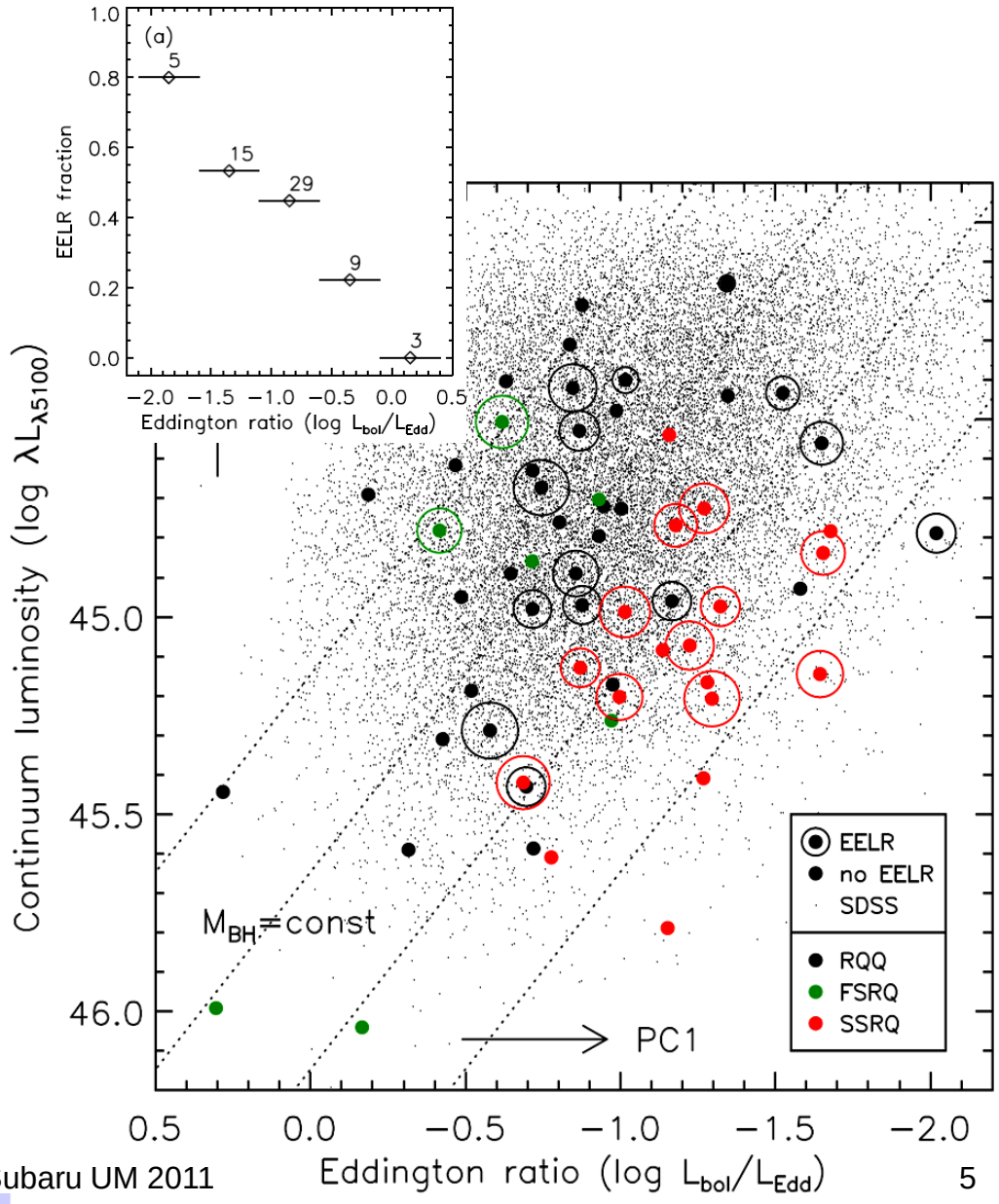
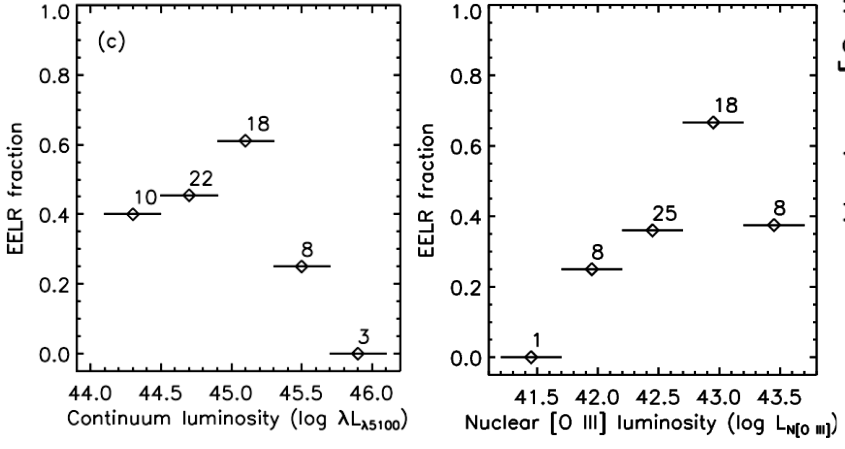
Origin of the ELR dependence on the PC 1 constituents

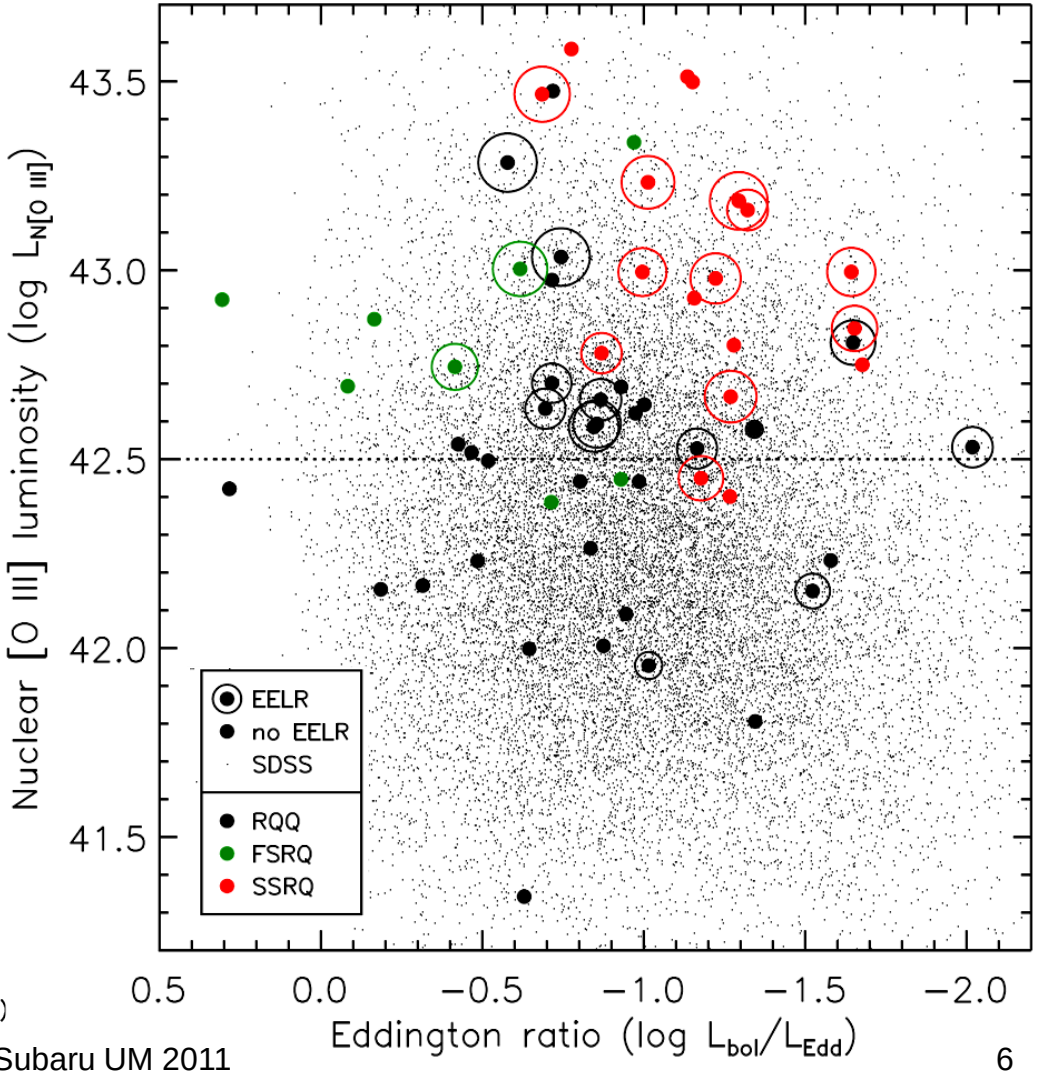


RESULTS – What regulates ELR emergence?

L (ELR) = L (AGN) x M (extended gas)

- no positive correlation between the ELR fraction and L(AGN); consistent with the previous studies
- → M (Extended gas) !
- Strong correlation between NLR and ELR [O III]
  … "Gas availability"

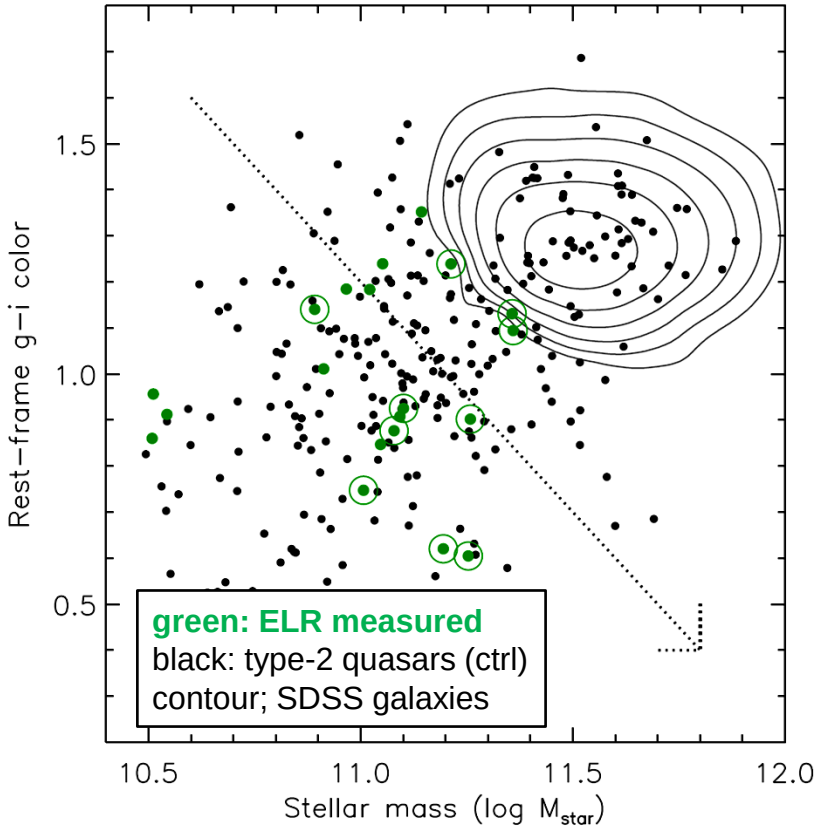


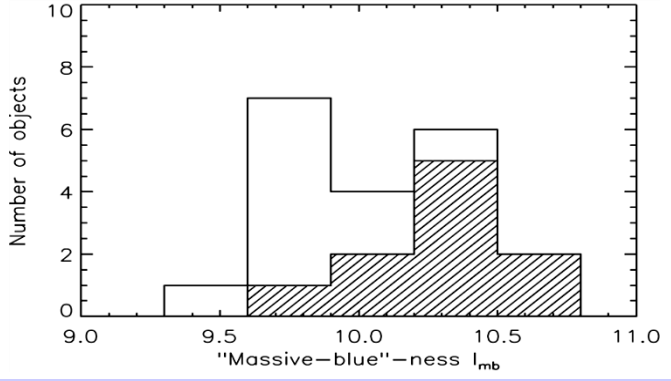


RESULTS – Host galaxies

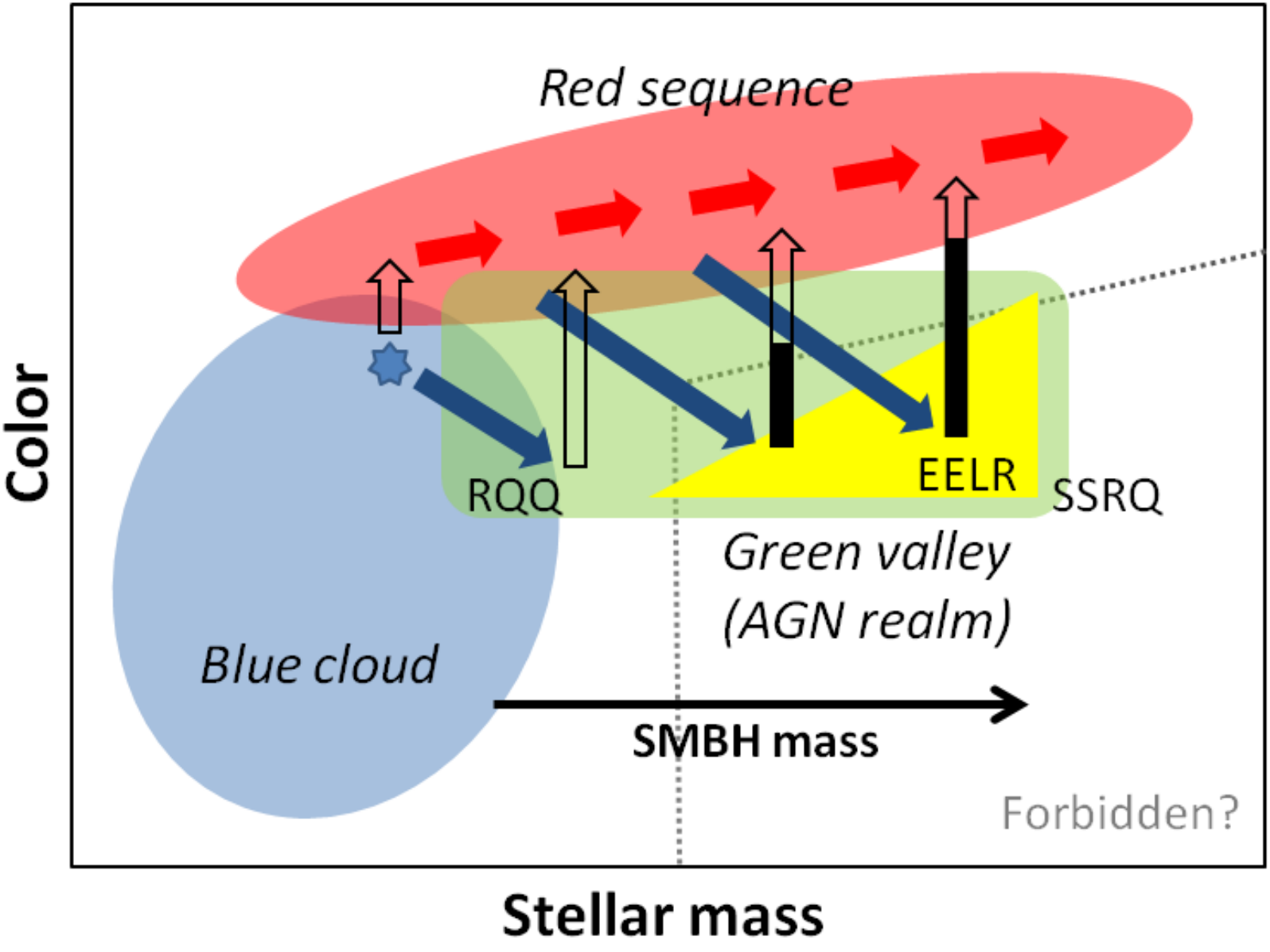
Stellar mass and rest-frame color of type-2 quasars

- AGNs … reside in the "green valley" between the red sequence and the blue cloud (e.g., Schawinski et al. 2010)
- ELR is preferentially associated with massive blue galaxies (→)
- Blue color
  - minor-merger origin of ELR gas
  - presence of ample gas for ELR
- Massiveness
  - Massive galaxies are the dominant hosts of radio-loud AGNs characterized with low Eddington ratio
  - may explain the whole set of observed correlations





DISCUSSION – In the context of galaxy evolution



SUMMARY

- Extended emission-line region (ELR) is massive ionized nebulae observed in some AGNs.
- It may be an important phenomenon related to the “AGN feedback”
- We carried out a new Subaru/Suprime-Cam observation and data compilation, resulting in 81 ELR measurements around type-1 and 2 quasars.
- We find that ELR
  - anti-correlates with Eddington ratio (hence radio emission),
  - is regulated by the amount of available gas,
  - is preferentially associated with massive blue galaxies.
- We suggest that ELR occupies massive-blue corner of the green valley, the AGN realm, on the galaxy color – stellar mass diagram. Once a galaxy is pushed to this corner, activated AGN would create ELR by the energy injection into the ISM and eventually blow it away, leading to star-formation quenching (AGN feedback process).