



可視変動により見つかった radio-loud narrow line Seyfert 1の 多波長観測

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DISCOVERY OF DRAMATIC OPTICAL VARIABILITY IN SDSS J1100+4421: A PECULIAR RADIO-LOUD NARROW-LINE SEYFERT 1 GALAXY?

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Narrow Line Seyfert 1 (NLS1)

- ▶ AGN w/ “narrow” broad emission lines
 - ▶ <2000 km/s
 - ▶ smaller supermassive black holes (SMBHs)
 - ▶ 10^{5-8} Msun SMBH
 - ▶ rare population
 - ▶ 15% of broad-line AGN (SDSS)
- ▶ high Eddington ratio \Rightarrow high accretion rate ($L_{\text{bol}}/L_{\text{Edd}} > 0.1$)
 - ▶ growing SMBH
- ▶ weak [OIII]: $[\text{OIII}]/\text{H}\beta < 3$
- ▶ small amplitude of variability(?)
- ▶ radio-quiet
 - ▶ Only $\sim 7\%$ of NLS1 are radio-loud ($R > 10$).

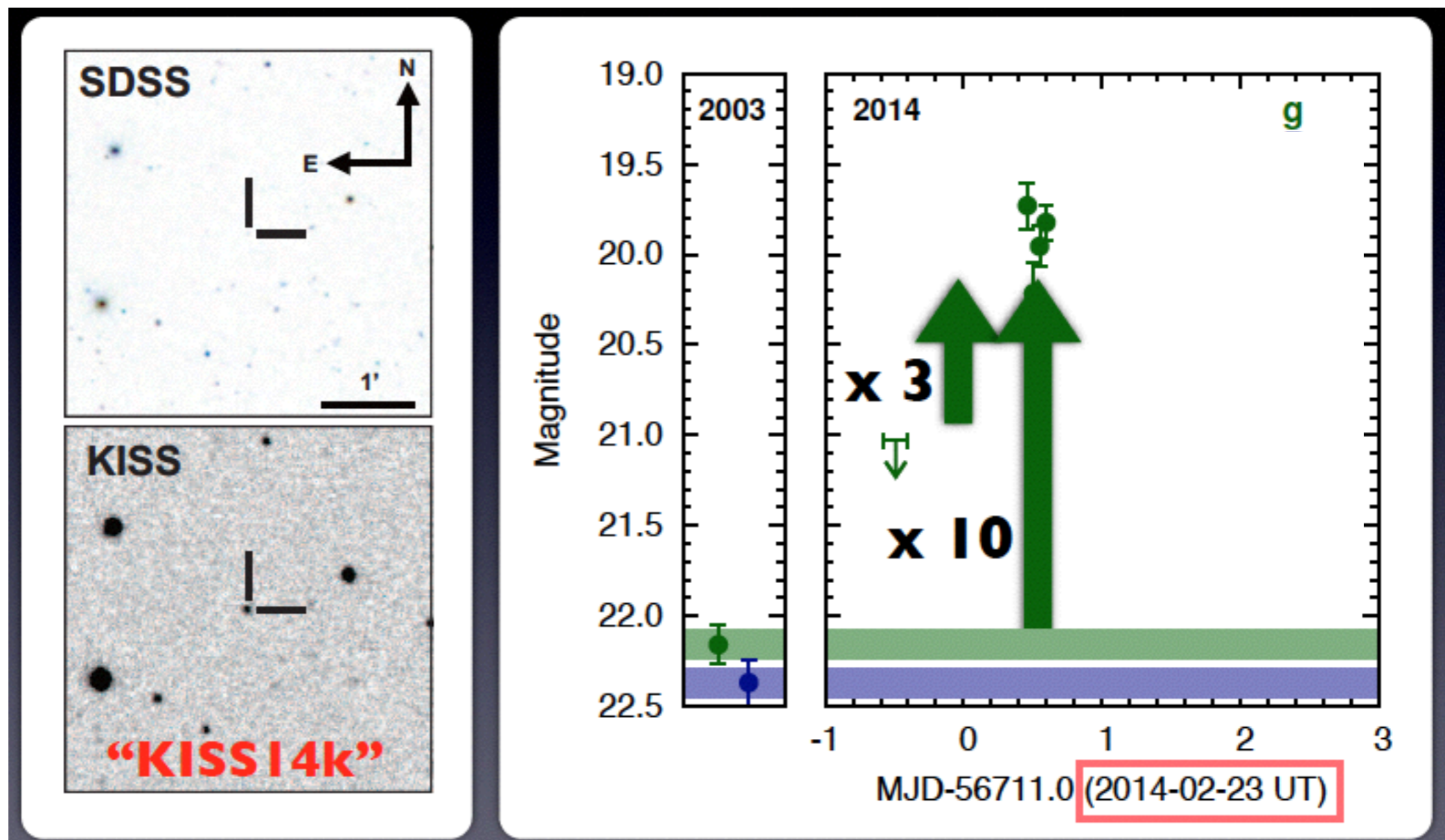
SDSS J1100+4420 (KISS14k): Peculiar NLS1?

- ▶ AGN w/ “narrow” broad emission lines
 - ▶ <2000 km/s: $v(\text{MgII})=2070\text{km/s}$, $v(\text{Hbeta})=1900\text{km/s}$
 - ▶ smaller supermassive black holes (SMBHs)
 - ▶ 10^{5-8} Msun SMBH: 1.5×10^7 Msun SMBH
 - ▶ rare population
 - ▶ 15% of broad-line AGN (SDSS)
- ▶ high Eddington ratio \Rightarrow high accretion rate ($L_{\text{bol}}/L_{\text{Edd}} > 0.1$): $L_{\text{bol}}/L_{\text{Edd}} \sim 0.3$
 - ▶ growing SMBH
- ▶ weak [OIII]: $[\text{OIII}]/\text{Hbeta} < 3$: high $L([\text{OIII}])$. $[\text{OIII}]/\text{Hbeta} \sim 7$
- ▶ small amplitude of variability(?): rapid optical “flare”
- ▶ radio-quiet
 - ▶ Only $\sim 7\%$ of NLS1 are radio-loud ($R > 10$).
 - ▶ radio-loudness $R \sim 3000$
 - ▶ extended radio emission: ~ 100 kpc?
- ▶ SED consistent with previous gamma-loud/radio-loud NLS1s

Discovery: SDSS J1100+4420 (KISS14k)

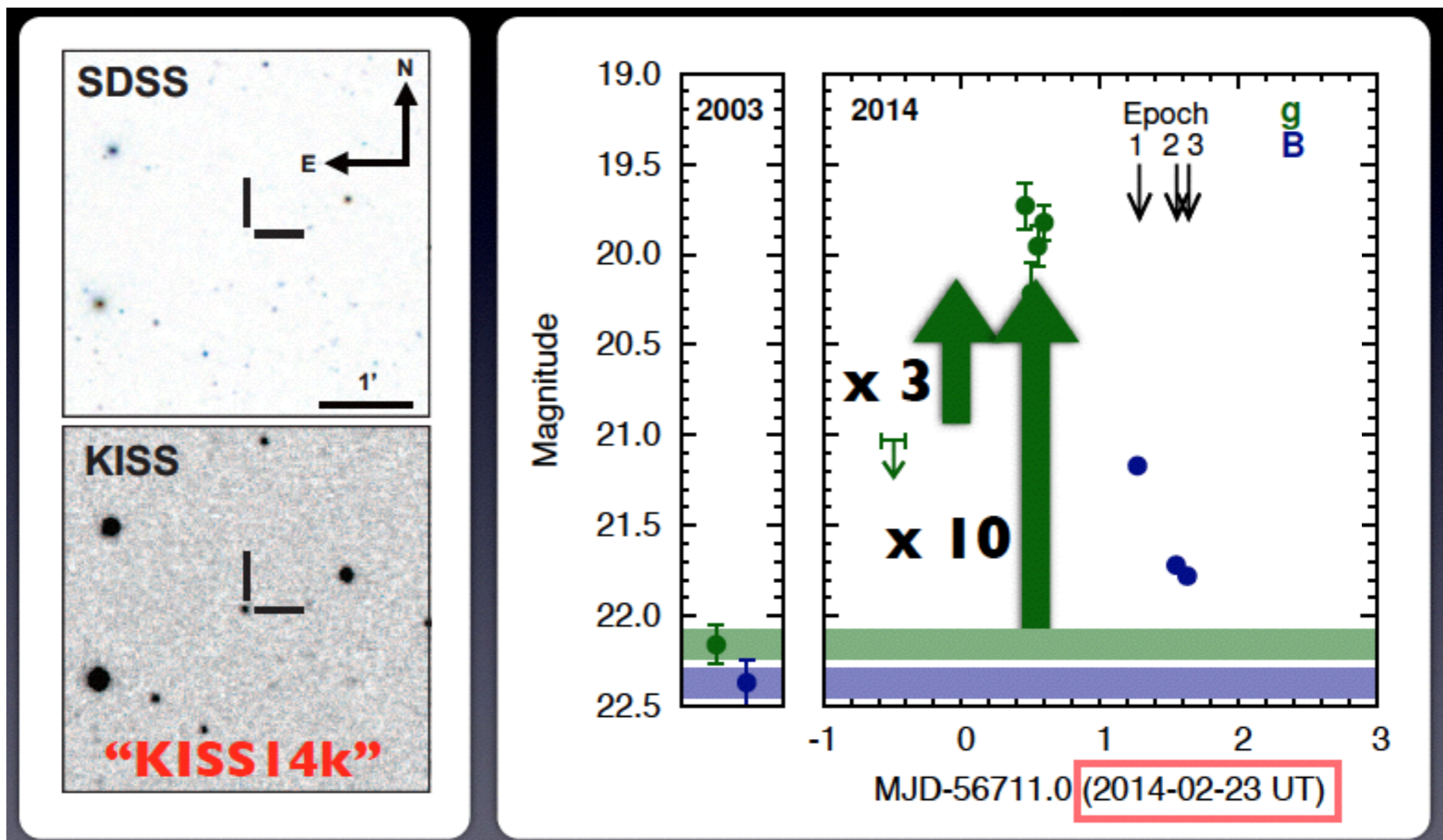
- rapid optical “flare” discovered in high-cadence supernova survey
 - Kiso Supernova Survey (KISS; Morokuma et al. PASJ, in press)
 - Kiso Schmidt (1.05m) + KWFC (4 deg² FoV)
 - supernova shock breakout !?!?!?

faint host
($g \sim 22$)
in SDSS



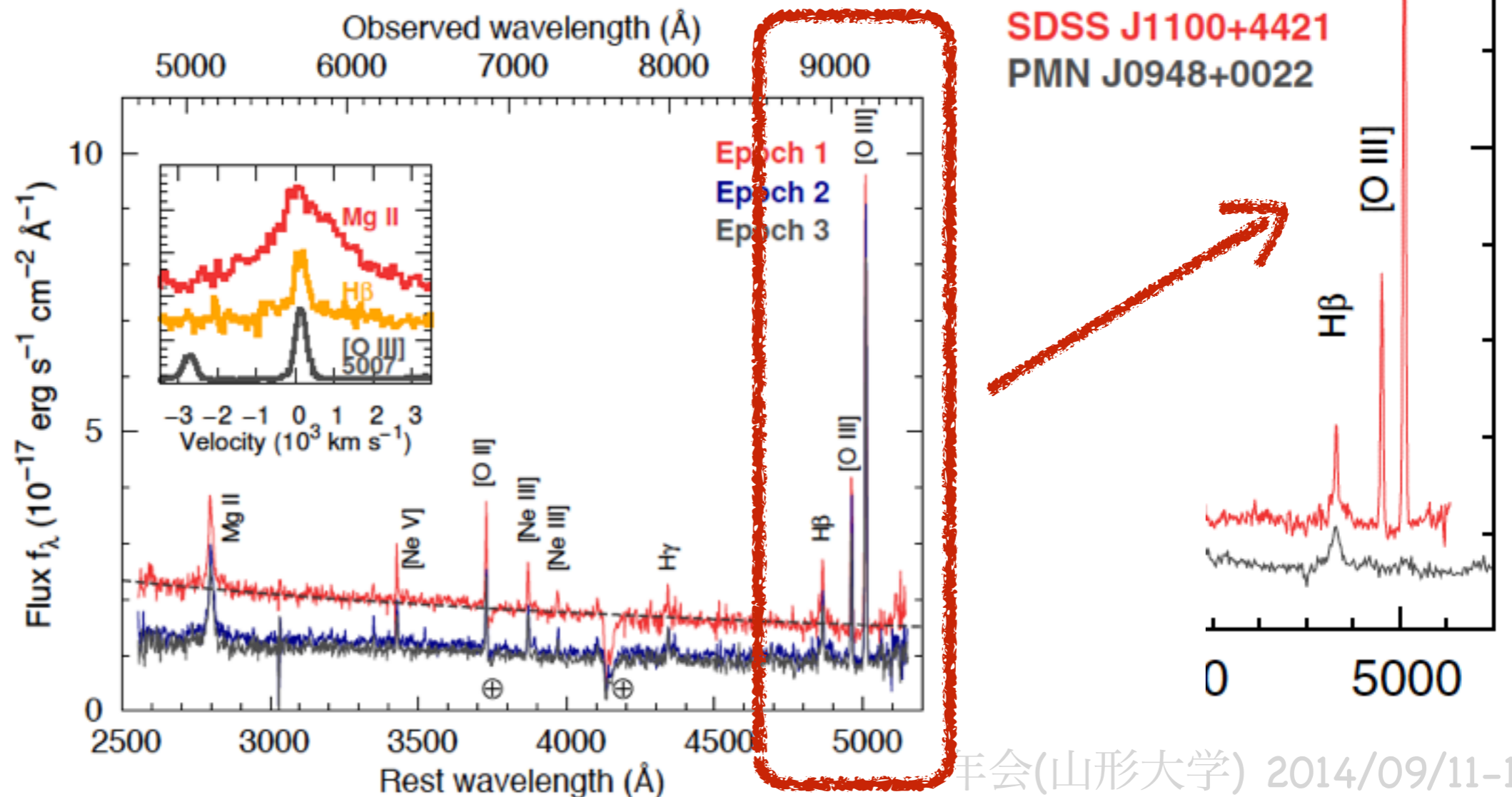
Follow-Up Observation (1): Optical w/ Subaru

- optical **imaging** & spectroscopy w/ Subaru/FOCAS
 - rapid decreasing phase

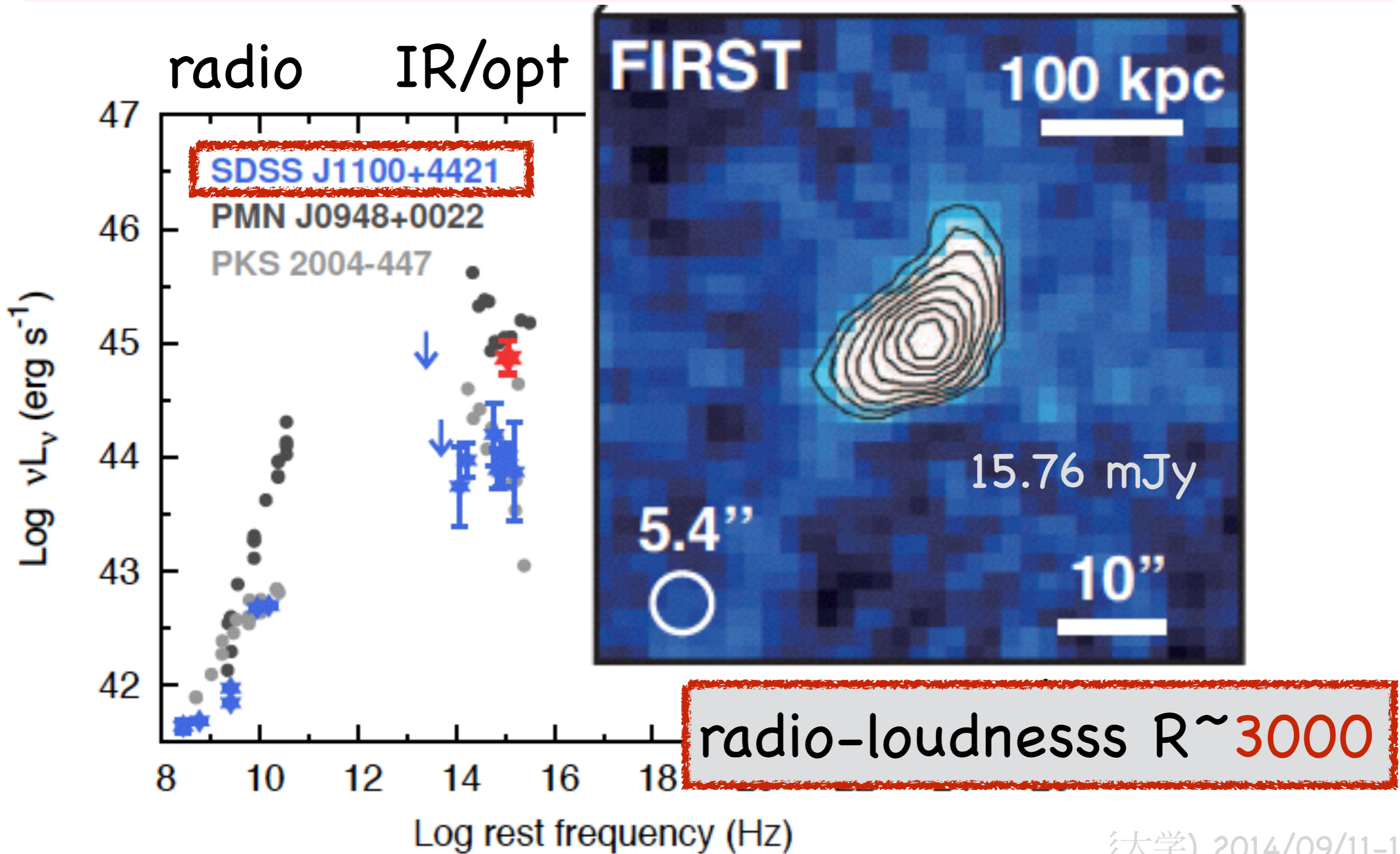


Follow-Up Observation (1): Optical w/ Subaru

- ▶ optical imaging & **spectroscopy** w/ Subaru/FOCAS
 - ▶ “narrow” ($\sim 2000\text{km/s}$) broad emission lines (MgII, Hbeta)
 - ▶ $\Rightarrow 1.5 \times 10^7 \text{ Msun SMBH}$
 - ▶ no changes of power-law indices (spectral slopes)
 - ▶ **strong [OIII] emission lines** ($[\text{OIII}]/\text{Hbeta} > 7$)



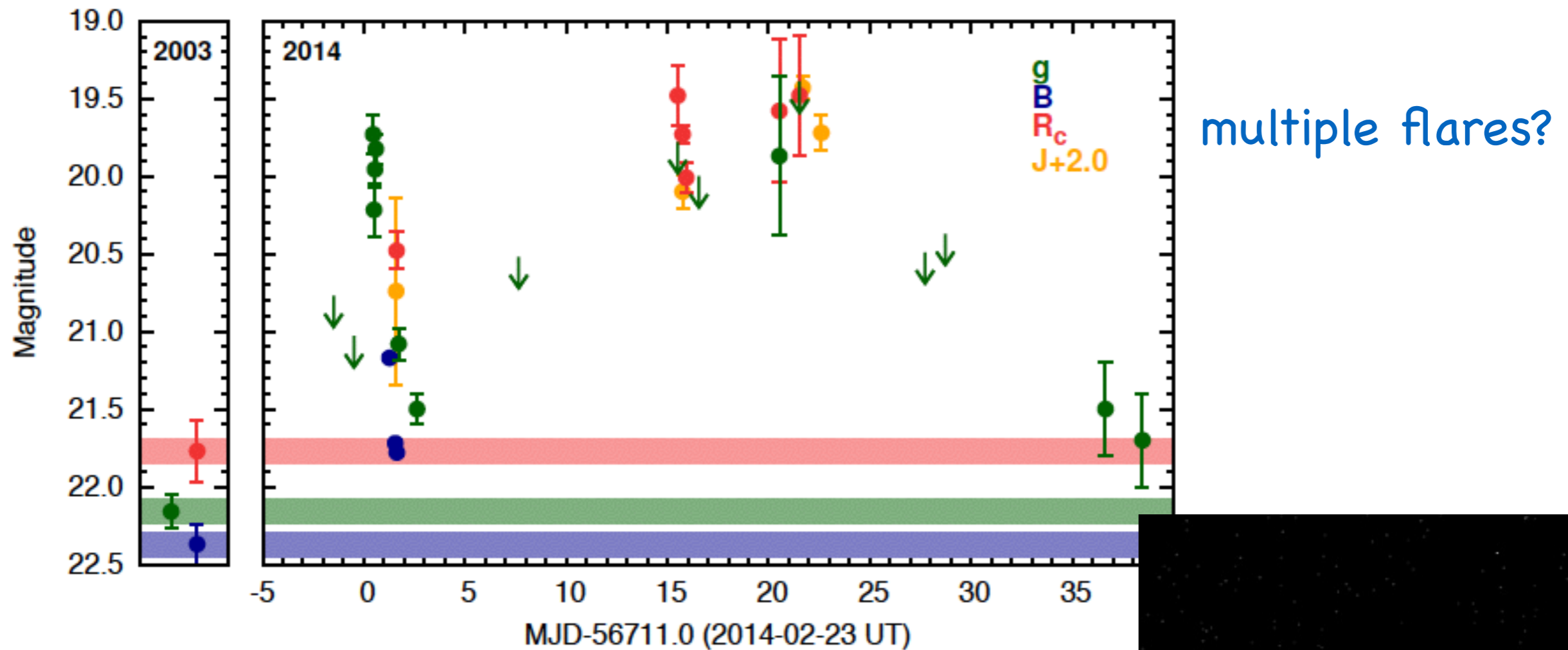
KISS14k is **very radio-loud** !!!



Follow-Up Observation (2): optical/NIR

Follow-Up Observation (3): X-ray/UV

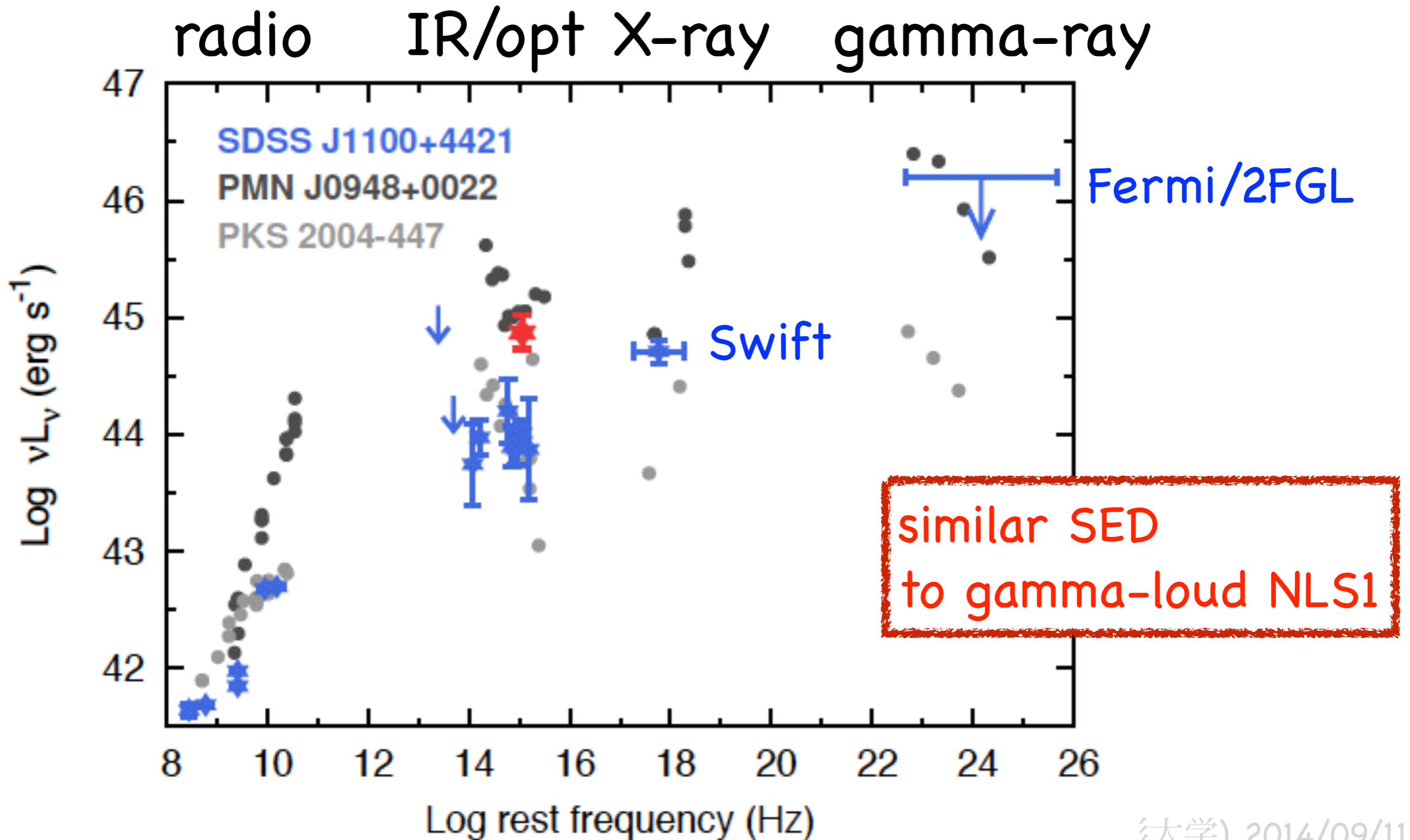
- ▶ continuous monitoring w/ **Kiso**/KWFC (1.05m), **Kanata**/HONIR (1.5m), **Akeno**/MITSuME (0.5m), **Kottamia** (1.88m, Egypt)



- ▶ ToO X-ray & UV imaging w/ Swift/XRT & UVOT (PI: M. Tanaka)

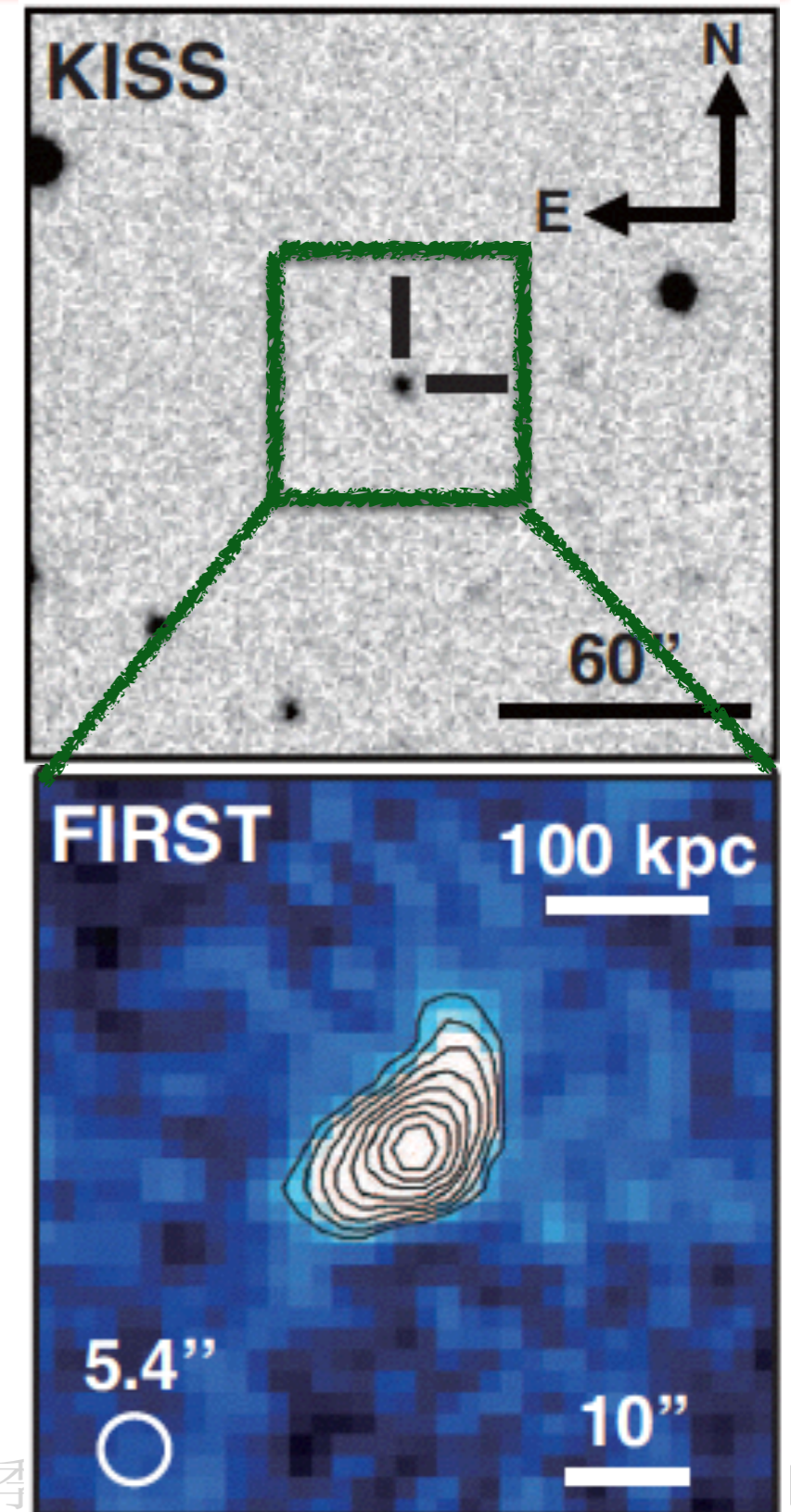


Spectral Energy Distribution of KISS14k



Follow-Up Observation (4): radio w/ JVN

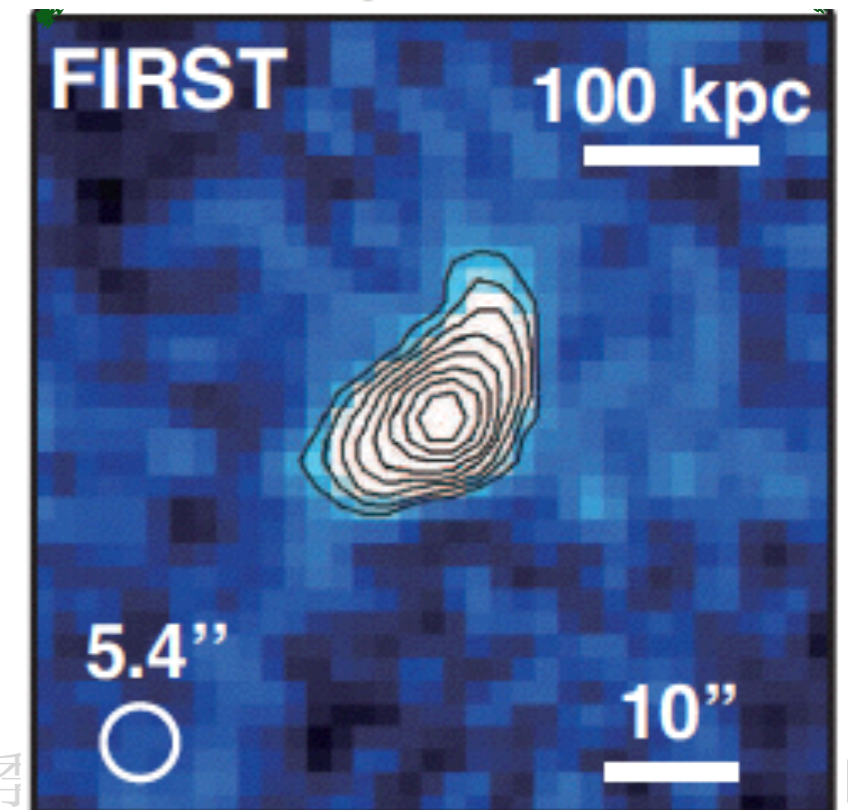
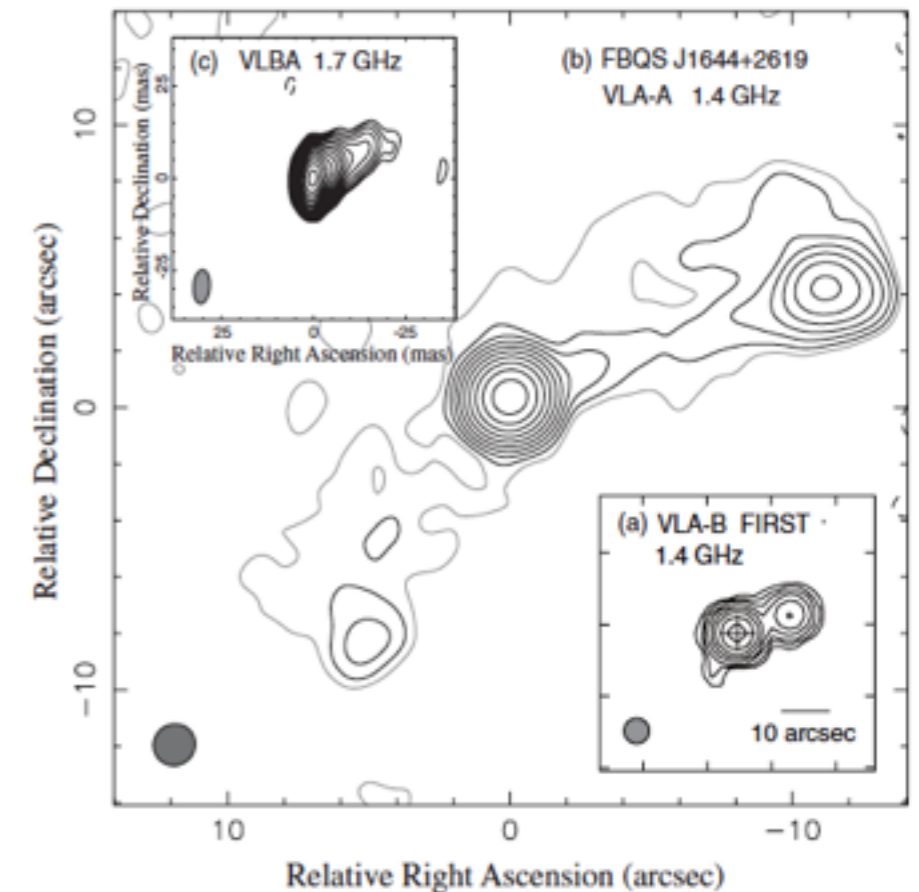
- ▶ Japan VLBI Network (JVN)
 - ▶ August 2, 2014 (UT)
 - ▶ 8 GHz
 - ▶ Yamaguchi, Hitachi, Usuda
 - ▶ aims
 - ▶ flux measurement (==> monitoring)
 - ▶ 37.6 mJy@5 GHz
 - ▶ spectral shape
 - ▶ morphology
 - ▶ under reduction
 - ▶ simultaneous optical/NIR observations
 - ▶ <== failed due to bad weather



Follow-Up Observation (4): radio w/ JVN

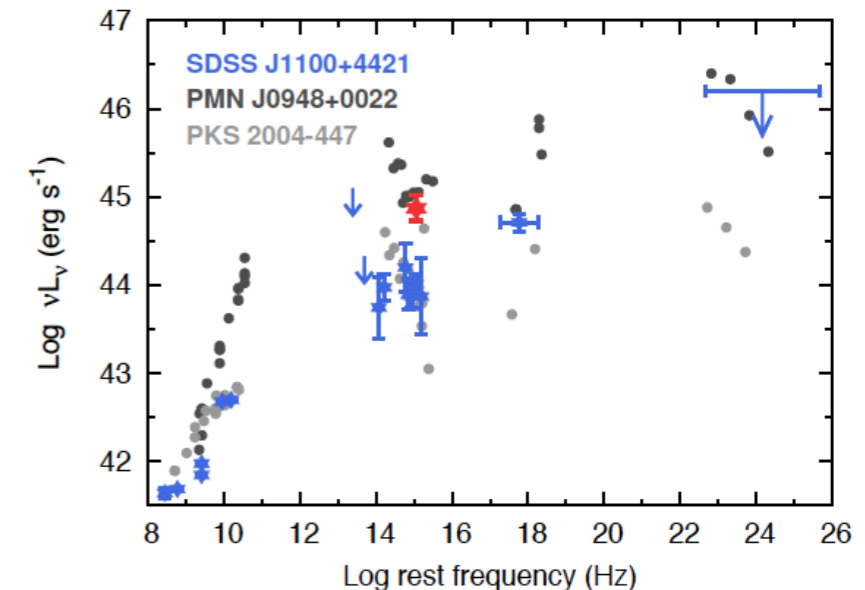
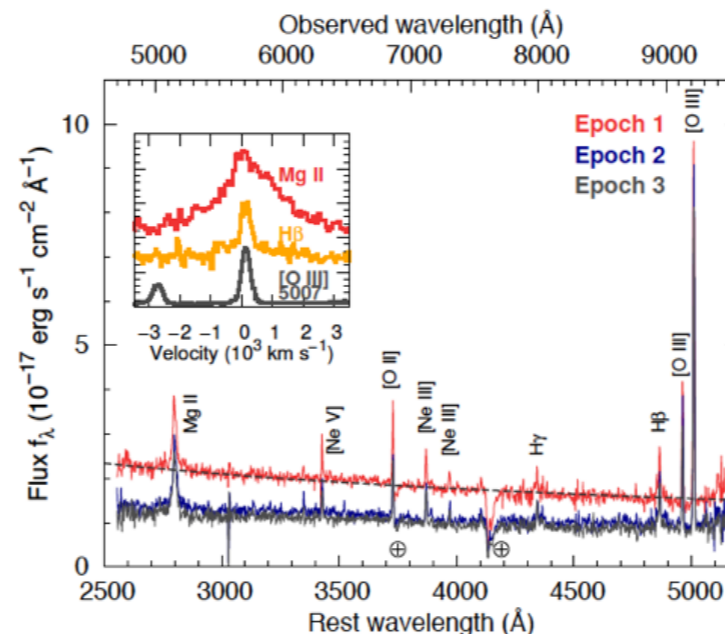
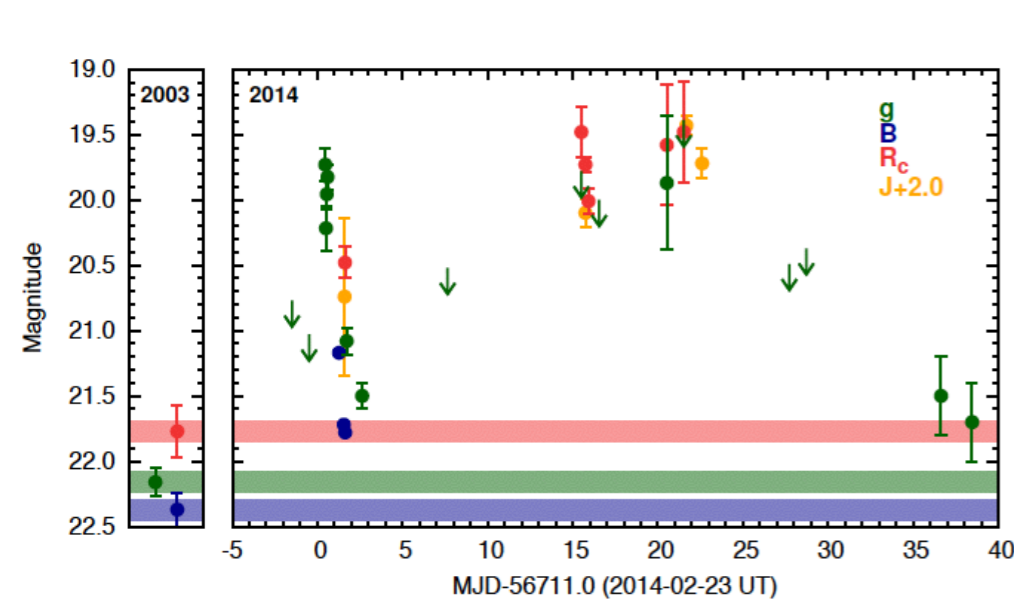
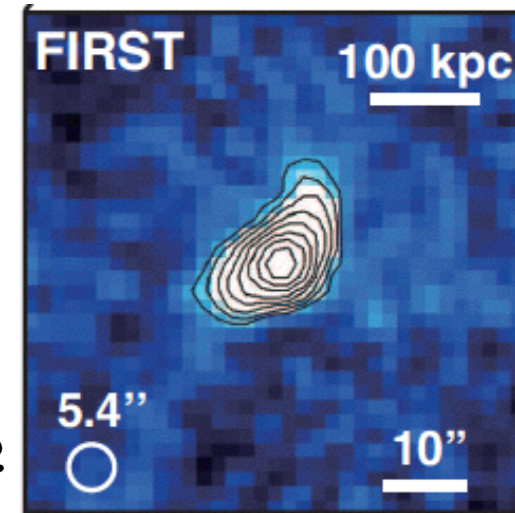
Doi+2012

- ▶ Japan VLBI Network (JVN)
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Nature of KISS14k

- ▶ short (\sim hours) time scale variability in optical
- ▶ “narrow” broad line $\Rightarrow 2 \times 10^7 M_{\text{sun}}$ SMBH
- ▶ SED consistent with other gamma-loud/radio-loud NLS1
- ▶ very radio-loud
- ▶ constant optical spectral slopes during luminosity change
 - ▶ \Rightarrow relativistic jet
- ▶ Extended (~ 100 kpc) radio structure
- ▶ Origin of high [OIII] luminosity? extended narrow line region?
 - ▶ \Rightarrow The jets are not aligned to the line-of-sight?
 - ▶ transition to more luminous quasar ???



Summary

- ▶ We detected a rapid optical flare from a radio-loud NLS1 in our high-cadence supernova survey KISS.
- ▶ Optical spectra
 - ▶ “narrow” broad emission line:
 - ▶ $v(\text{MgII})=2070\text{km/s}$, $v(\text{Hbeta})=1900\text{km/s}$
 - ▶ $2 \times 10^7 \text{ Msun SMBH}$
 - ▶ high [OIII] luminosity: $[\text{OIII}]/\text{Hbeta} \sim 7$
- ▶ very radio-loud: $R \sim 3000$
 - ▶ extended ($\sim 100 \text{ kpc}$) emission

Future Plans

- ▶ Simultaneous observations over wide wavelength range
 - ▶ coordinated observation of OISTER (optical/NIR) & JVN (radio)
- ▶ High-resolution interferometric observation
- ▶ Deep optical imaging/spectroscopy for the nature of a possible extended [OIII]?