Uncovering Buried Dual and Triple AGNs in Galaxy Mergers

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Shobita Satyapal, Nathan J. Secrest, Mario Gliozzi, Claudio Ricci, Barry Rothberg, Jenna M. Cann, Christina Manzano-King, Remington O. Sexton, Jenna B. Harvey, Krisztina Gabányi, Gabriela Canalizo, Sara Ellison, Anca Constantin, Laura Blecha, Sandor Frey, James K. Williams

20 Years of Chandra Symposium

Boston – 12 Nov. 2019

Motivation: Major Mergers

- **ΛCDM** predicts interactions are ubiquitous throughout Universe
- Theory predicts gas is funneled towards center – feeds central engines and triggers SF
- Dual AGN: The most accessible forerunner to binary SMBHs

Many questions remain:

- How much do SMBHs grow in mergers?
  → Do mergers dominate growth of SMBHs?
- How are the SMBH and galaxy scaling relations established?
- Do mergers host the most obscured AGN?

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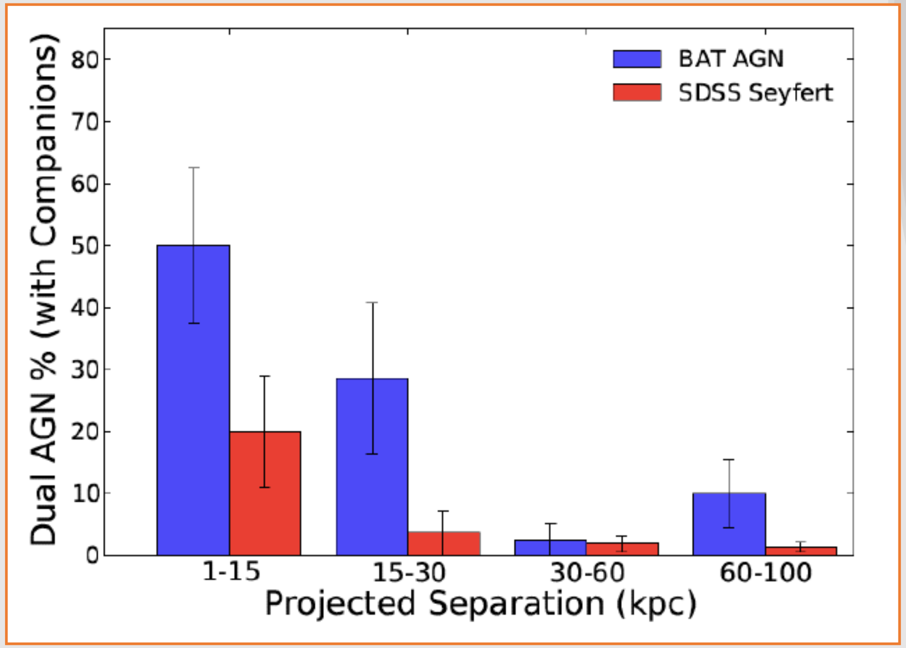
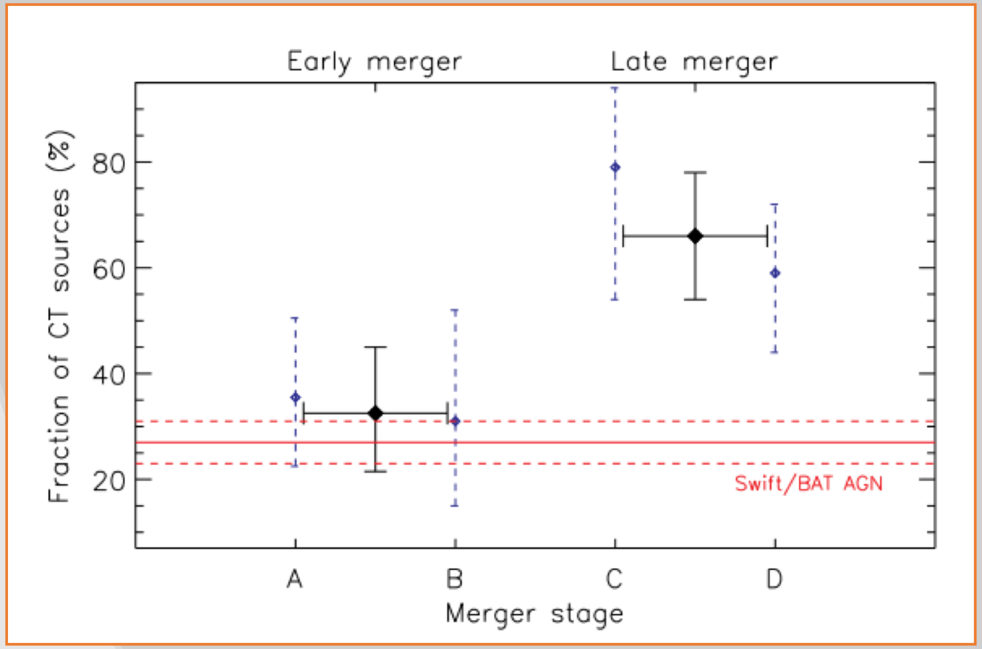
Major Merger connection: Mounting evidence



(Koss et al. 2012)



(Ricci et al. 2017)

<u>Results consistent with other observational studies</u>: Koss et al 2010, Ramos-Almeida et al. 2011, Silverman et al. 2011, Ellison et al. 2011, Treister et al. 2012, Shabala et al. 2012, Sabater et al. 2013, Satyapal et al. 2014, Kaviraj et al. 2015, Kocevski et al. 2015, Glikman et al. 2015, Fan et al. 2016, Goulding et al. 2017, Donley et al. 2018, <u>and more…</u>

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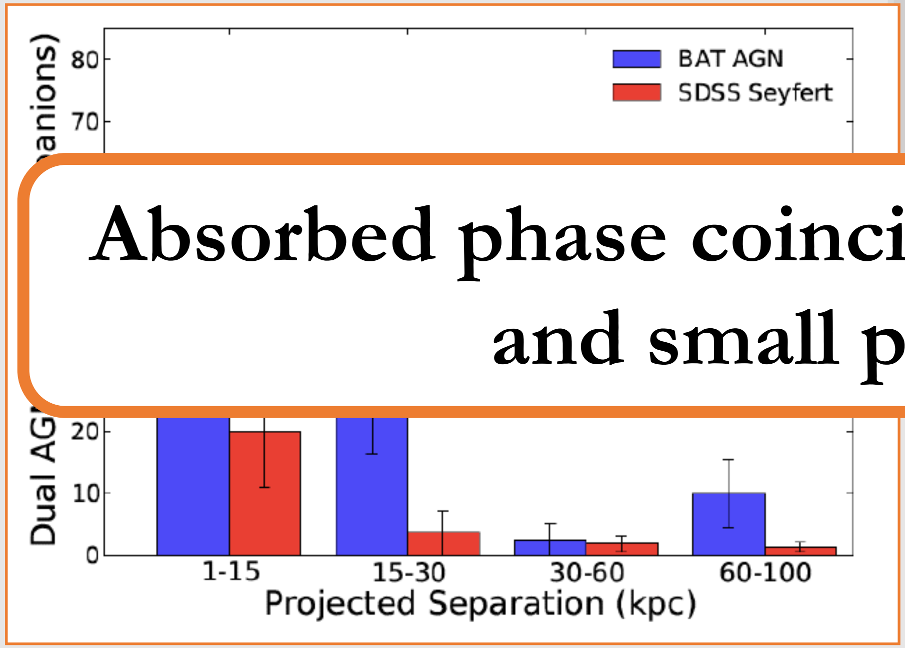

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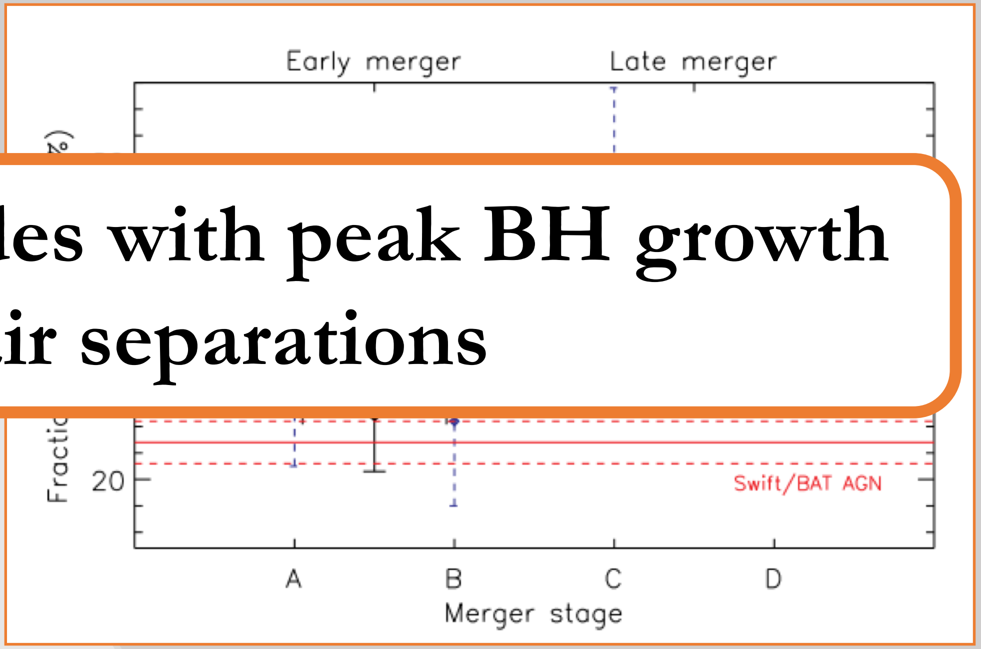

(Ricci et al. 2017)

Absorbed phase coincides with peak BH growth and small pair separations

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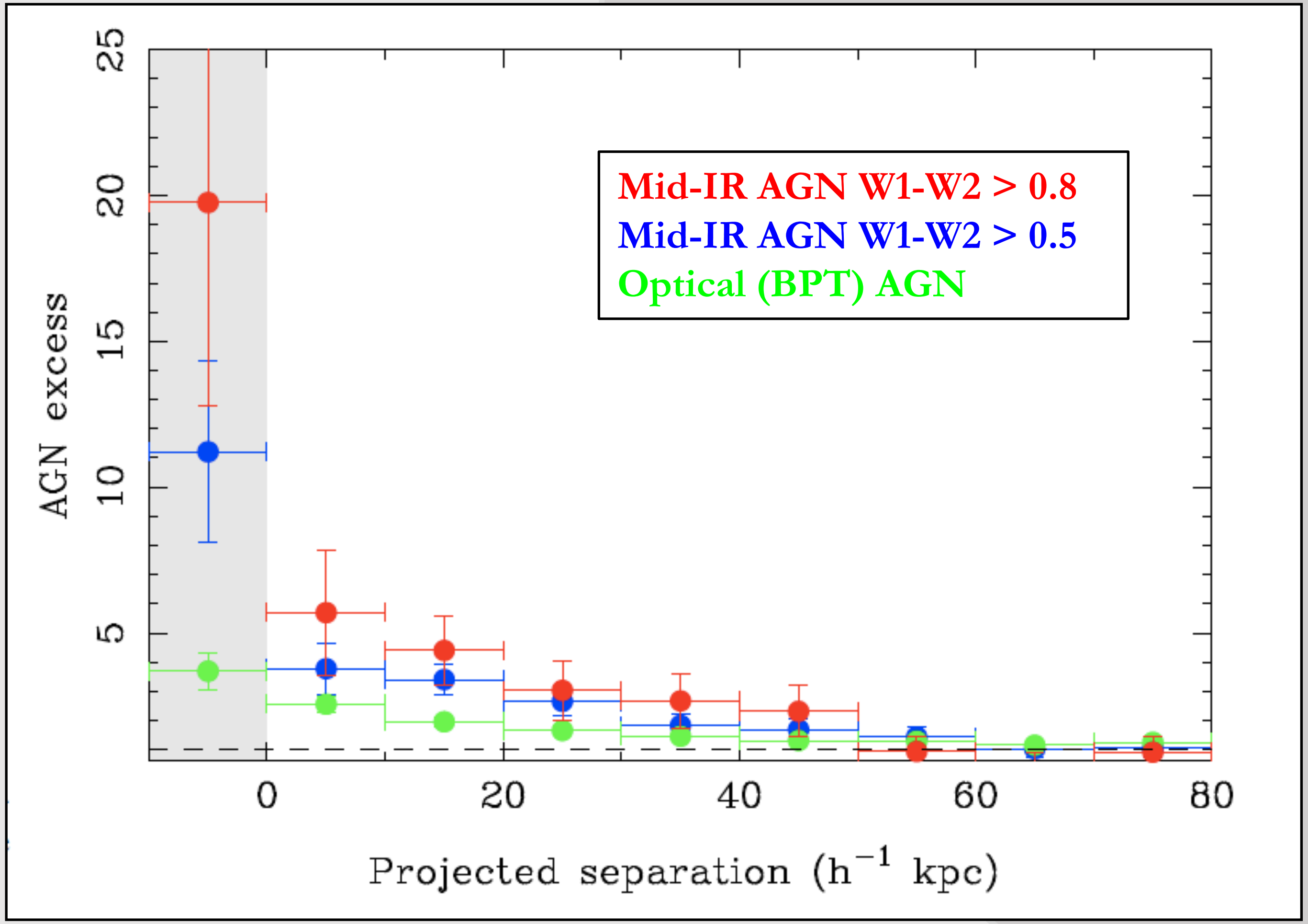
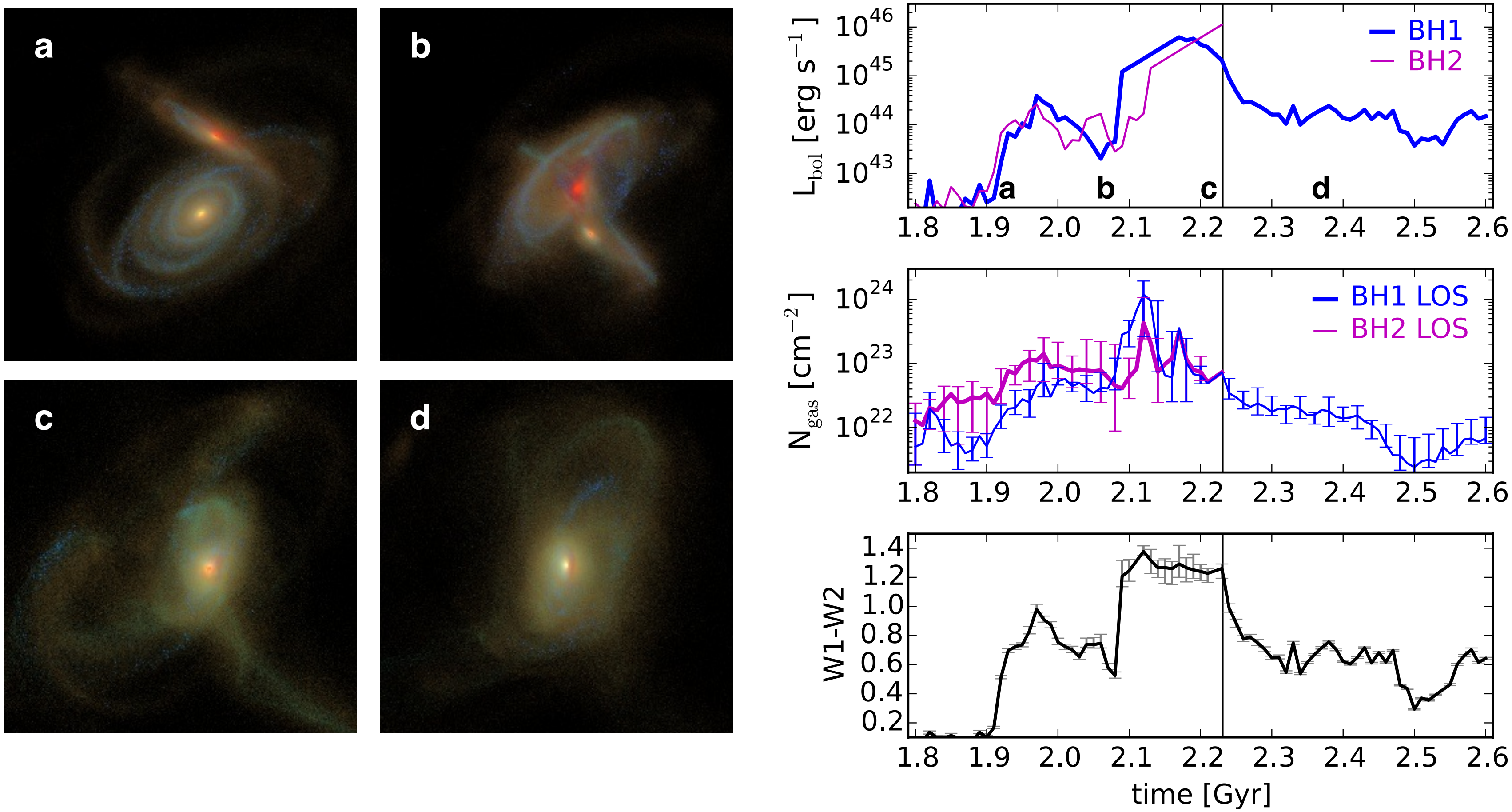
But there are many papers which argue against the importance of mergers, too.

Excess of Obscured AGNs at Small Pair Separations



Satyapal et al. (2014)

SIMULATIONS PREDICT HIGH N_H



(Blecha et al. 2018)

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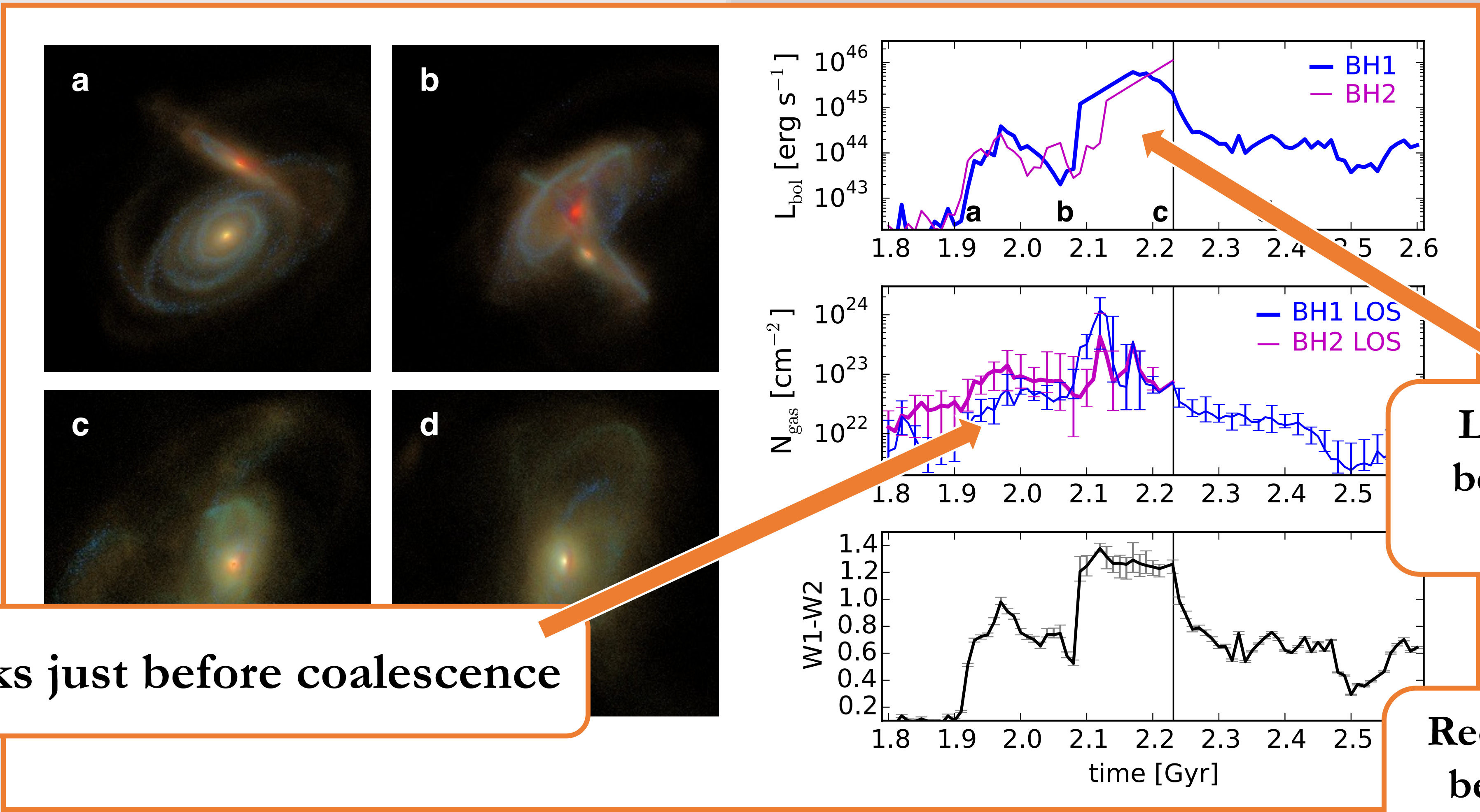

L_{bol} peaks just before/right at coalescence

N_H peaks just before coalescence

Red WISE colors before/right at coalescence

(Blecha et al. 2018)

Consistent with evidence that peak BH growth obscured

Goal of this work:

Study IR-preselected mergers to quantify incidence of obscured (dual) AGNs triggered by interactions.

Quantify levels of obscuration in late stage (dual AGN phase) mergers.

↓

***Wide Field Infrared Survey Explorer* (*WISE*)**

+ *Chandra* + LBT NIR Ground-based Spectroscopy

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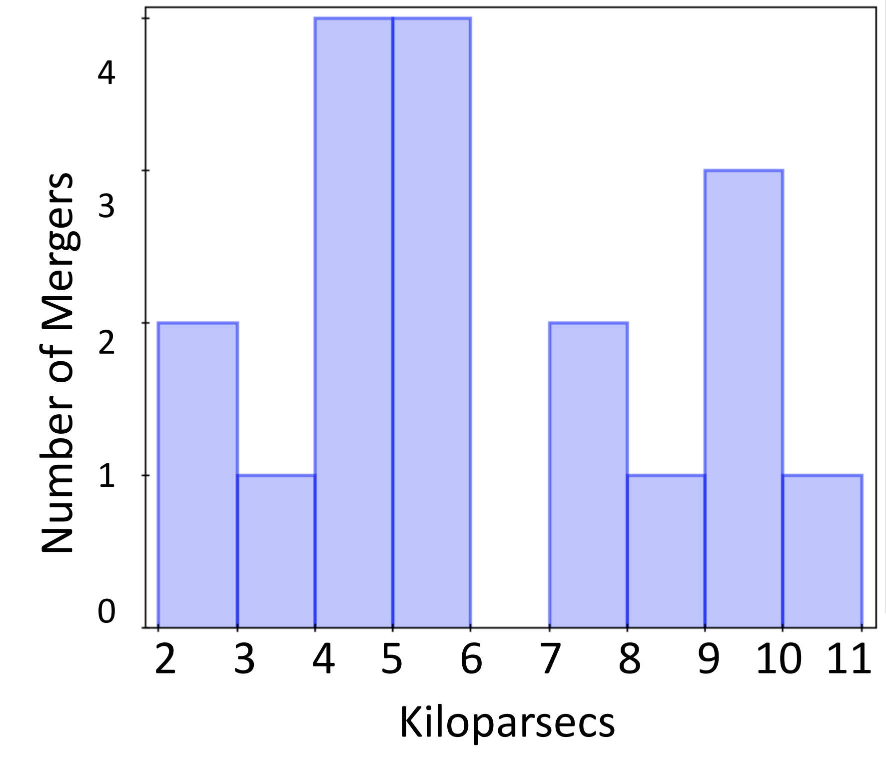
Dual Candidates Sample Selection

- Drawn from Galaxy Zoo (667,000 galaxies)
- Applied merger probability cut
- Pair separations $\lesssim$ 10 kpc
- W1-W2 > 0.5
- Most *optically normal*
- 15 brightest candidates followed up with Chandra and LBT



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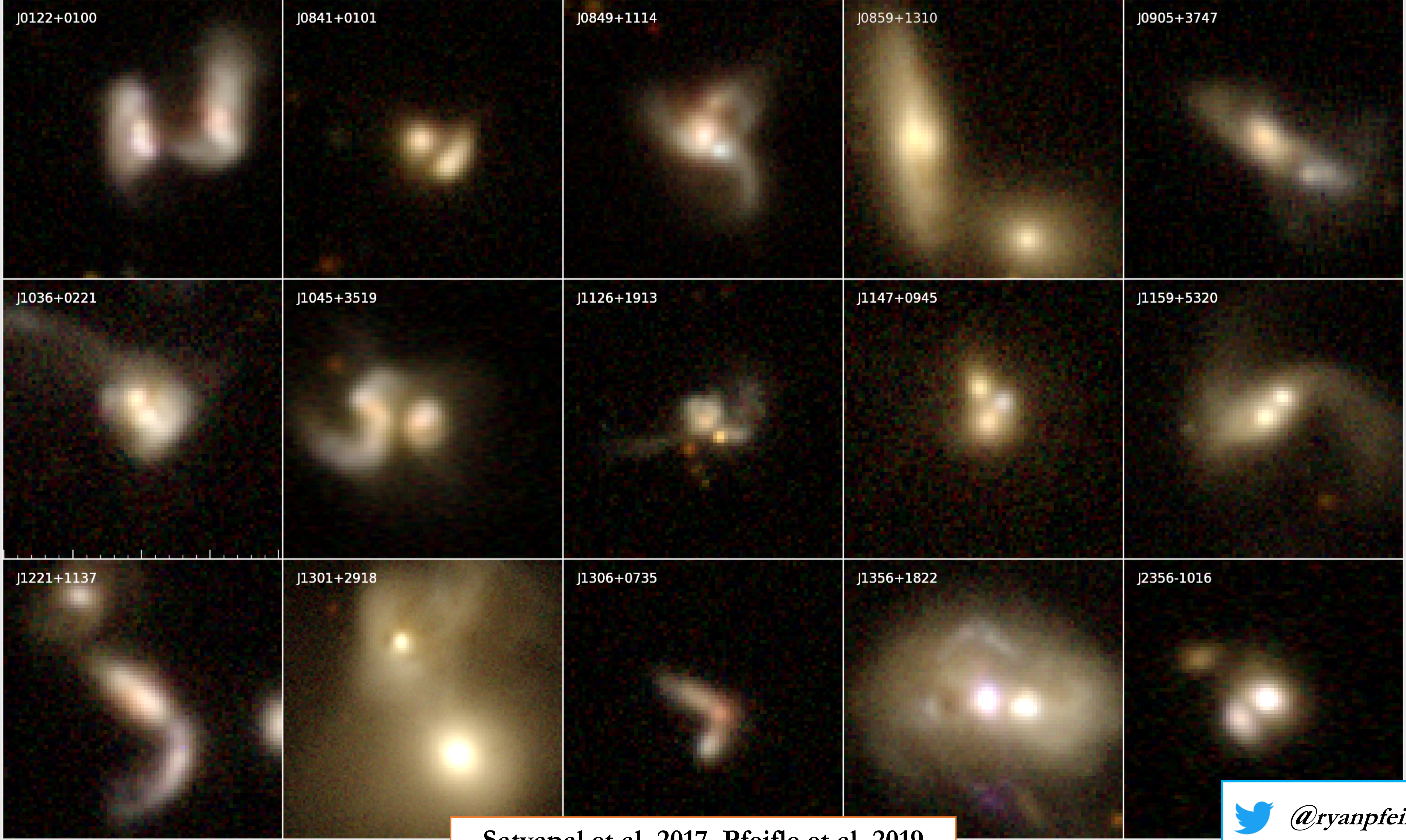

Satyapal et al. 2017, Pfeifle et al. 2019

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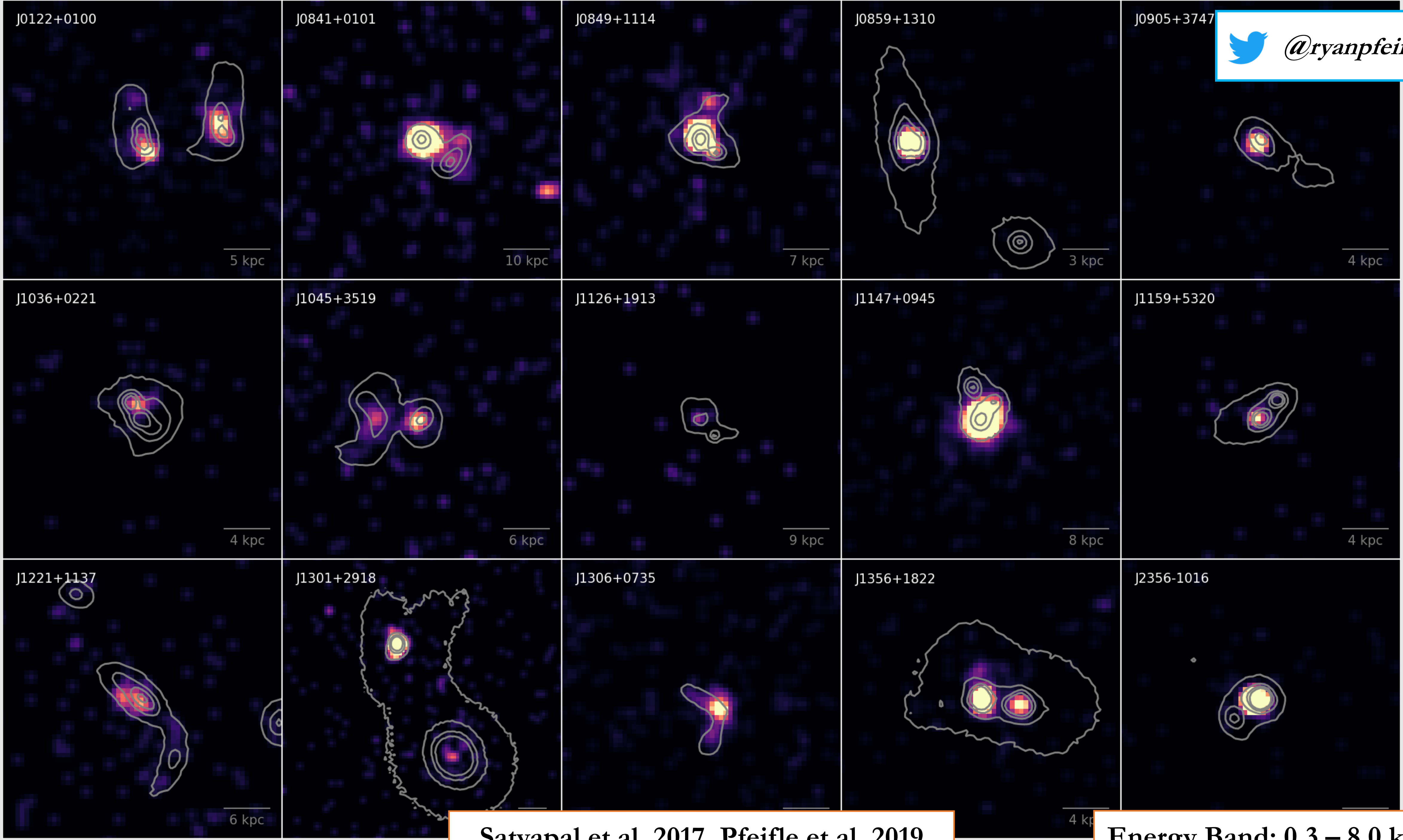

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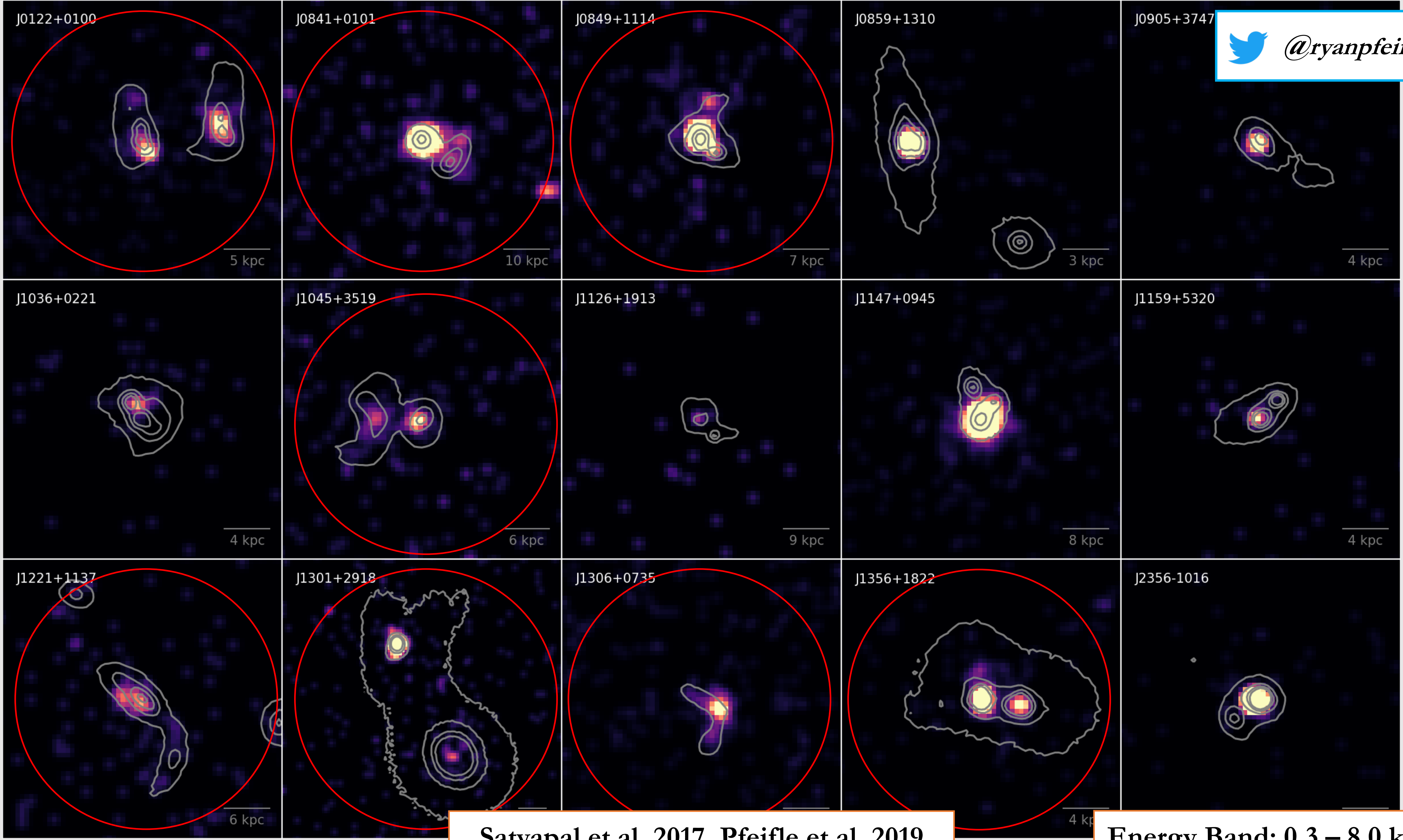
Satyapal et al. 2017, Pfeifle et al. 2019

Energy Band: 0.3 – 8.0 keV



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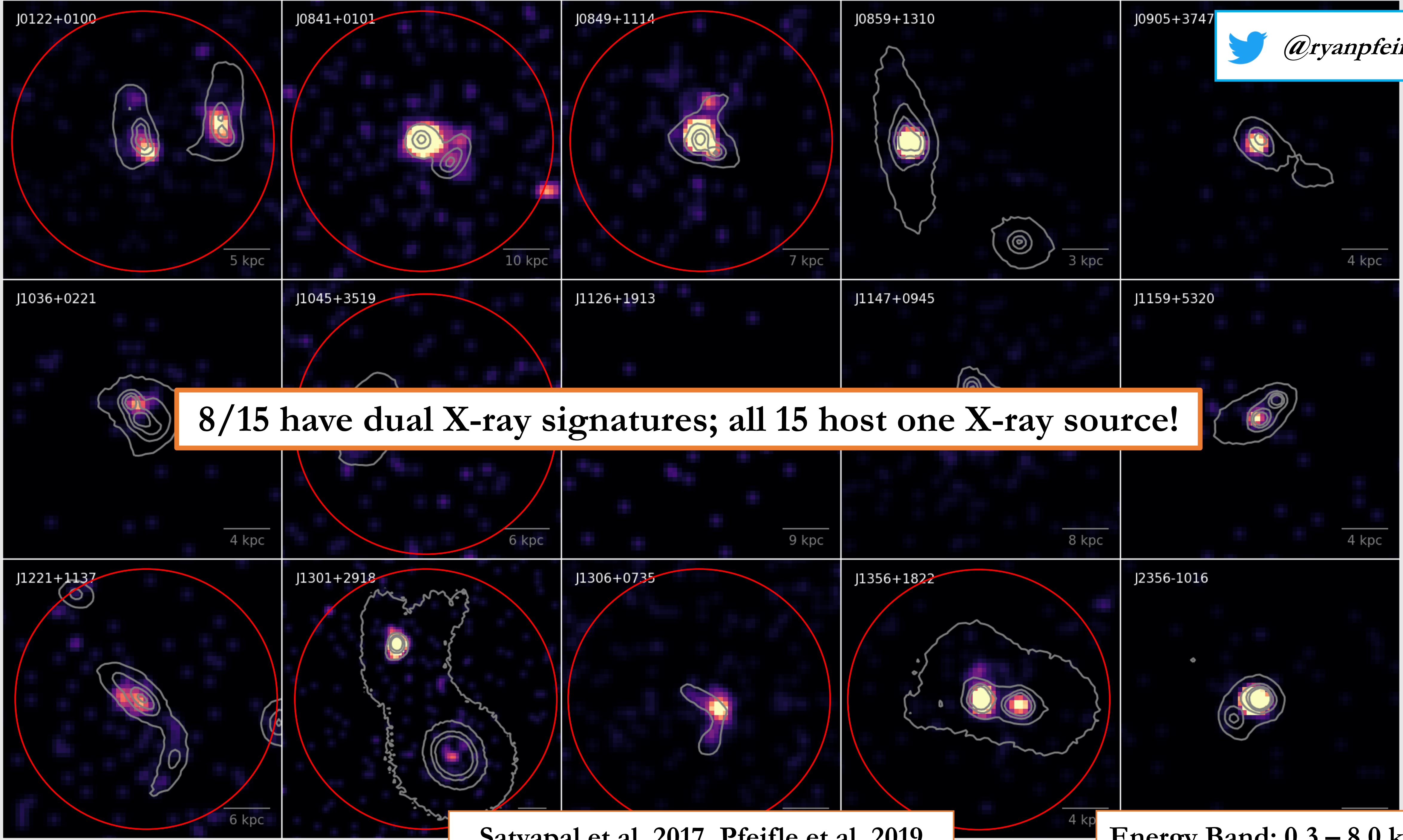

8/15 have dual X-ray signatures; all 15 host one X-ray source!

Satyapal et al. 2017, Pfeifle et al. 2019

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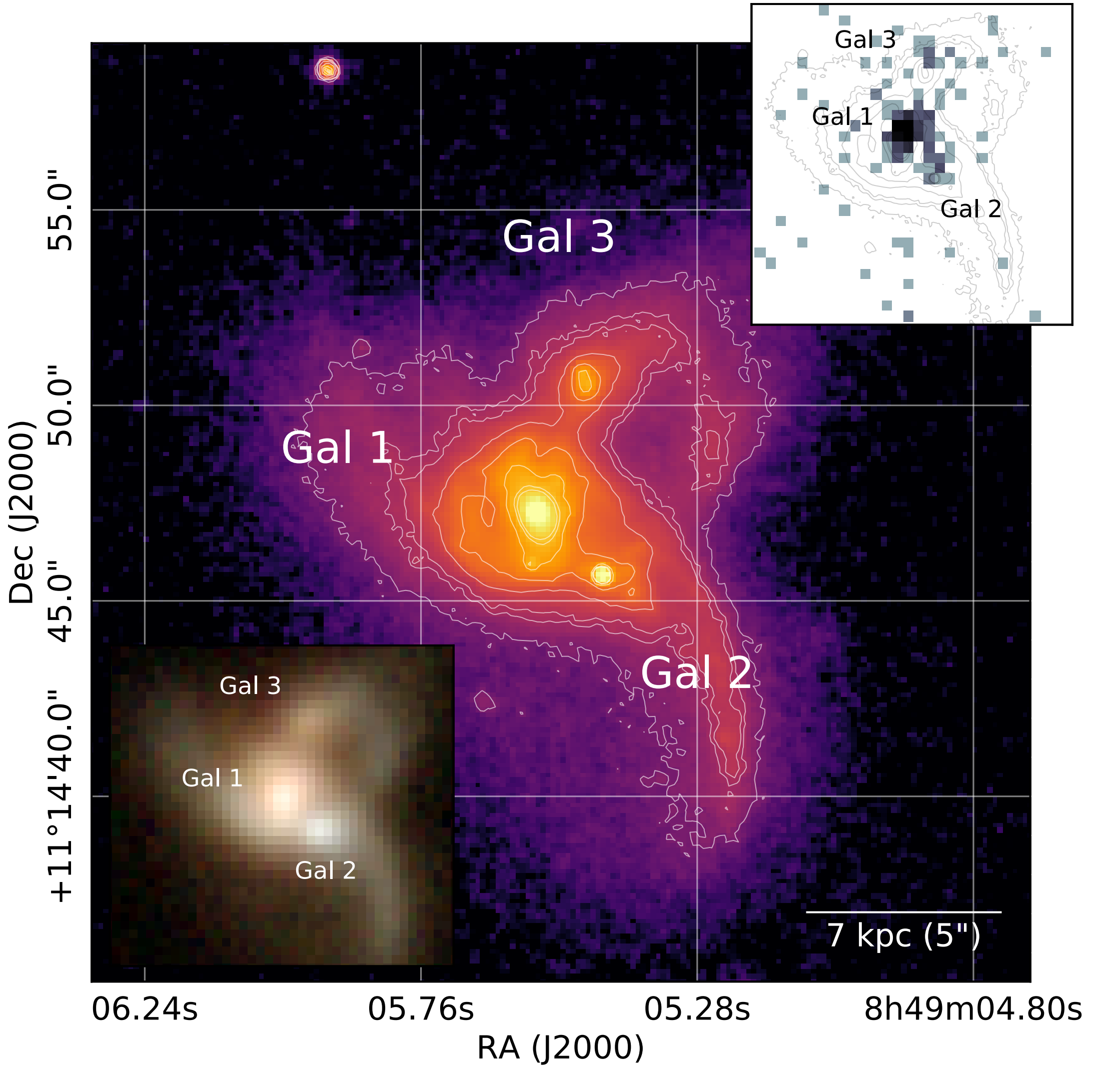
Case Study: SDSSJ0849+1114 - An AGN Triplet



Pfeifle et al. 2019b, [1908.01732]

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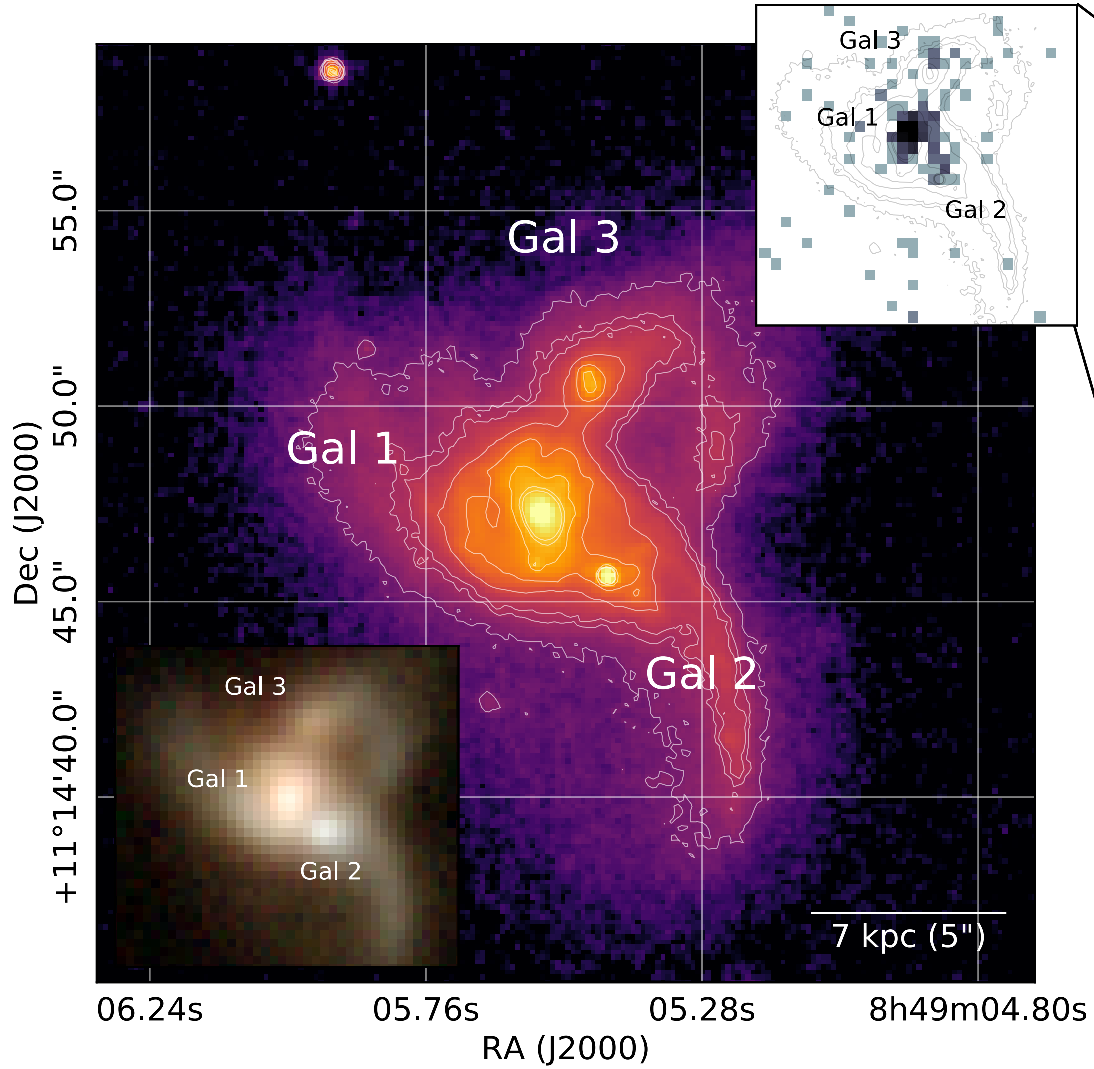
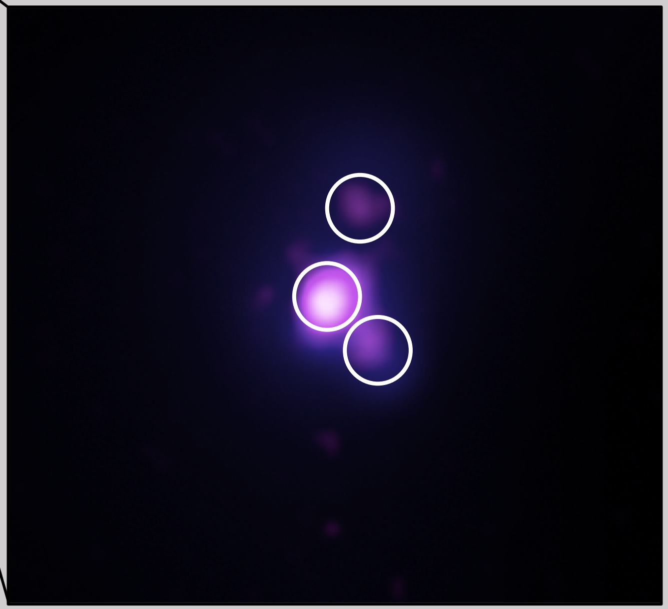


Pfeifle et al. 2019b



Chandra revealed three nuclear X-ray sources indicative of AGNs

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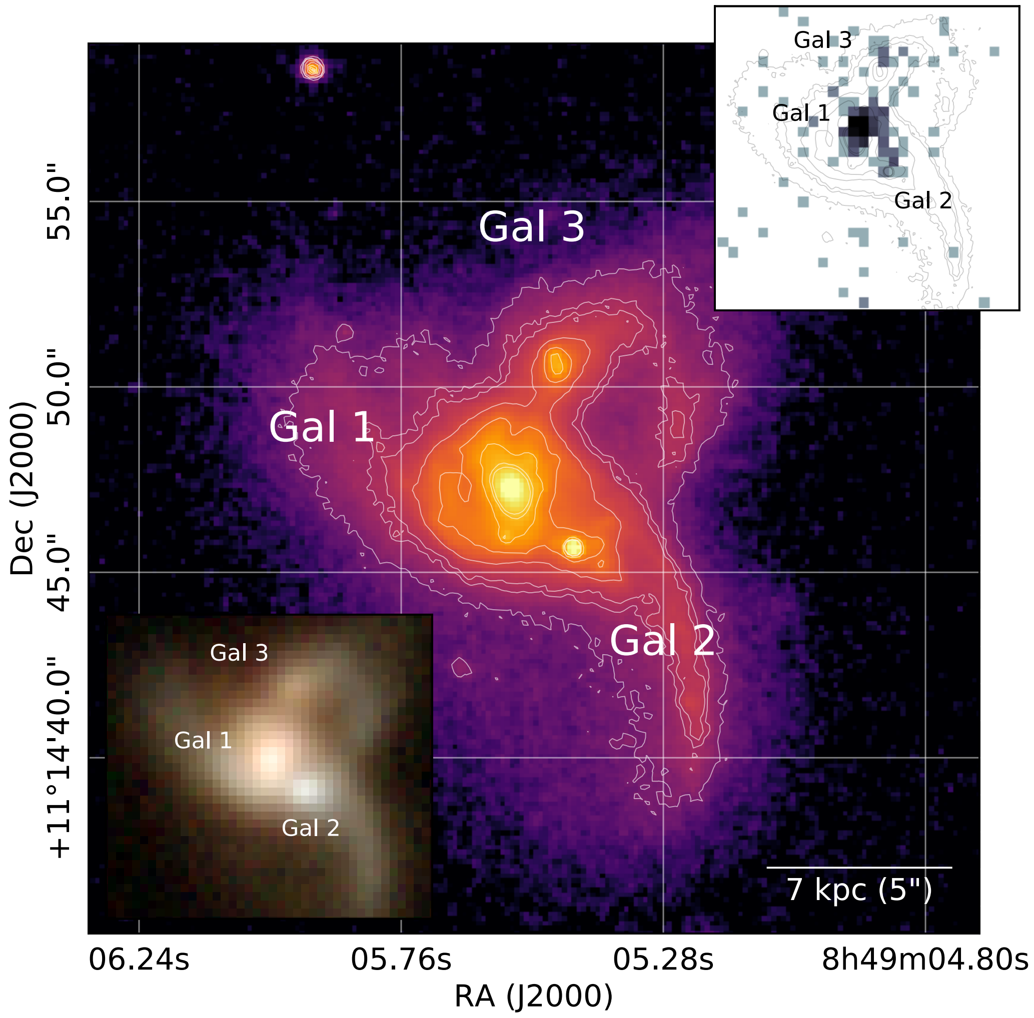
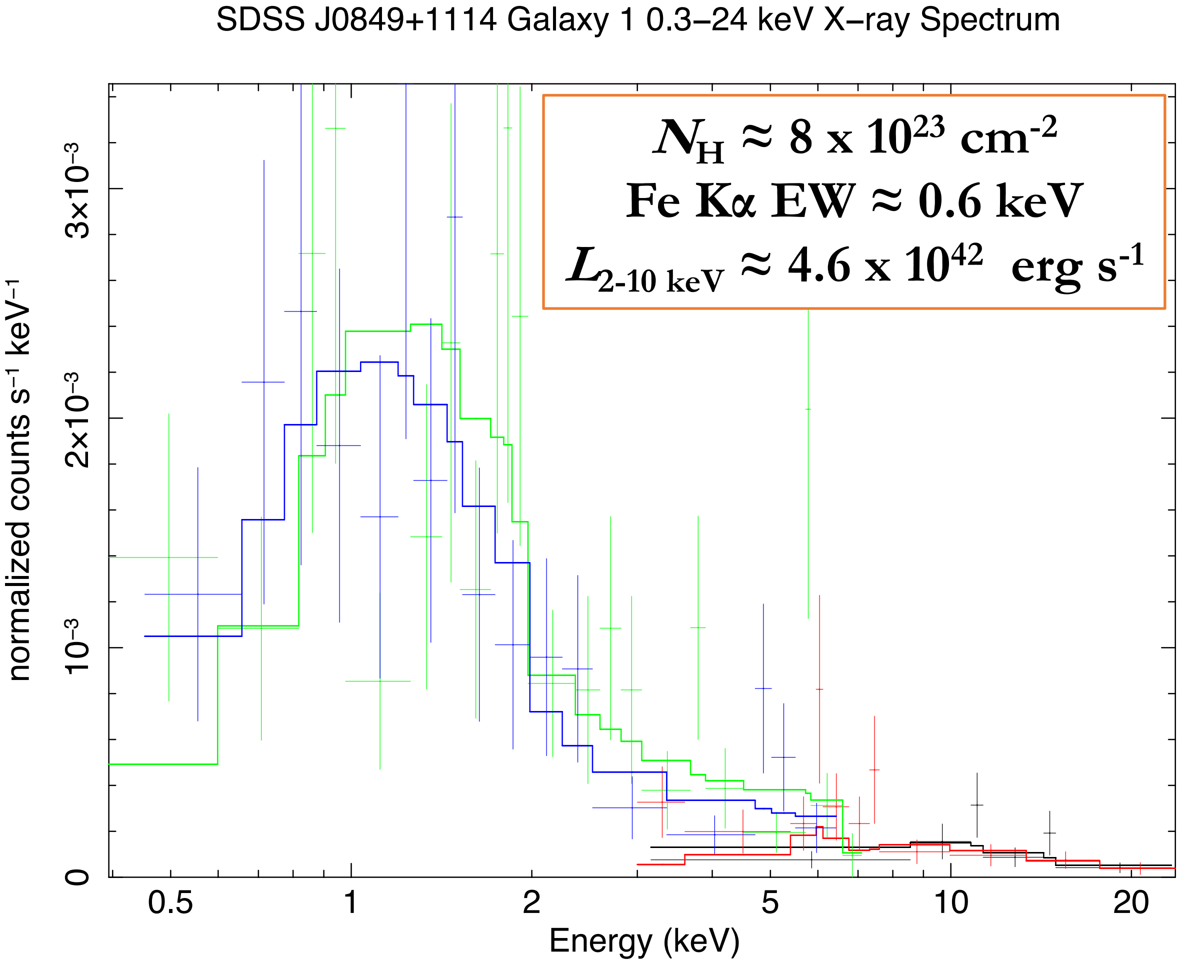
NuSTAR + Chandra Reveal High Absorbing Column



Pfeifle et al. 2019; Pfeifle et al. 2019b



$N_H \approx 8 \times 10^{23}$ cm^{-2}

Fe Kα EW $\approx$ 0.6 keV

$L_{2\text{-}10\ \mathrm{keV}} \approx 4.6 \times 10^{42}$ erg s^{-1}

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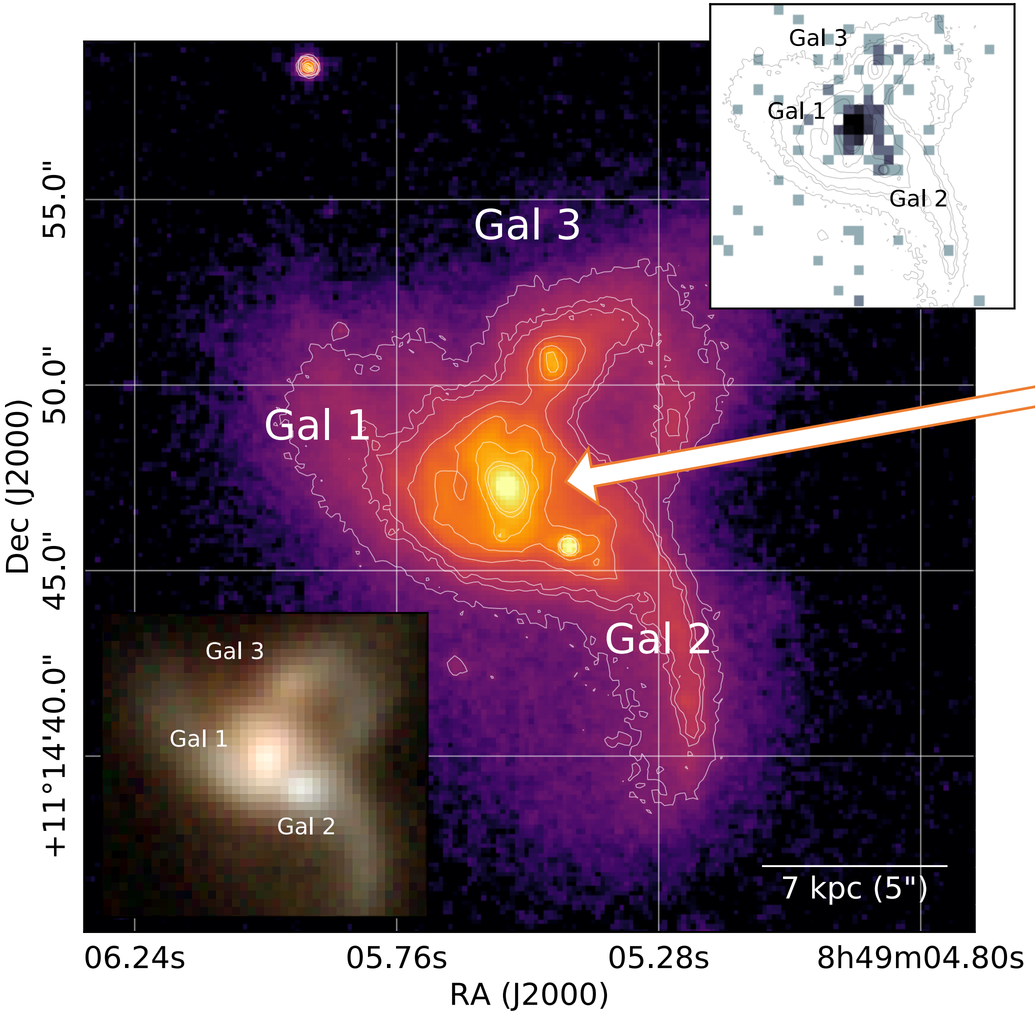
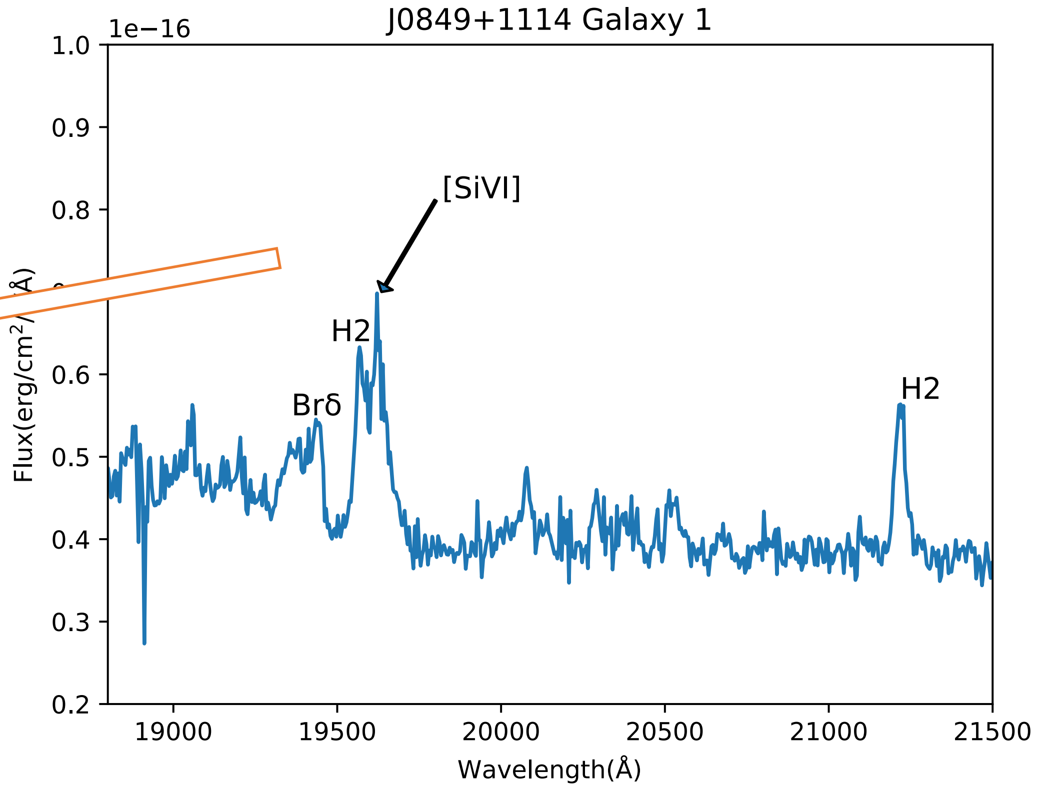
LBT Reveals [Si VI] Emission in Galaxy 1





Pfeifle et al. 2019; Pfeifle et al. 2019b

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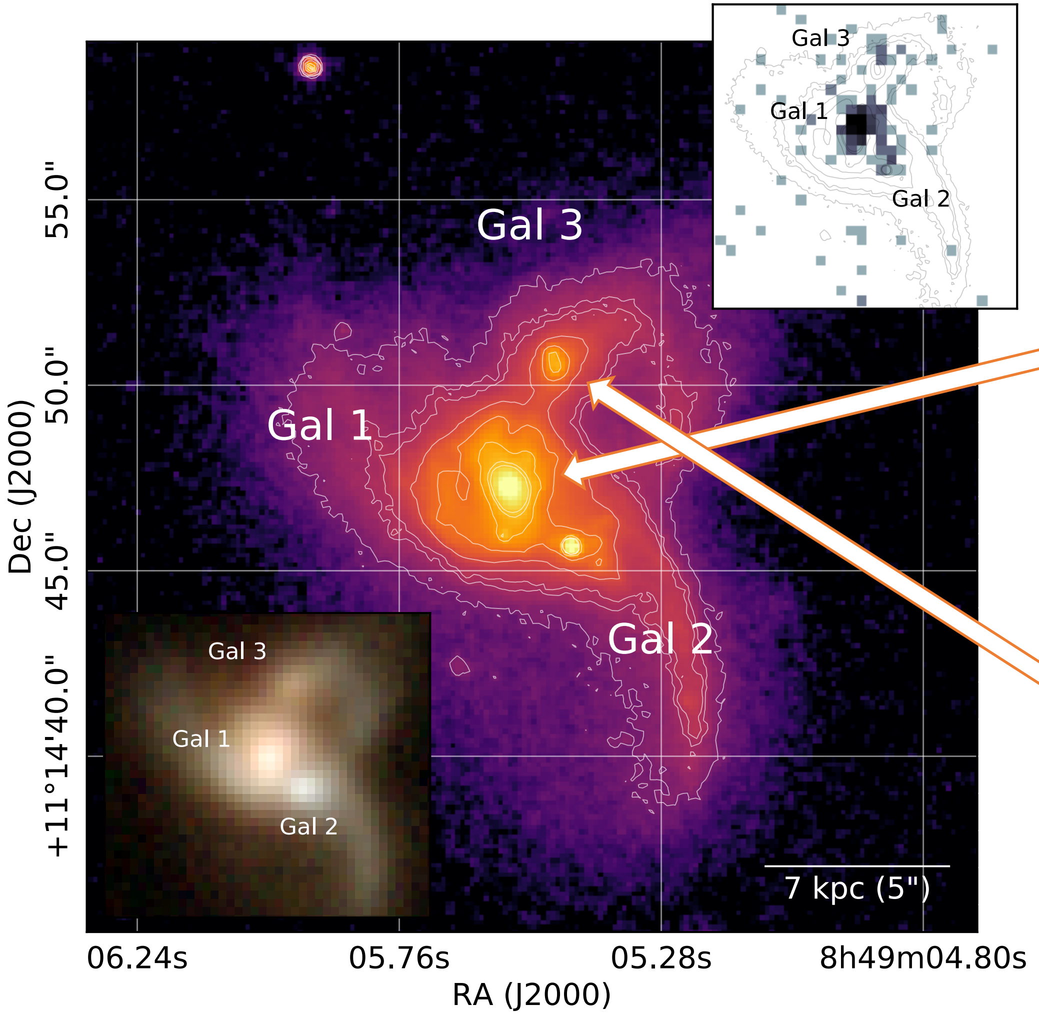
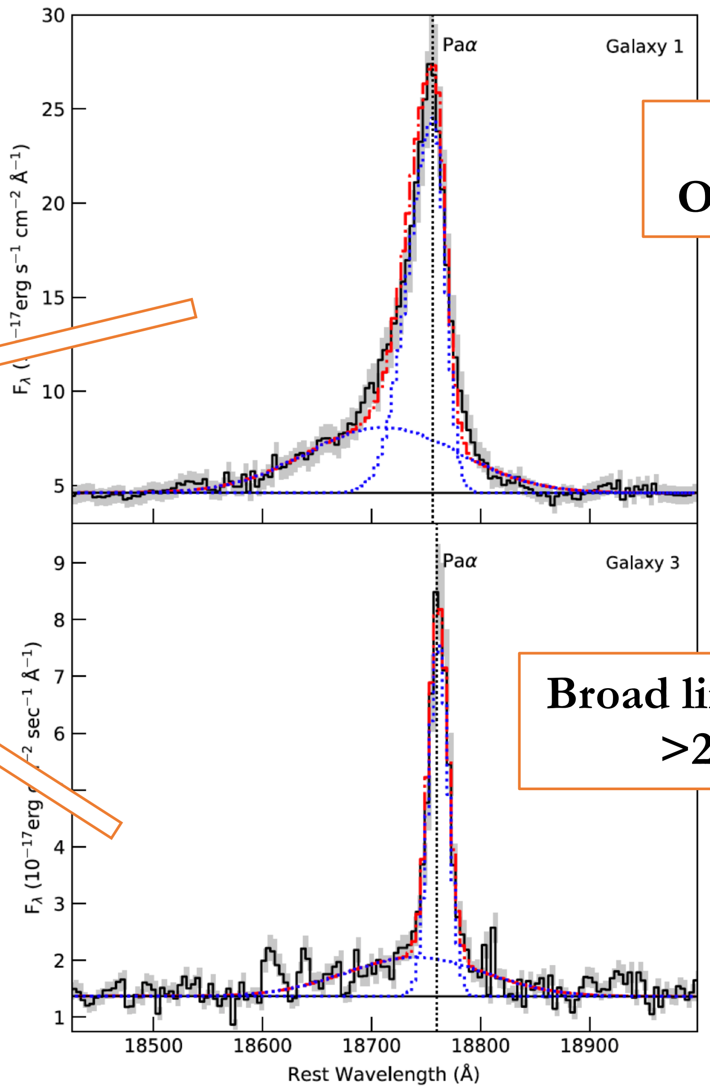
LBT: Broad Paα Emission Observed in Two Nuclei



Pfeifle et al. 2019b



(LBT NIR Observations)

Broad line components >2400 km/s

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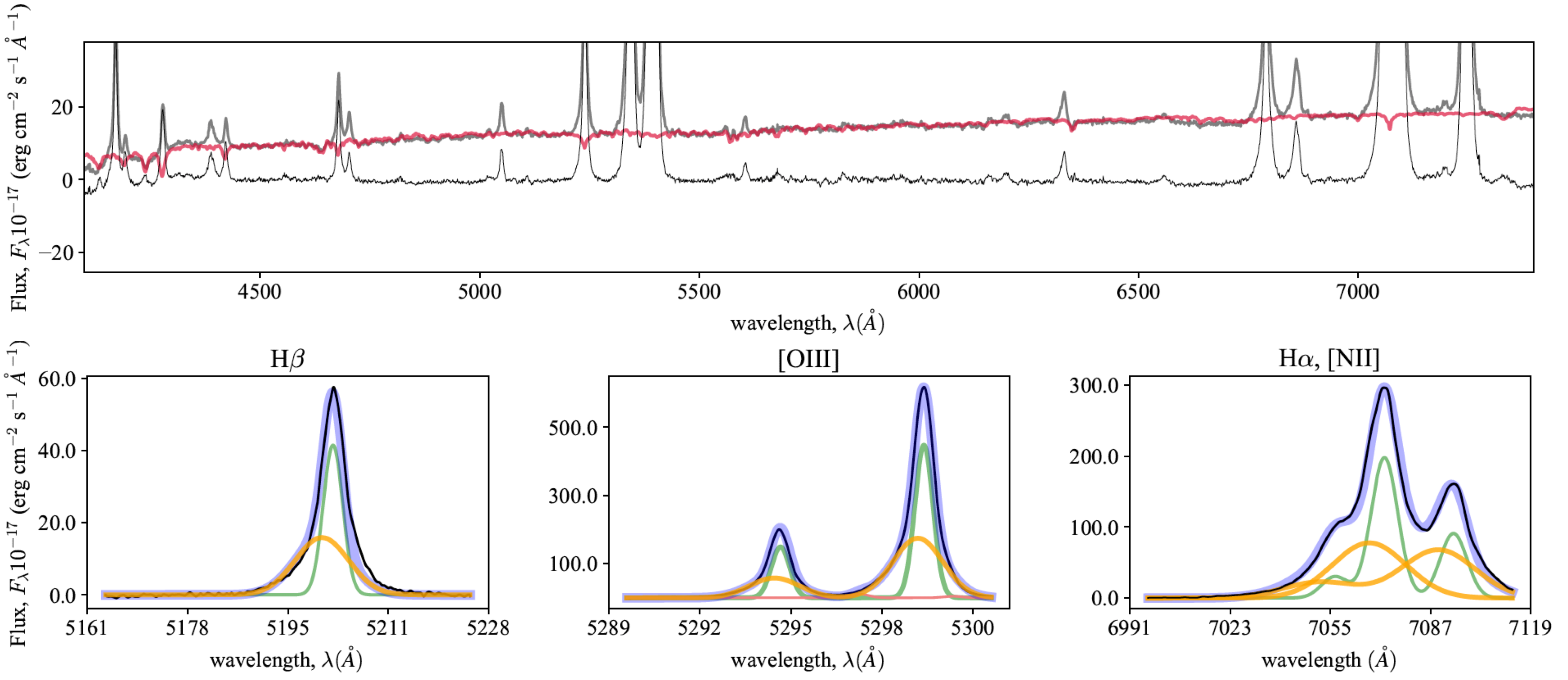
LBT+SDSS: Outflows Observed in the Optical Spectra



Pfeifle et al. 2019b

Outflow speeds of 1300-1600 km/s

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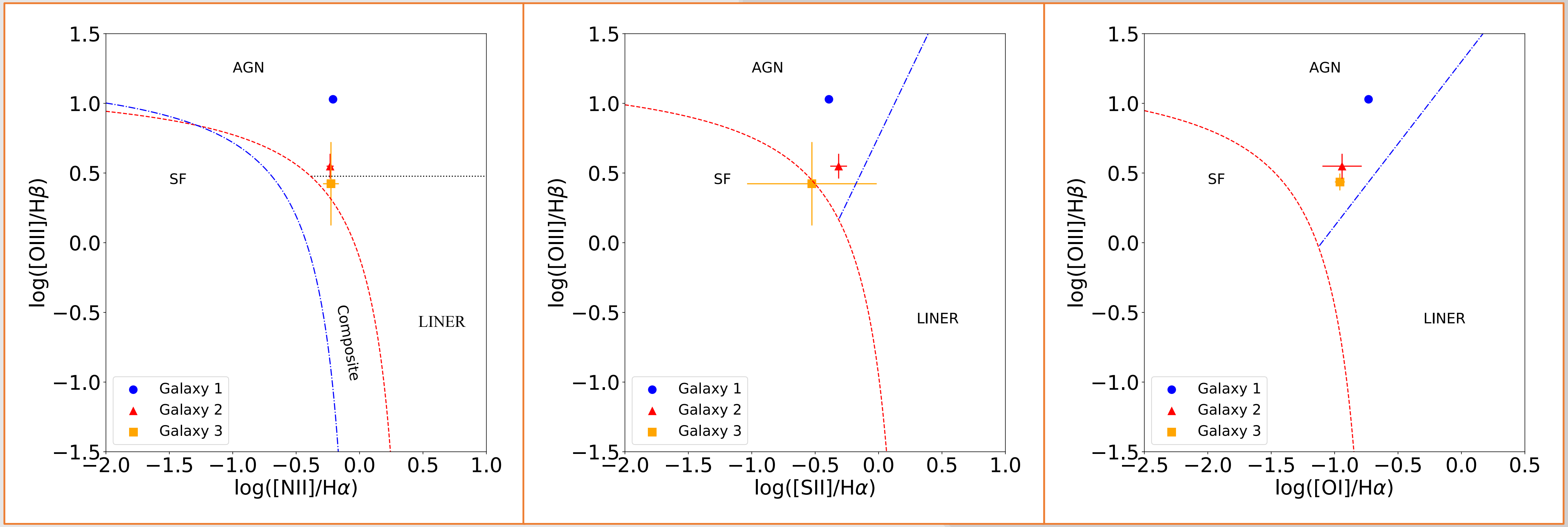
LBT Long Slit Spectra Reveal 3 BPT AGNs



Pfeifle et al. 2019b

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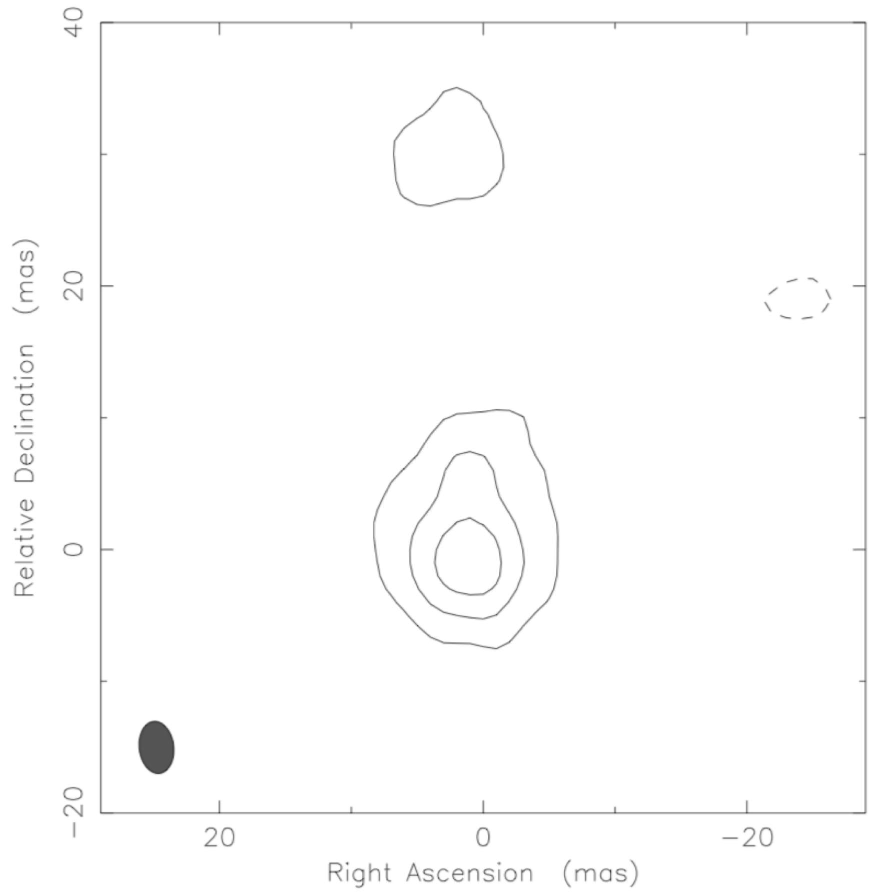
EVN Reveals One Compact Radio Source at 1.7 GHz



Gabanyi et al. 2019, [1909.03259]

- Radio source coincident with brightest AGN
- 1.7 GHz Flux Density: $S = 5.0 \pm 0.1$ mJy
- Brightness Temperature: $T_B = 3.3E{+}7$ K

  → Radio Power ($\alpha = 0$) = 6.7E+22 W Hz^{-1}

  → Emission must be AGN in origin

- From the fundamental plane:

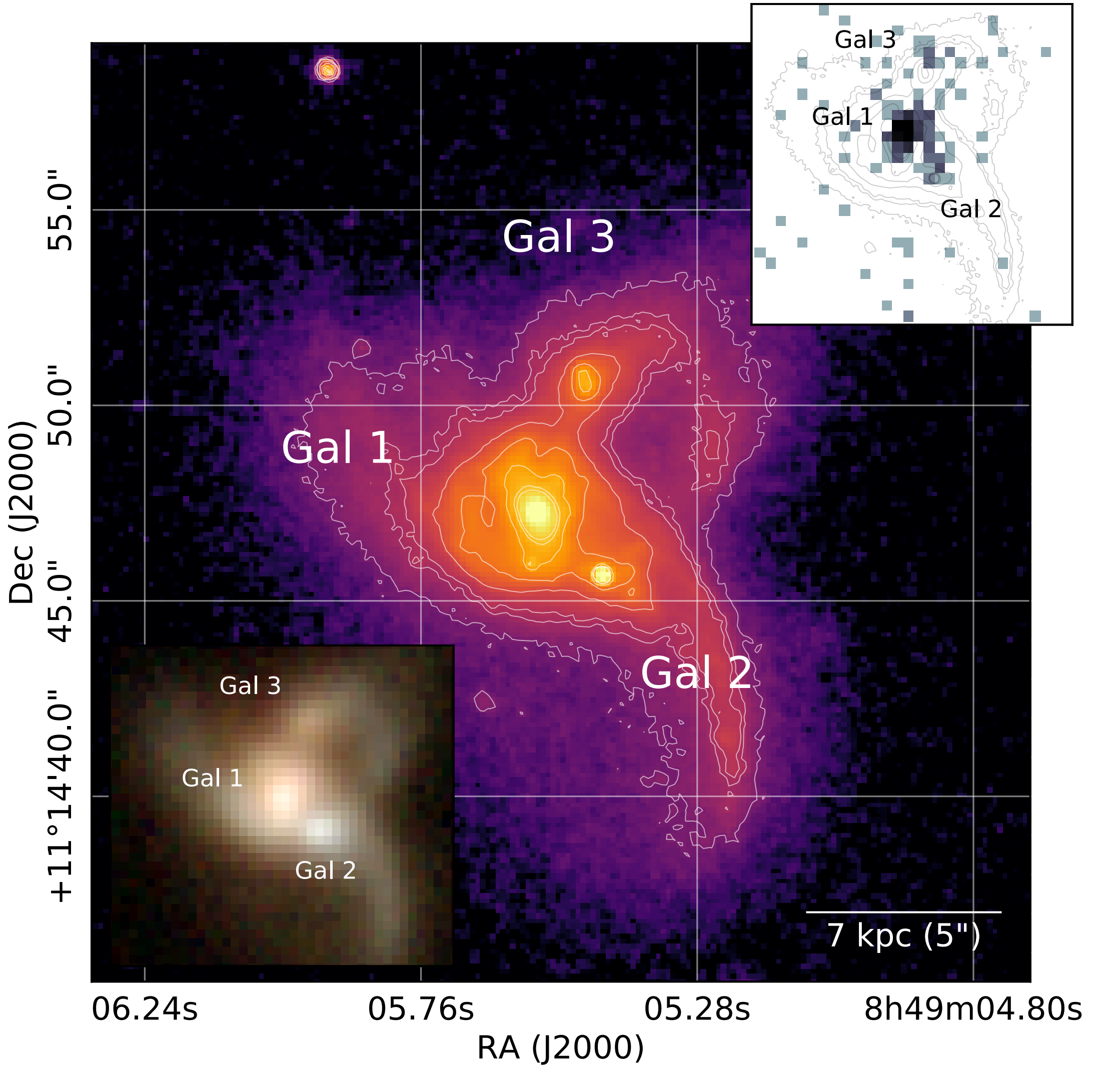
  $M_{BH} \sim 0.46 – 2.9 \times 10^9\ M_\odot$

  (depending upon whether $\alpha = -0.7$ or $\alpha = 0.1$)

SDSSJ0849+1114 - An AGN Triplet

<u>NIR Spectroscopy:</u>
- NIR High Excitation Line
- Optically Hidden Broad Lines

<u>Optical Spectroscopy:</u>
- 3 BPT AGN
- Outflow Signatures in Optical Spectra



Pfeifle et al. 2019b, [1908.01732]

<u>X-rays:</u>
- Three nuclear X-ray sources
- High Obscuring Columns

<u>Radio:</u>
- 1 compact source detected at 1.7 GHz

See also Liu et al. (ApJ, in press) [1907.10639].

See also poster #81 (M. Hou)

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Conclusions

- WISE pre-selection offers efficient method of detecting AGN w/in late-stage mergers.
  - Selects AGN missed by optical studies
  - Selects dual (and higher order) AGN systems

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- AGN in advanced mergers are heavily absorbed and obscured.
  - Consistent with previous observational and theoretical studies

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Thank you for your attention!
I would be happy to take questions.

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Extra Slides

The AGN-Merger Debate

- Dahari et al. 1984
- Keel et al 1985
- Raffanelli et al 1995
- Canalizo & Stockton 2001
- Woods & Geller 2007
- Bennert et al. 2008
- Rogers et al. 2009
- Veilleux et al. 2009
- Koss et al 2010, 2012
- Ramos-Almeida et al. 2011
- Silverman et al. 2011
- Ellison et al. 2011
- Triester et al. 2012
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- Glikman et al. 2015
- Fan et al. 2016
- Ricci et al. 2017
- Goulding et al. 2017
- Donley et al. 2018

Still a controversial topic!

- Schmitt 2001
- Dunlop et al. 2003
- Grogin et al 2005
- Coldwell & Lambas 2006
- Pierce et al. 2007
- Li et al. 2006, 2008
- Ellison et al. 2008
- Darg et al. 2009
- Gabor et al 2009
- Reichard et al. 2009
- Cisternas et al 2011
- Boehm et al. 2012
- Kocevski et al 2011,2012
- Simmons et al. 2012
- Villforth et al. 2014,2017
- Schawinski et al. 2011
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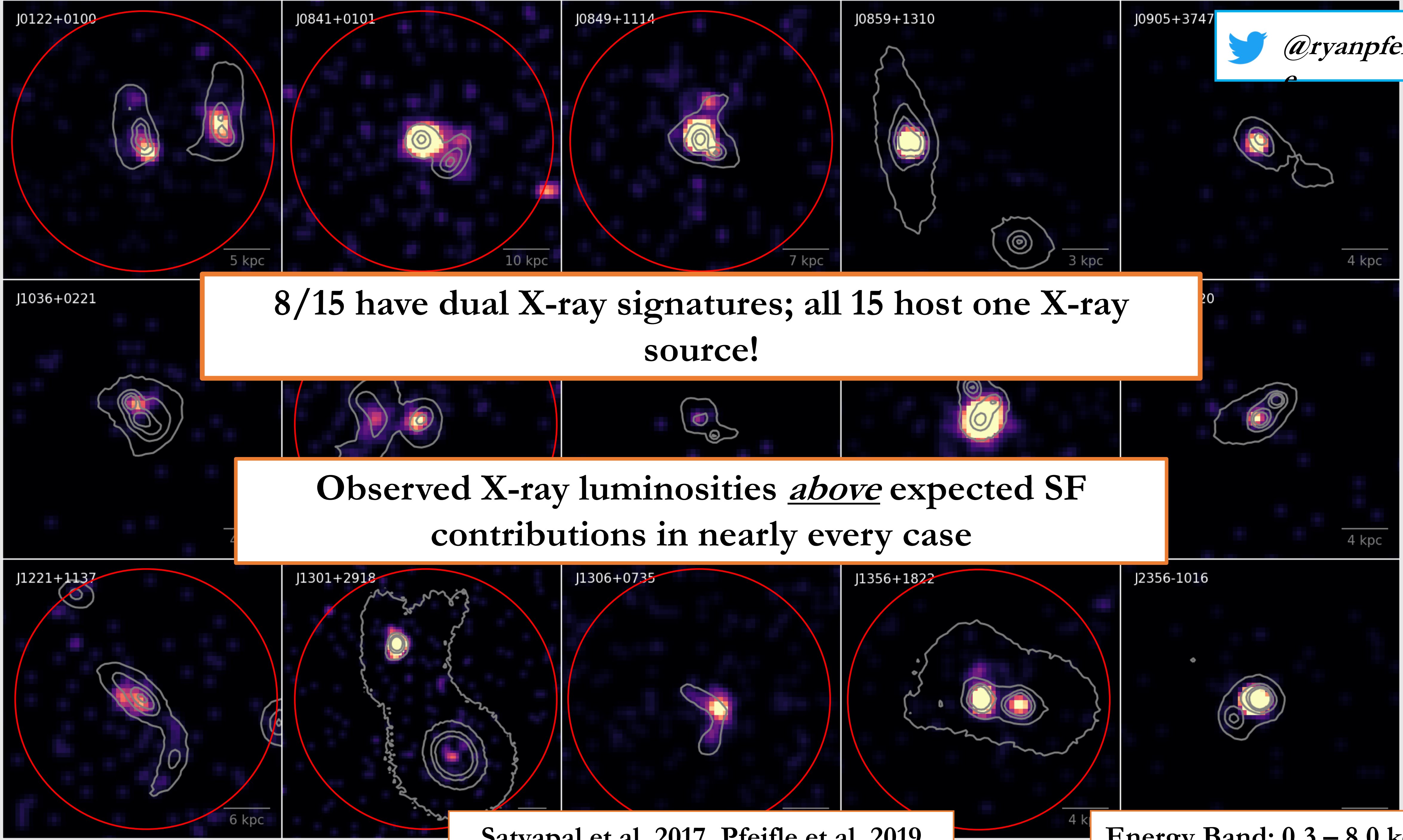
- Rosario et al. 2015
- Bruce et al. 2016
- Mechtley et al. 2016
- Hewlett et al. 2017



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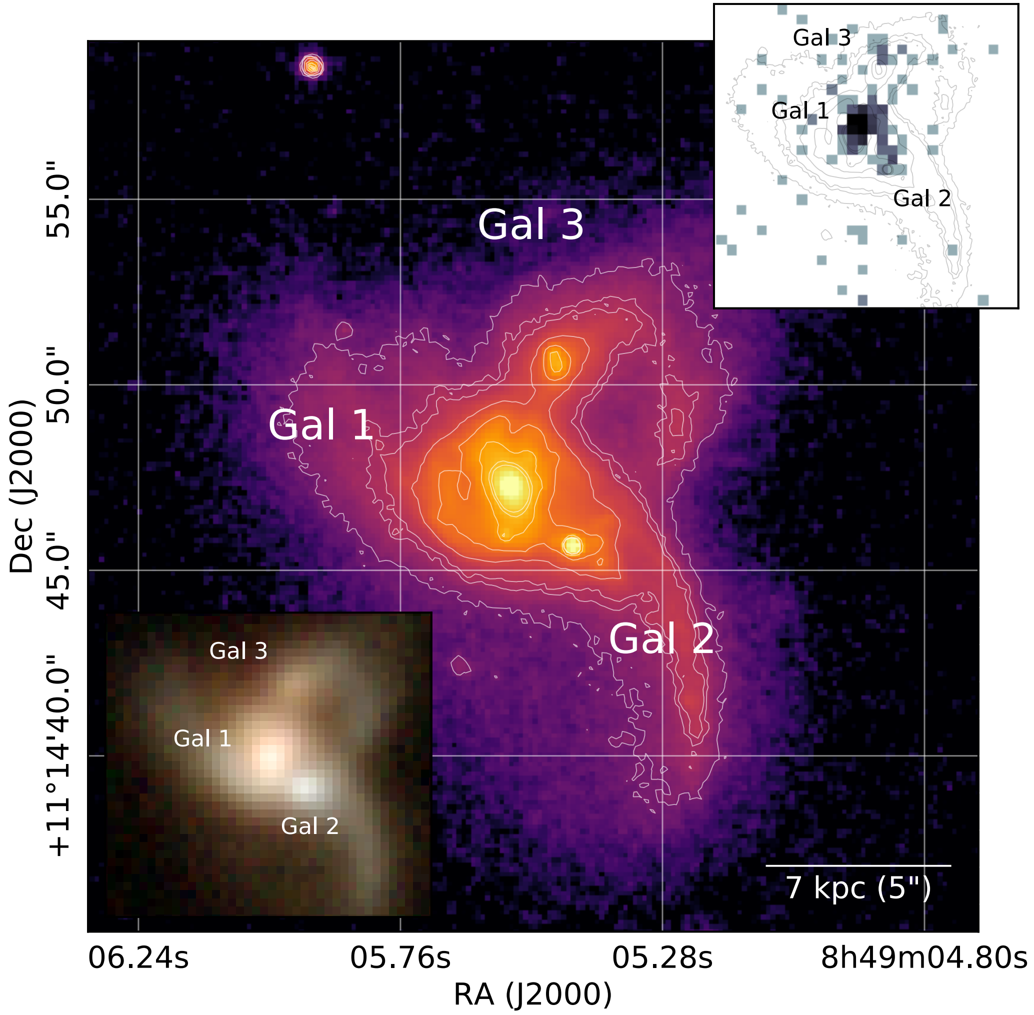
8/15 have dual X-ray signatures; all 15 host one X-ray source!

Observed X-ray luminosities *__above__* expected SF contributions in nearly every case

Satyapal et al. 2017, Pfeifle et al. 2019

Energy Band: 0.3 – 8.0 keV

SDSSJ0849+1115 - An AGN Triplet



Pfeifle et al. 2019; Pfeifle et al. 2019b

Summary:

- **3 nuclear X-ray sources**
    - Luminosities > expected SF contribution
- **[SiVI] near-IR coronal line** detected in Gal 1
- **3** optical BPT AGN signatures
- NuSTAR + Chandra reveal **high obscuring columns**

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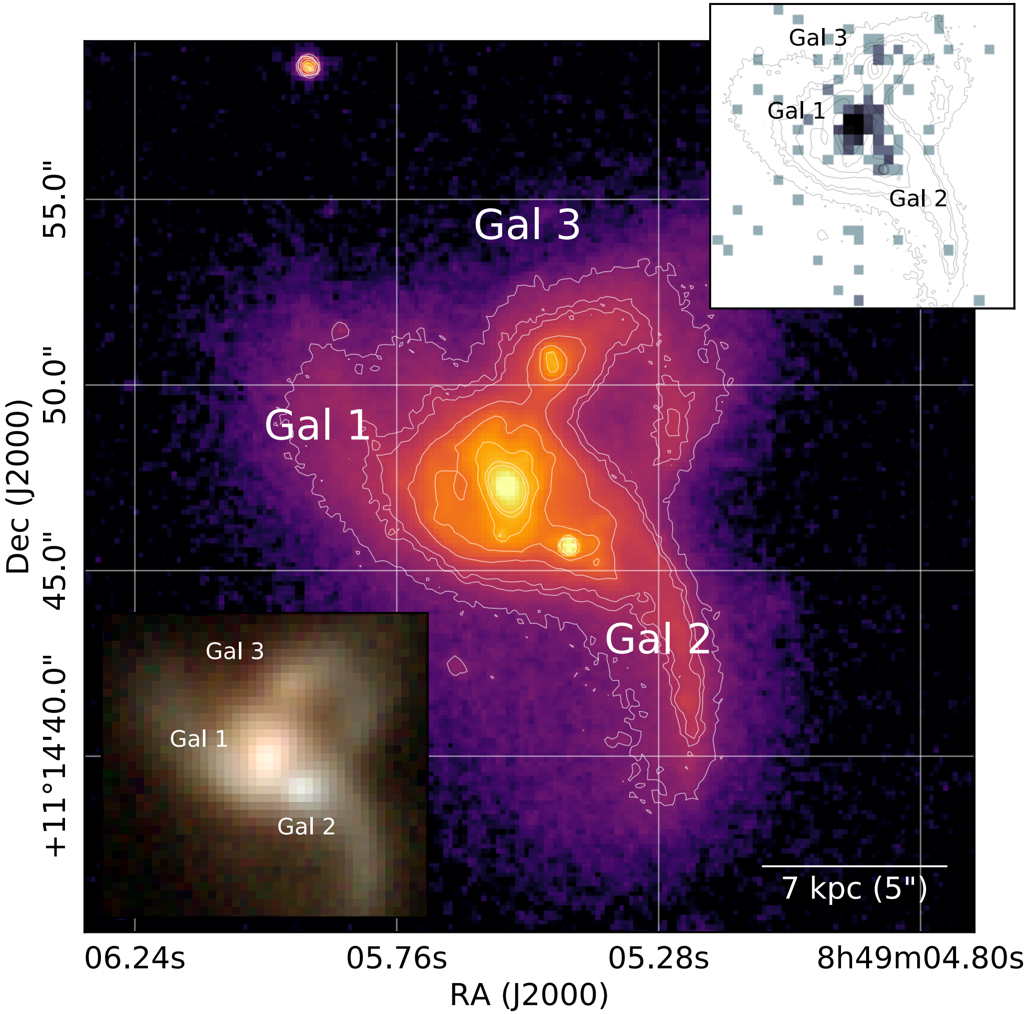

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Eliminating Alternative Scenarios:

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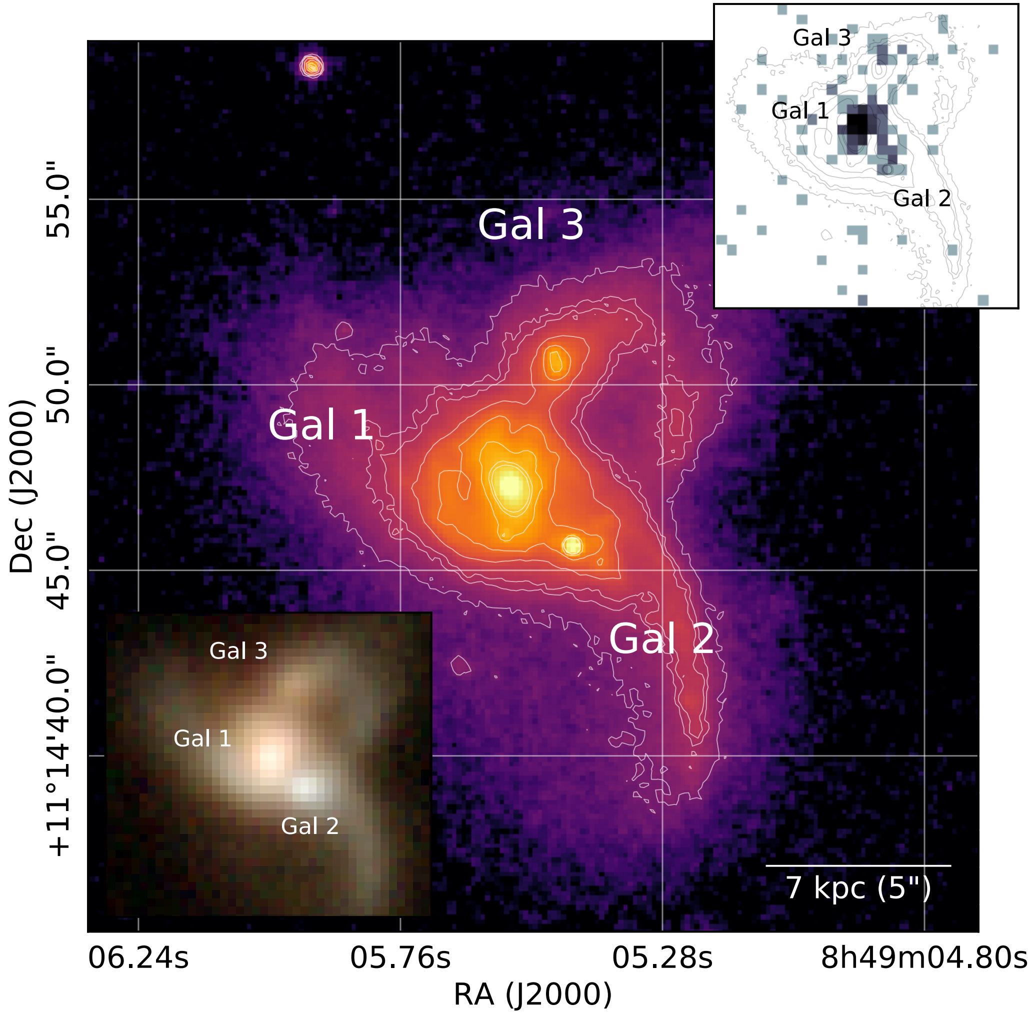

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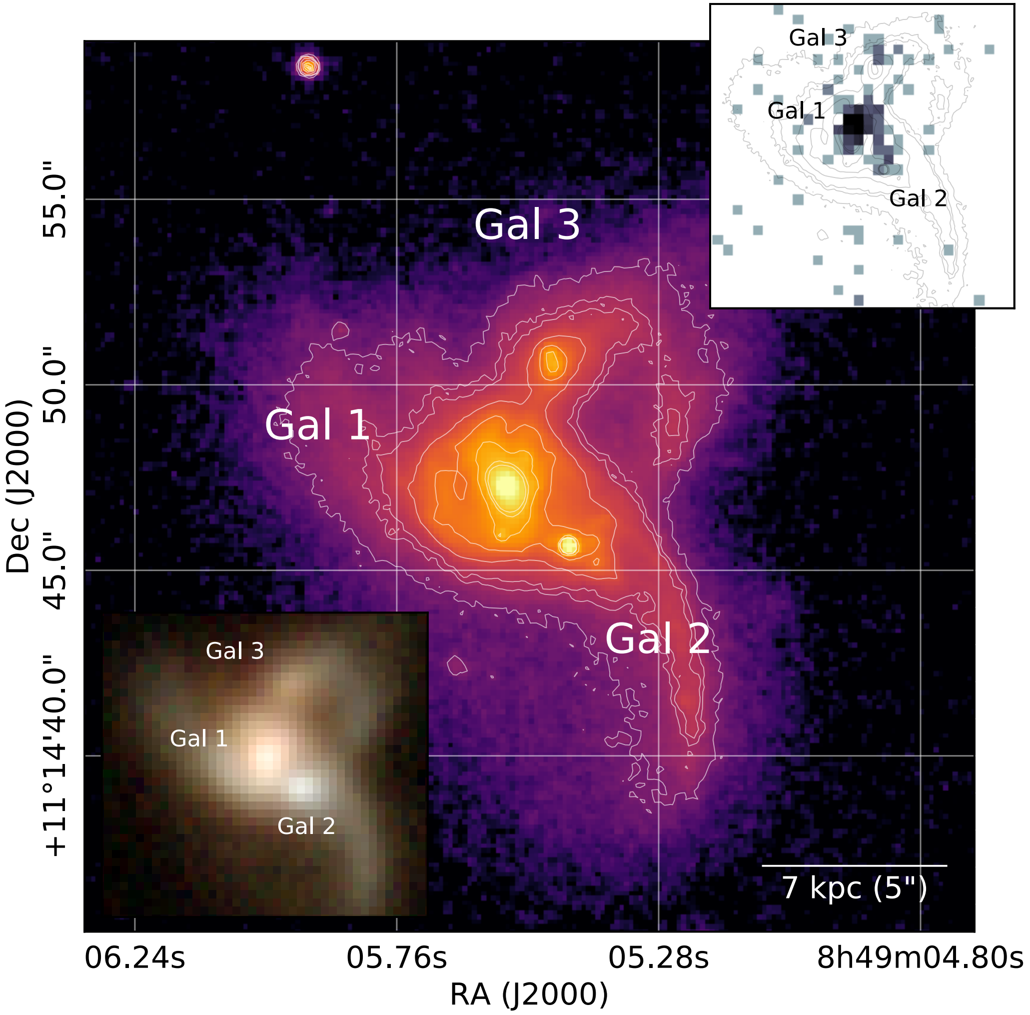

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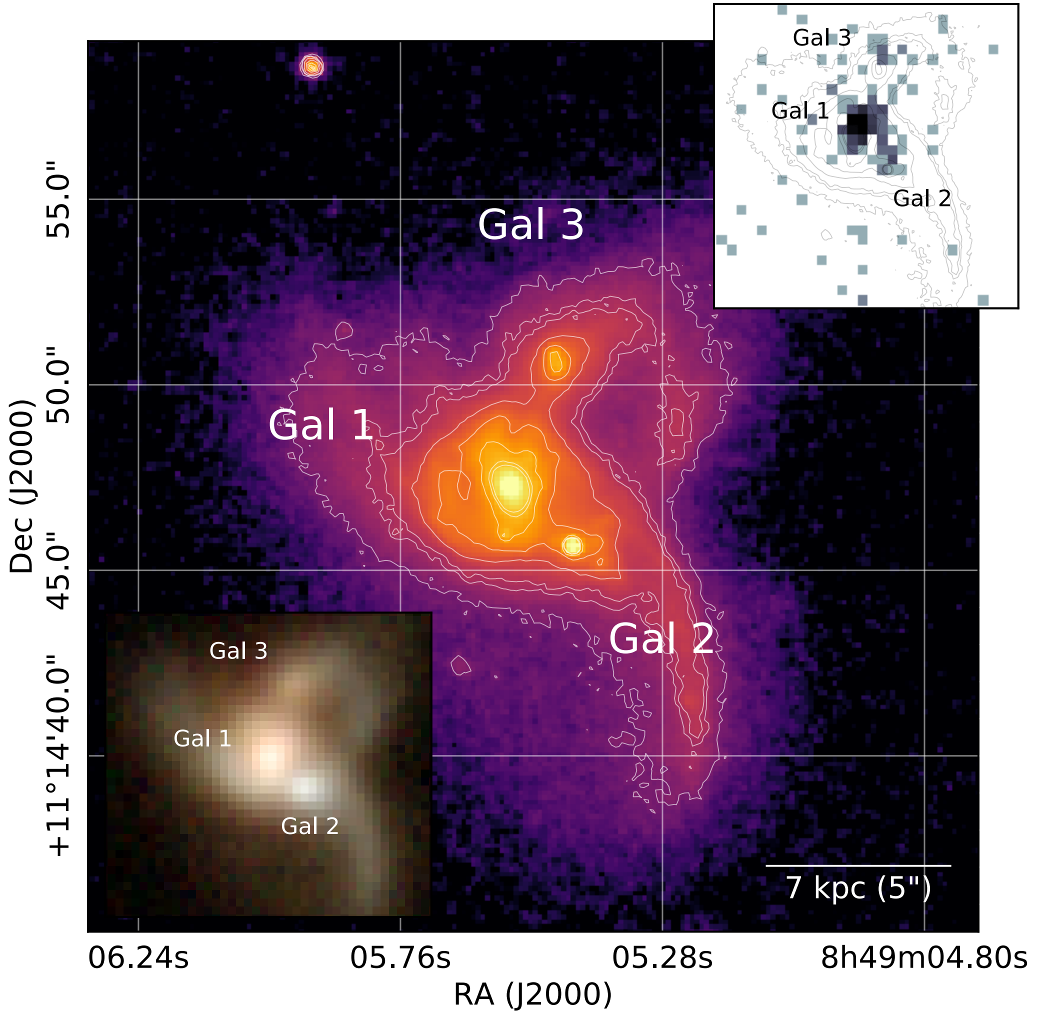

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- **Star formation:**
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- **Less than 3 AGN:**
    - Three distinct X-ray sources
    - No ionizing stratification in optical emission

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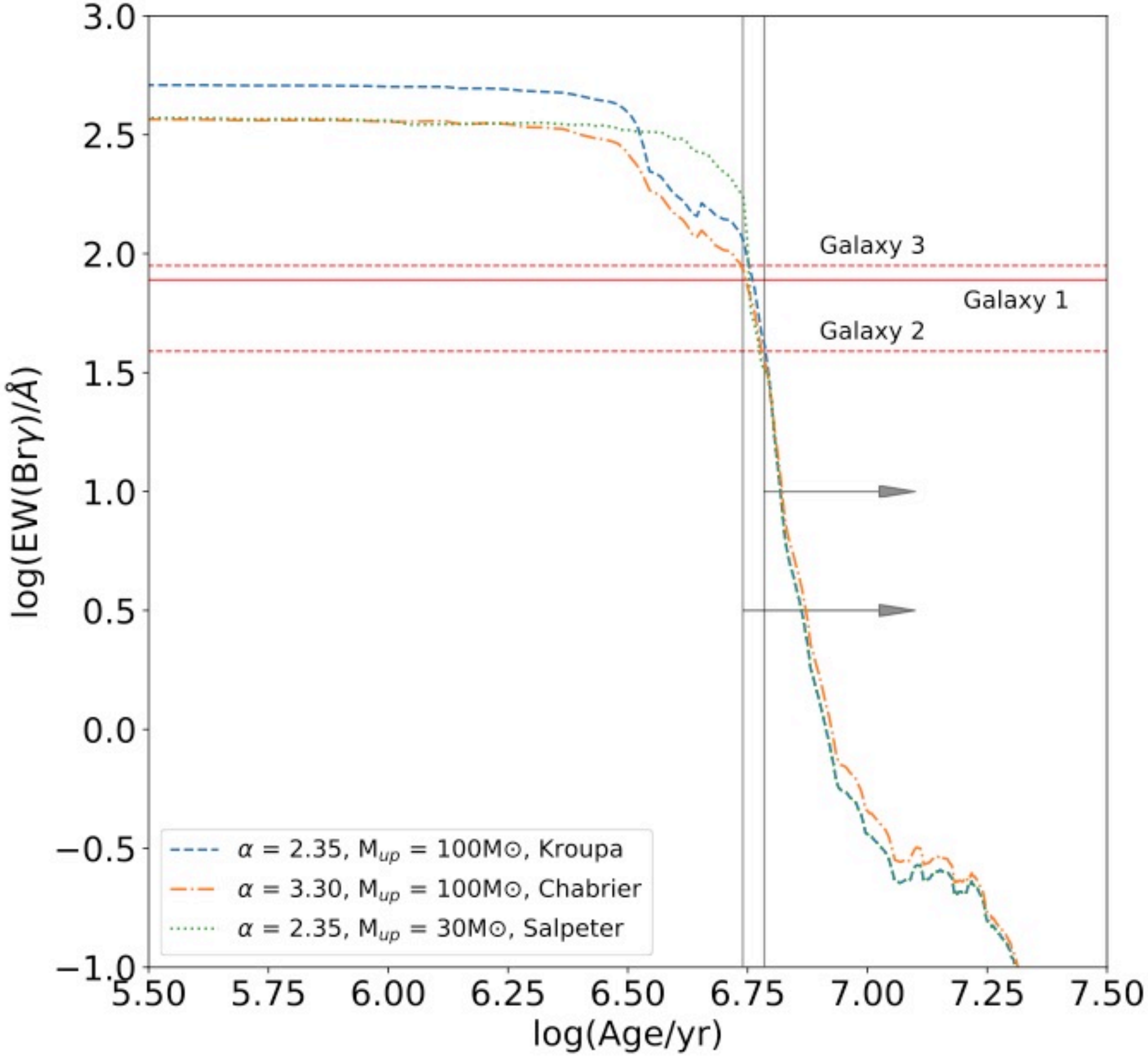
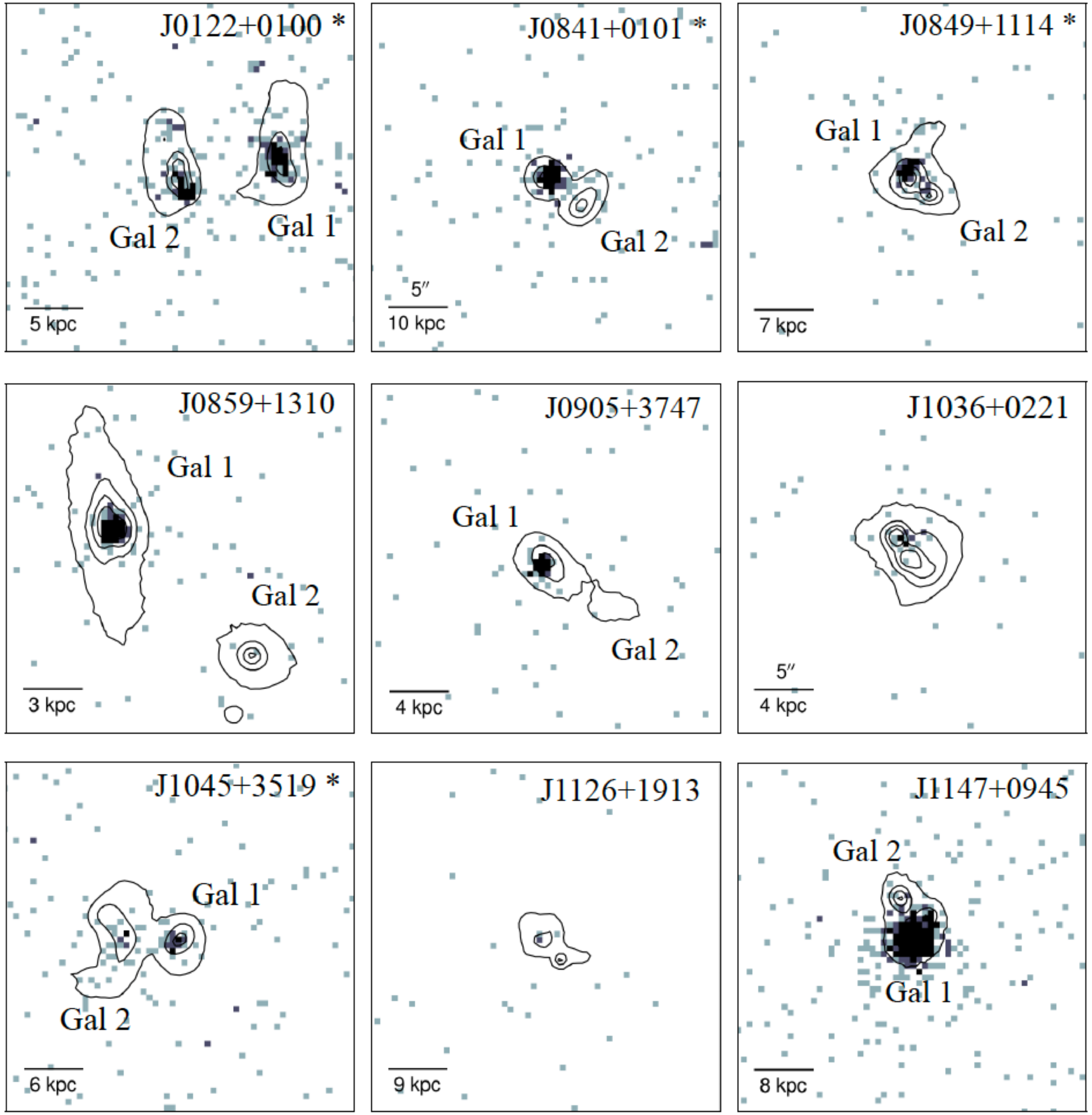
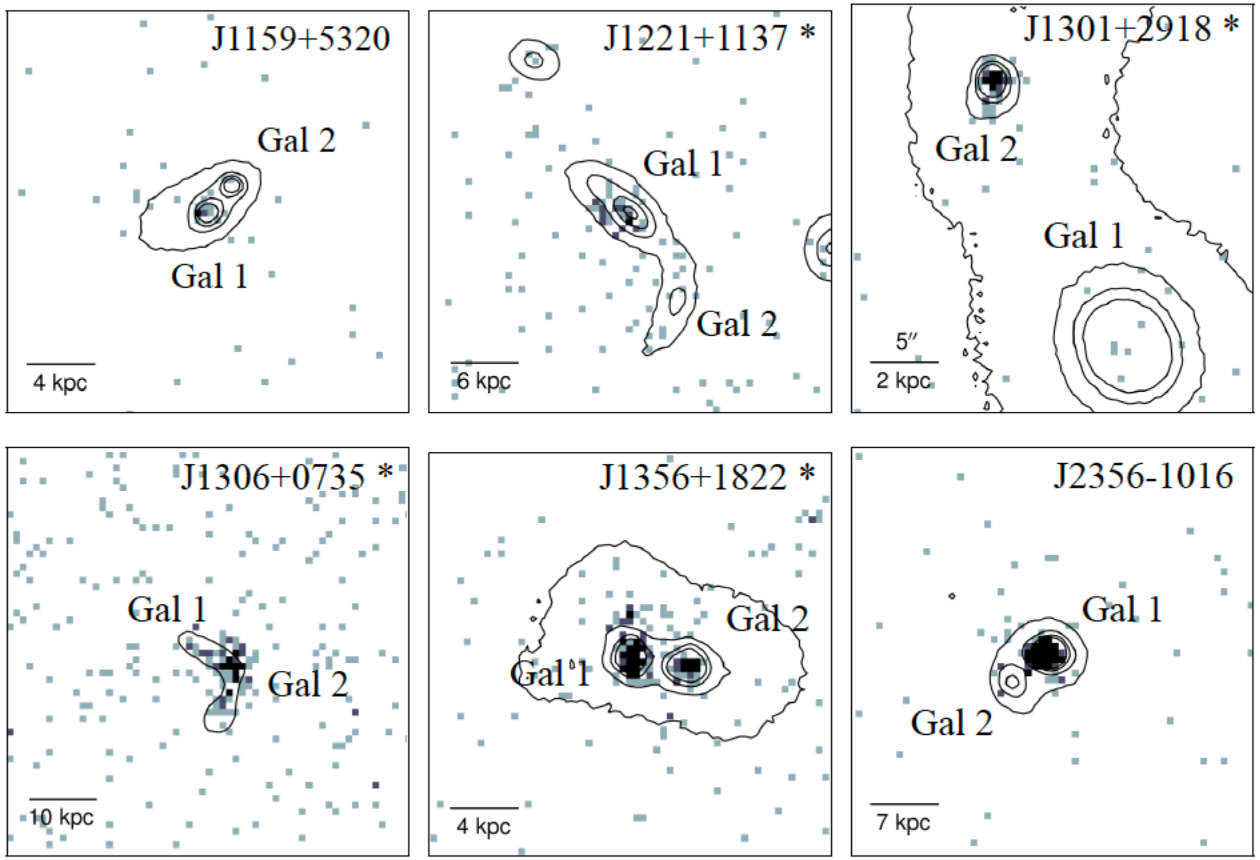
SDSS J0849+1114: Stellar Ages





J0122+0100 *
Gal 2
Gal 1
5 kpc
J0841+0101 *
Gal 1
Gal 2
5″
10 kpc
J0849+1114 *
Gal 1
Gal 2
7 kpc
J0859+1310
Gal 1
Gal 2
3 kpc
J0905+3747
Gal 1
Gal 2
4 kpc
J1036+0221
5″
4 kpc
J1045+3519 *
Gal 1
Gal 2
6 kpc
J1126+1913
9 kpc
J1147+0945
Gal 2
Gal 1
8 kpc



J1159+5320
Gal 2
Gal 1
4 kpc
J1221+1137 *
Gal 1
Gal 2
6 kpc
J1301+2918 *
Gal 2
Gal 1
5″
2 kpc
J1306+0735 *
Gal 1
Gal 2
10 kpc
J1356+1822 *
Gal 2
Gal 1
4 kpc
J2356-1016
Gal 1
Gal 2
7 kpc