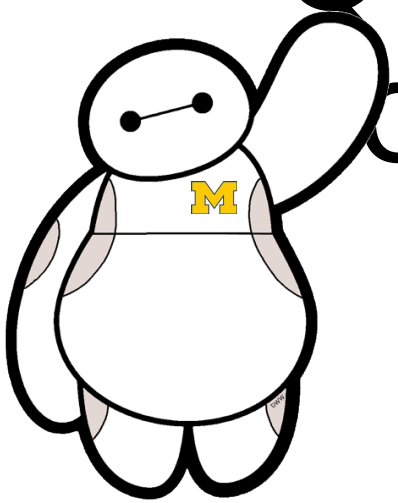
Quantifying the Rate of Dual AGNs with BAYMAX *



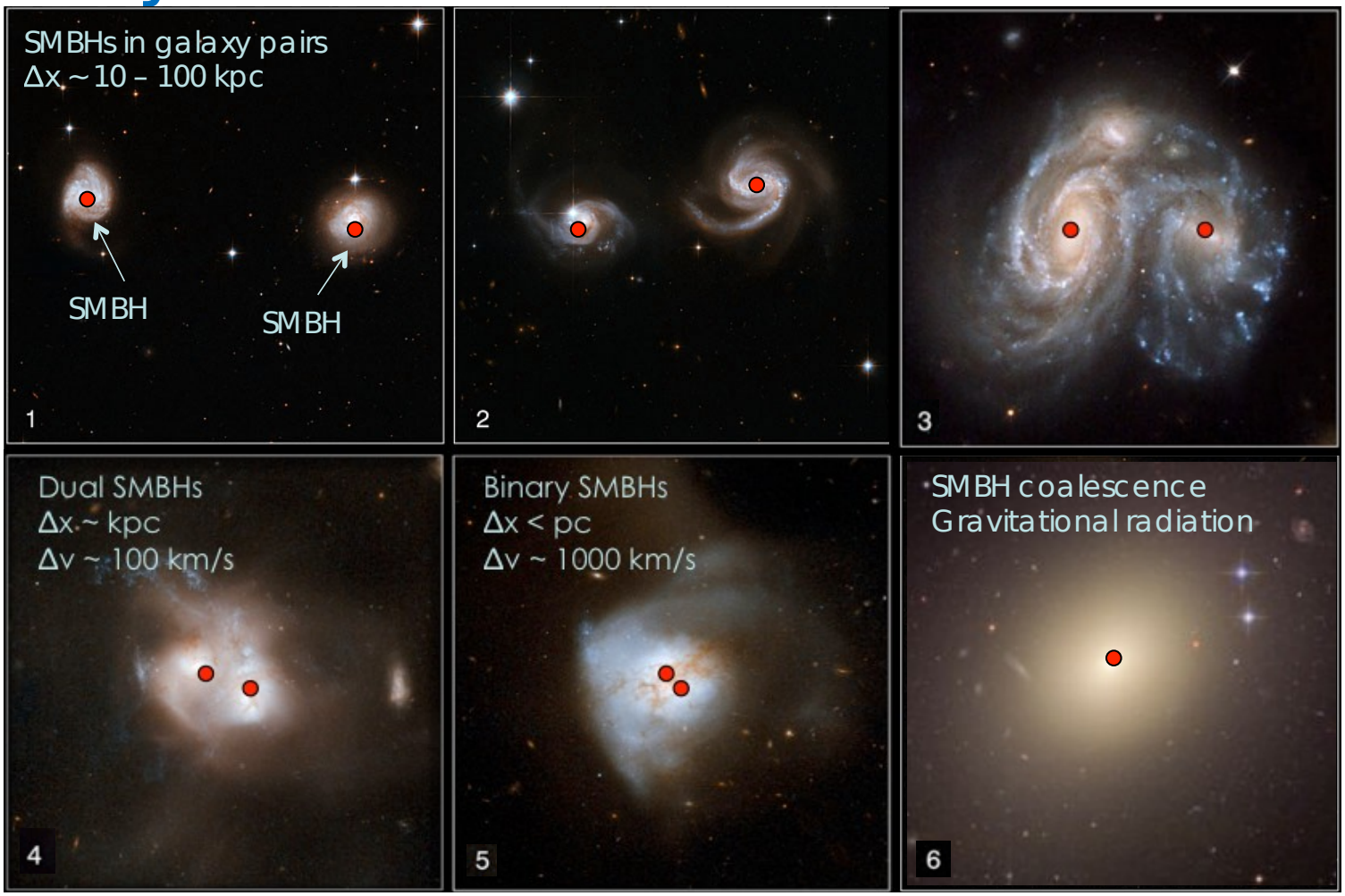
* (***B**ayesian **A**nal**Y**sis of **M**ultiple **A**GN in **X**-rays)*

X-ray Astronomy 2019: Current Challenges and New Frontiers in the Next Decade

September 12, 2019

Adi Foord

Galaxy mergers lead to dual- & binary-SMBHs



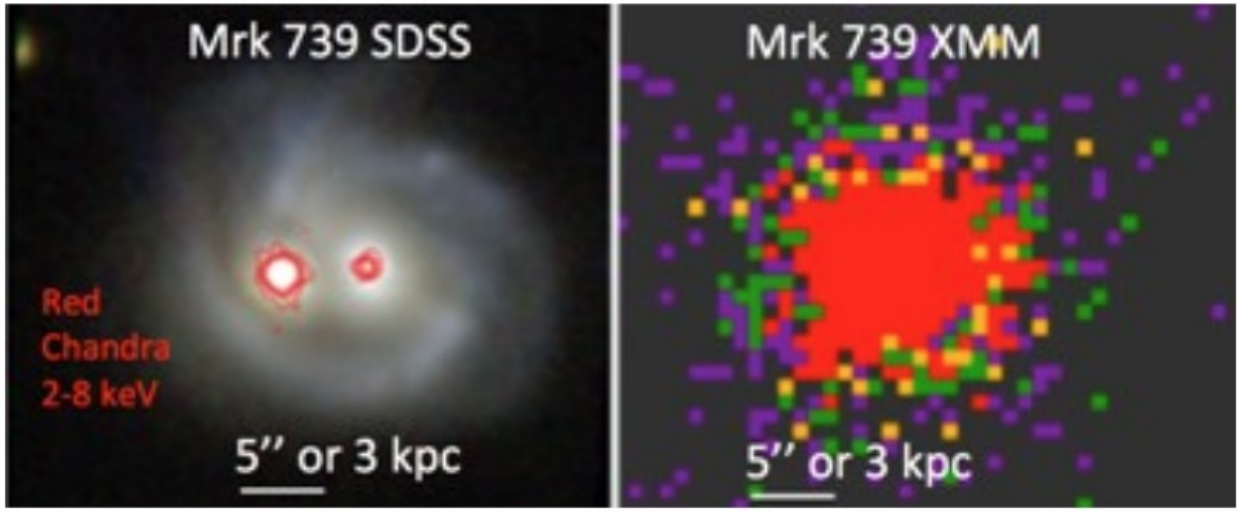
Dual AGNs are the progenitors to the GWs detected with PTAs

(●—●) Quantifying the Rate of Dual AGNs with BAYMAX

X-ray observations allow for a direct detection of dual AGN systems

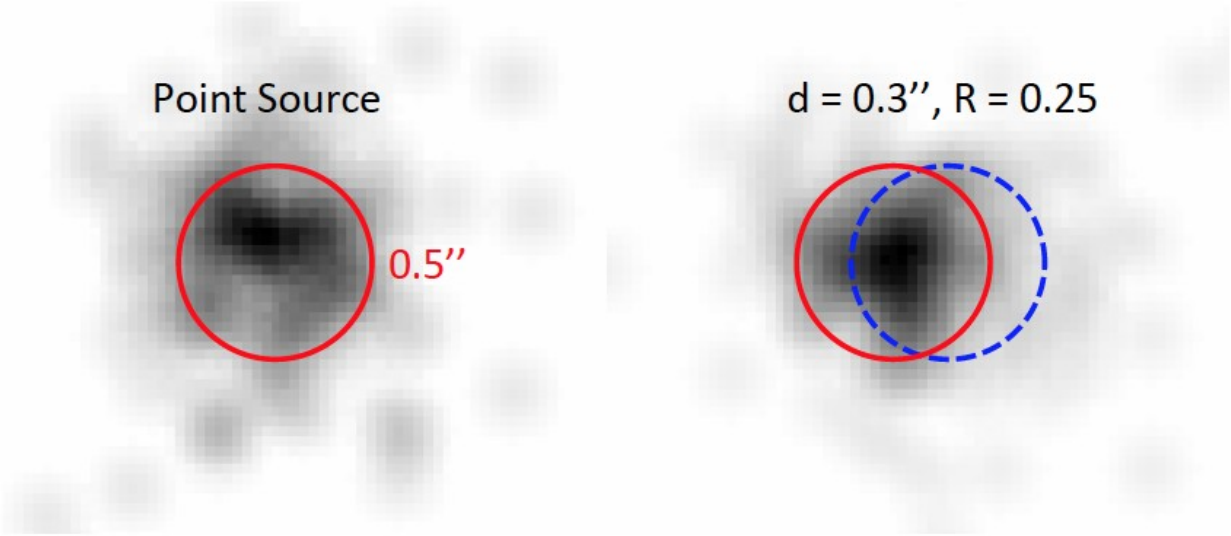
Can confirm dual-SMBHs observationally *if they power dual-AGN and if you have the necessary resolution.*

Chandra's superb resolution is necessary for X-ray analyses!



Δx = 3.4 kpc = 5.8 arcsec

Resolving close (< 1”) dual-AGN becomes difficult even with *Chandra*’s resolution



At separations close to the instrumental PSF, you can not say with certainty whether an observation is composed of one or two point sources!

BAYMAX (**B**ayesian **A**nal**Y**sis of **M**ultiple **A**GN in **X-**rays) allows for statistical analyses on *Chandra* observations

BAYMAX calculates the Bayes factor:

$$P(M|D) = \frac{\int P(D|\theta_1, M_1) P(\theta_1|M_1) d\theta_1}{\int P(D|\theta_2, M_2) P(\theta_2|M_2) d\theta_2}$$

which represents the posterior odds or the degree to which we favor one hypothesis over the other, will then be used to evaluate the likelihood of a dual point source system

P(M|D)	Strength of evidence*
<0	negative
1-3	not worth more than a bare mention
3-20	positive
20-150	strong
>150	very strong

* as arbitrarily defined in Jeffreys 1935 and Kass & Raffery 1995

BAYMAX
(**B**ayesian **A**nal**Y**sis of **M**ultiple **A**GN in **X**-rays)

The main components of the code are:

1) Generate likelihood models for single and double point sources

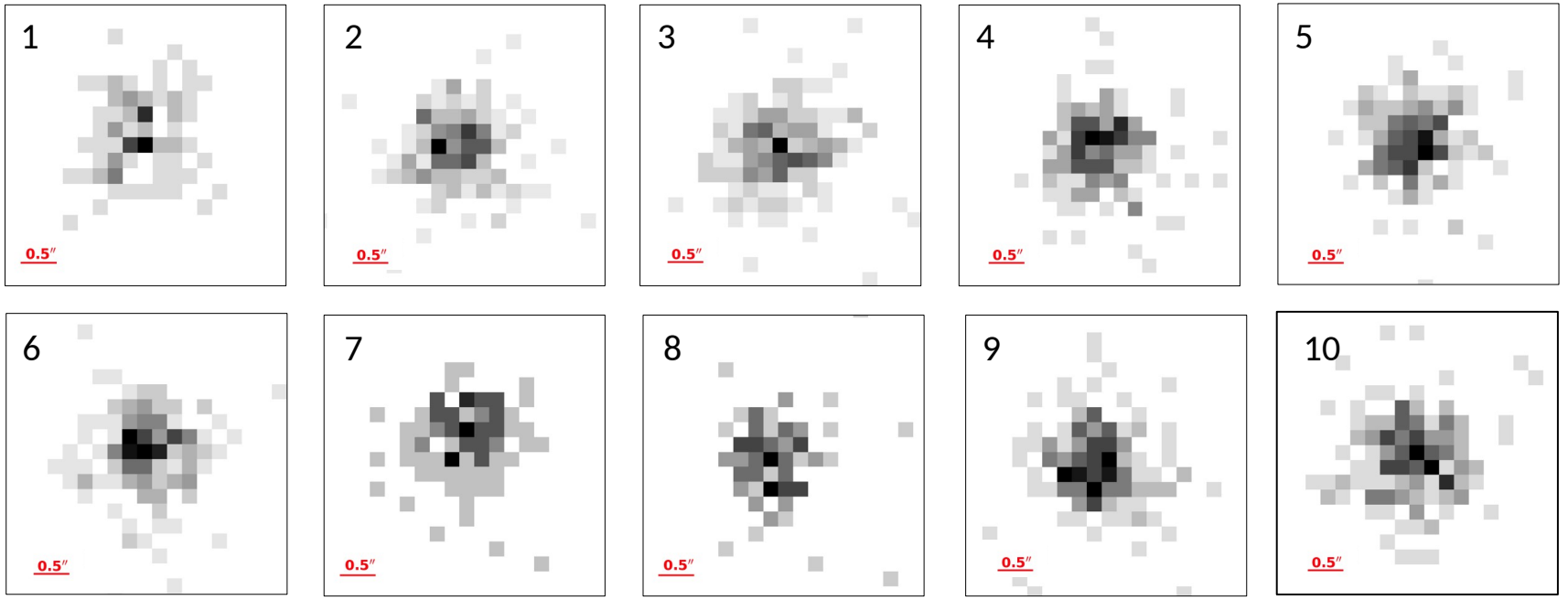
2) Define the priors, which can be either user-defined or non-informative but are flexible to incorporate preexisting optical observations.

3) Calculate Bayes Factor via Nested Sampling

4) Using an MCMC algorithm, PyMC3, the maximum likelihood of parameters such as the separation of dual point sources and count ratio F_2/F_1, as well as their uncertainties are estimated.

BAYMAX
(**B**ayesian **A**nal**Y**sis of **M**ultiple **A**GN in **X**-rays)

By eye, can you tell which data-sets are single- vs. dual-AGN?



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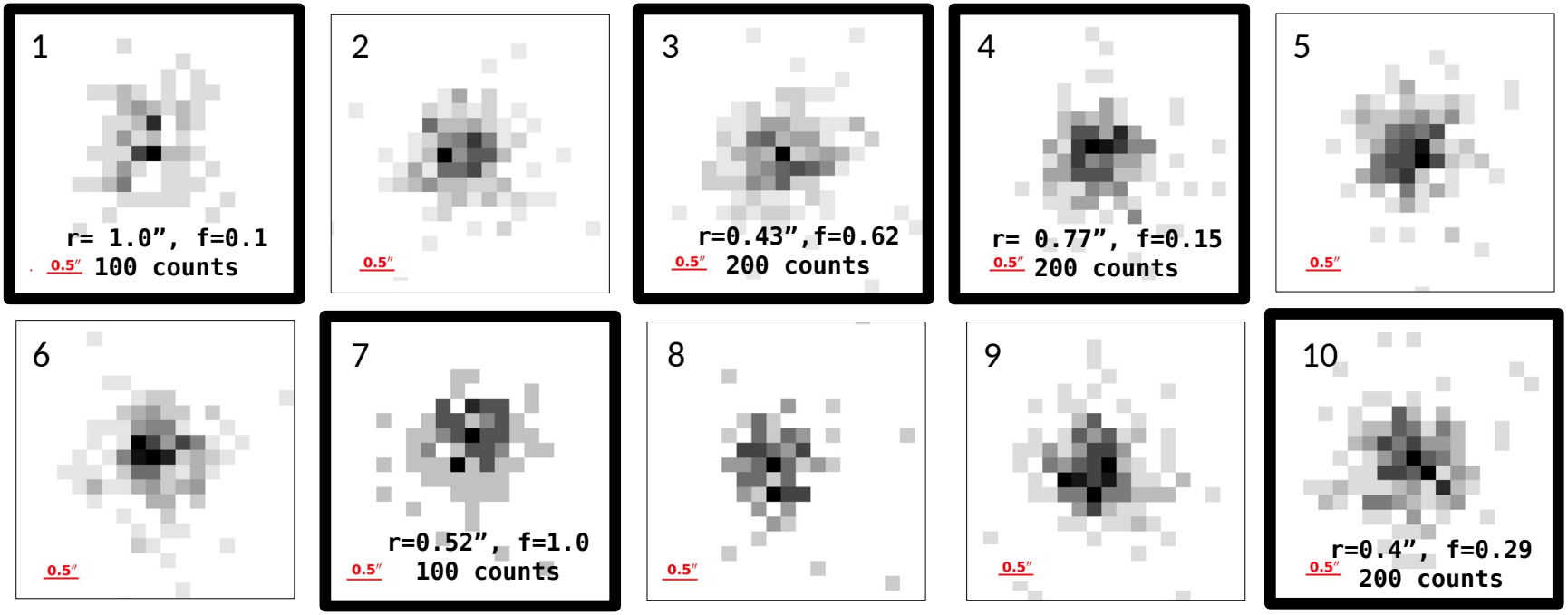
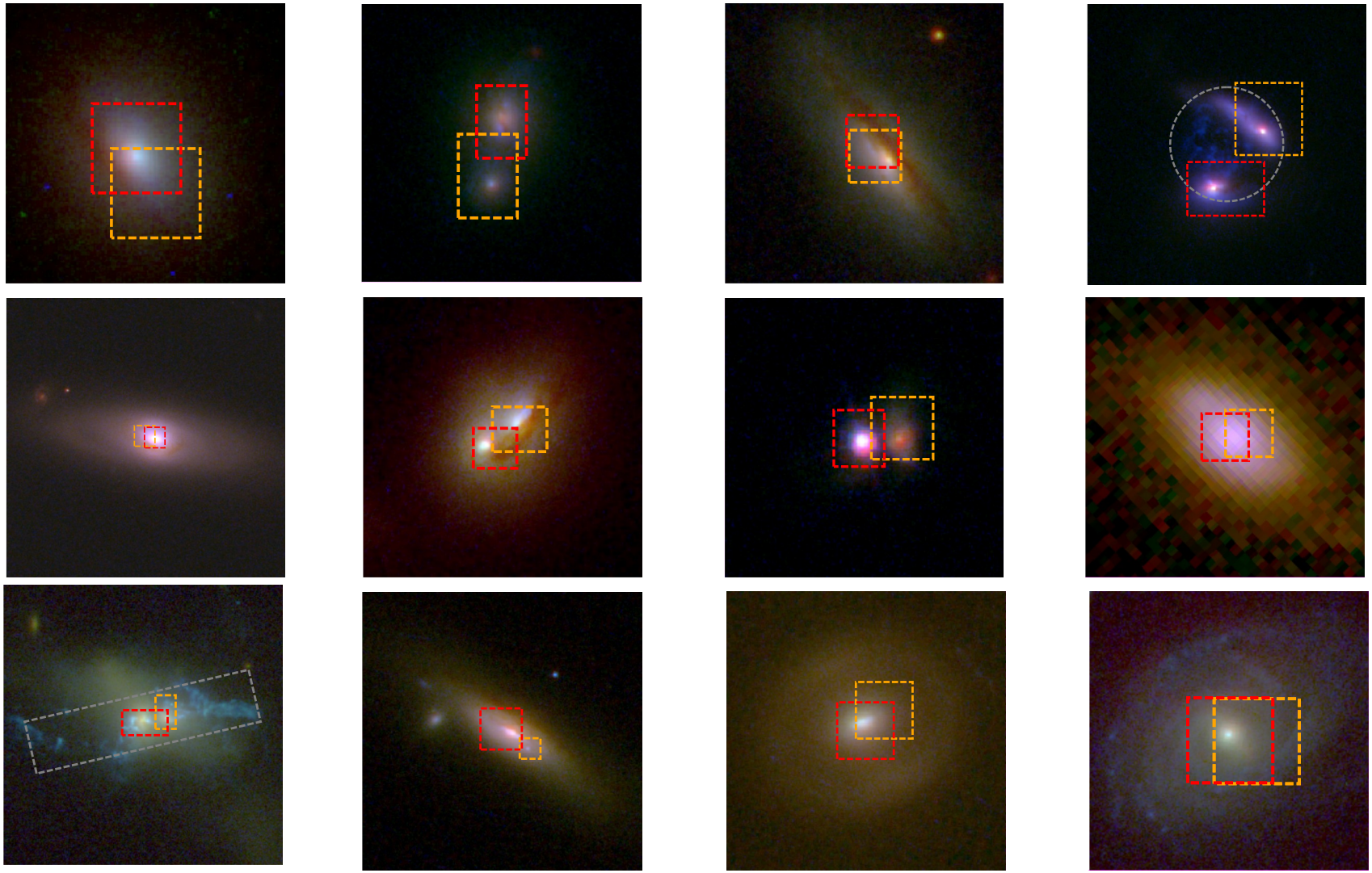


BAYMAX is can discern between single- and dual-AGN for both low flux-ratios (as low as ~10 counts from the secondary), and separations <0.5”!

BAYMAX is currently investigating ``borderline" cases in the literature



(●—●) Quantifying the Rate of Dual AGNs with BAYMAX

Foord et al. 2019, in prep.

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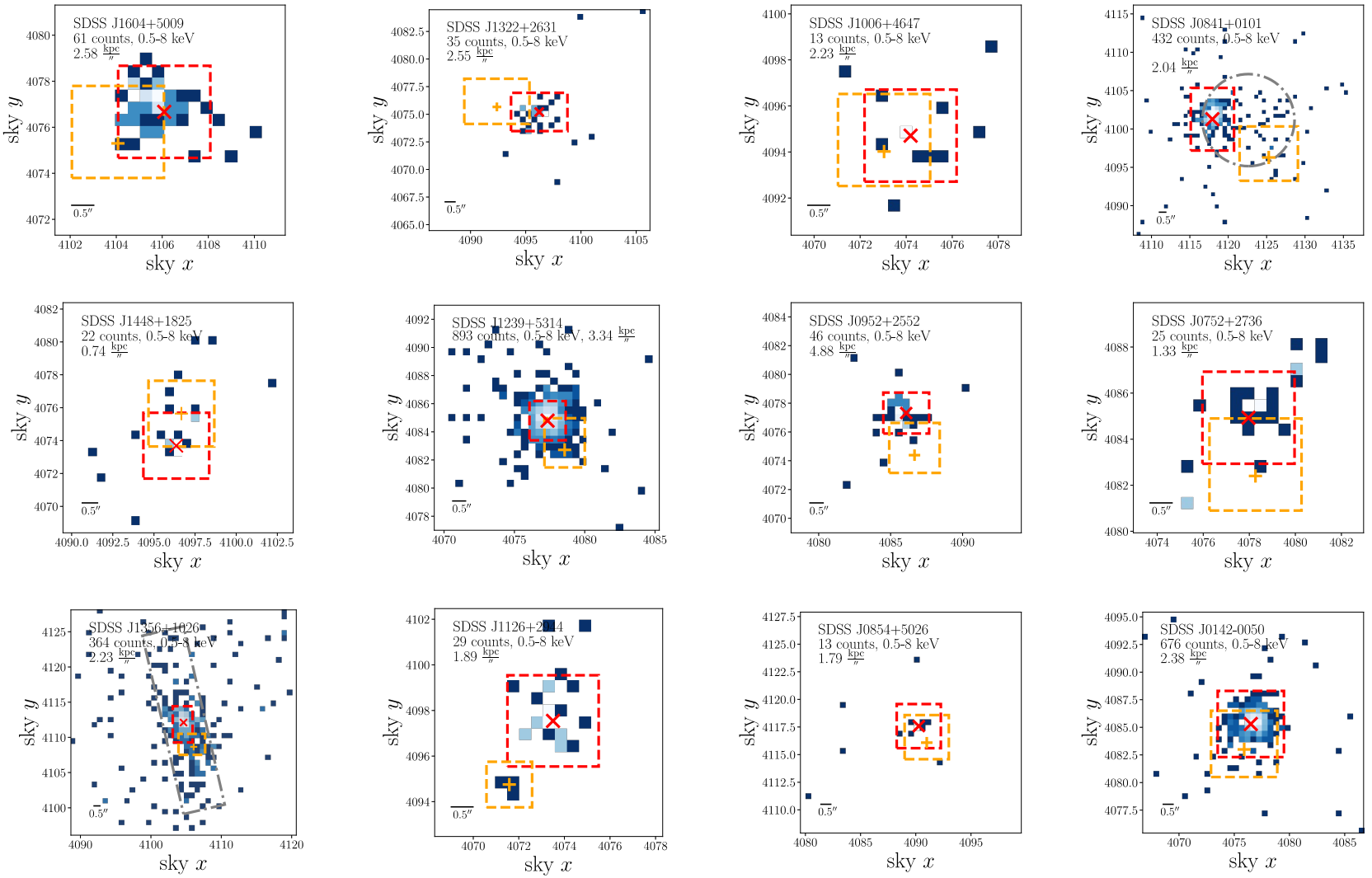

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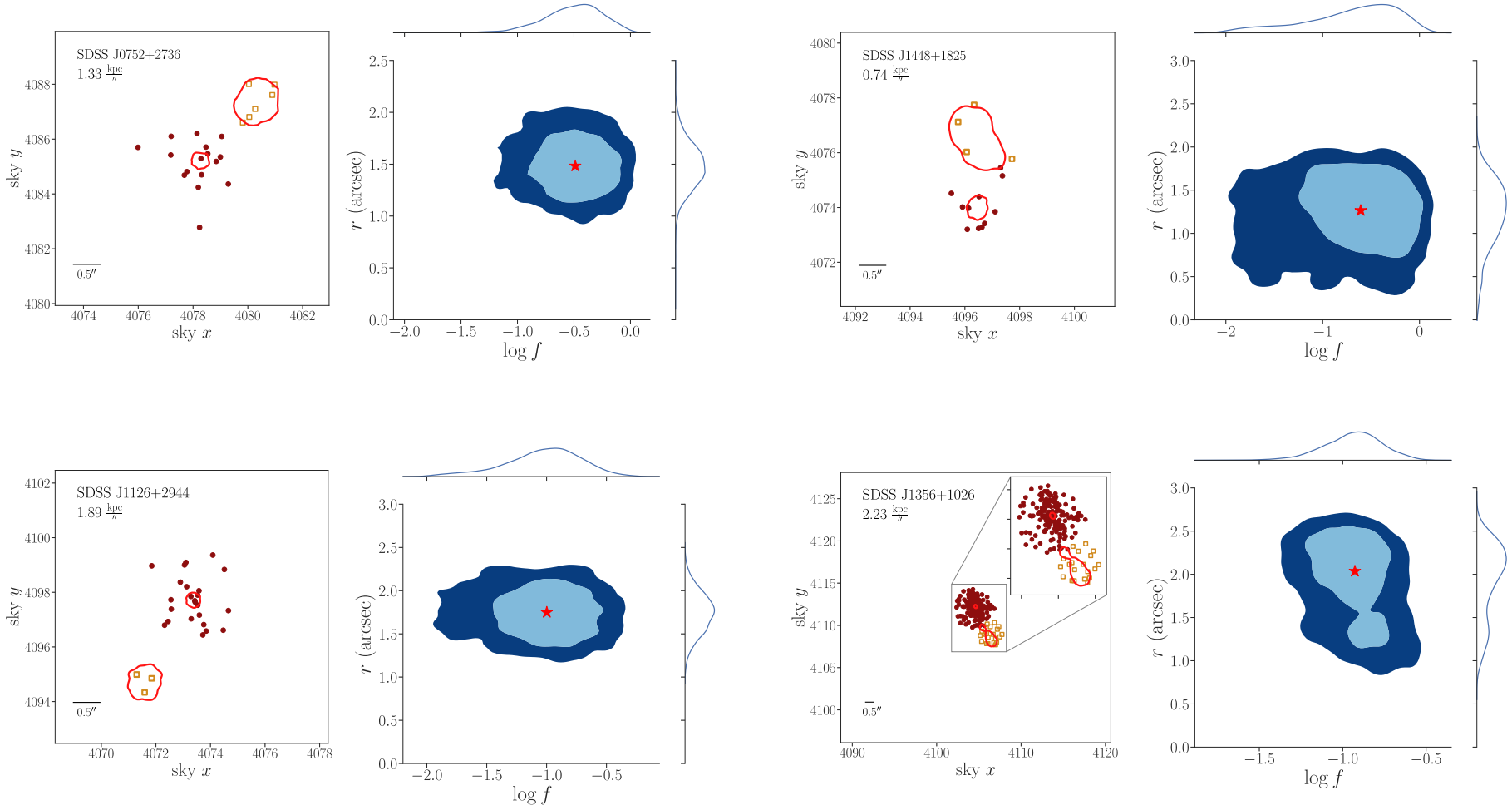
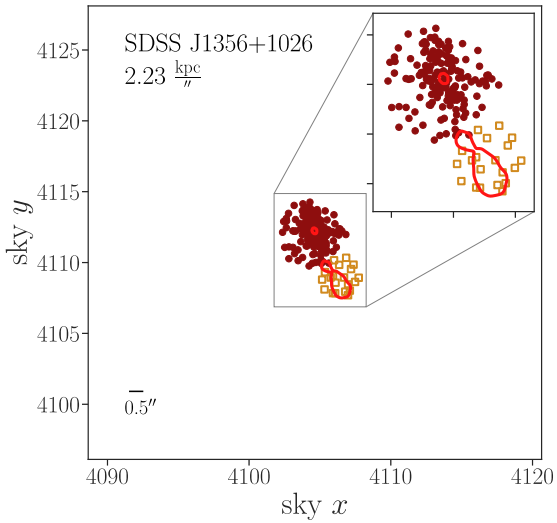
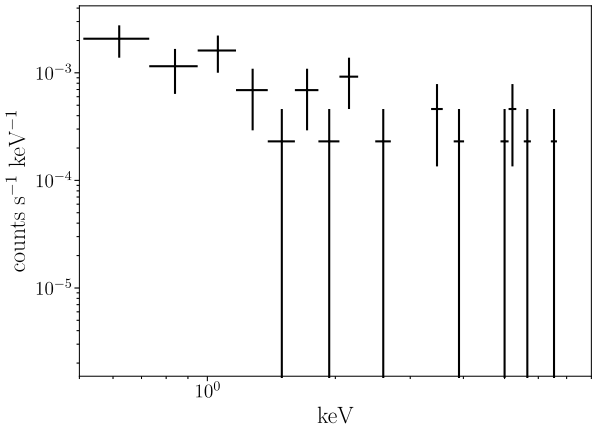
We've discovered 4 systems that are likely composed of two X-ray point sources



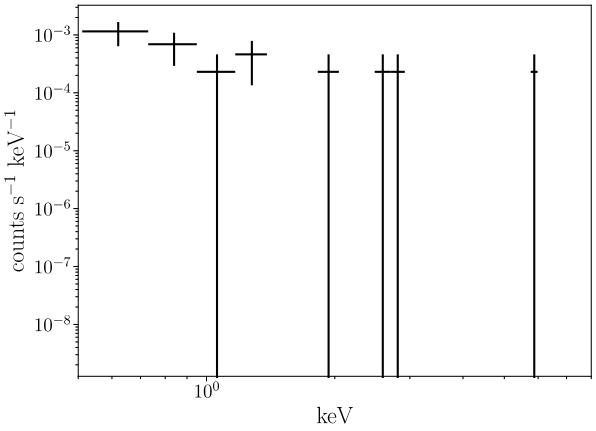
Foord et al. 2019, in prep.

Spectral analyses with BAYMAX allows for further classification





Primary point source
1000 realizations



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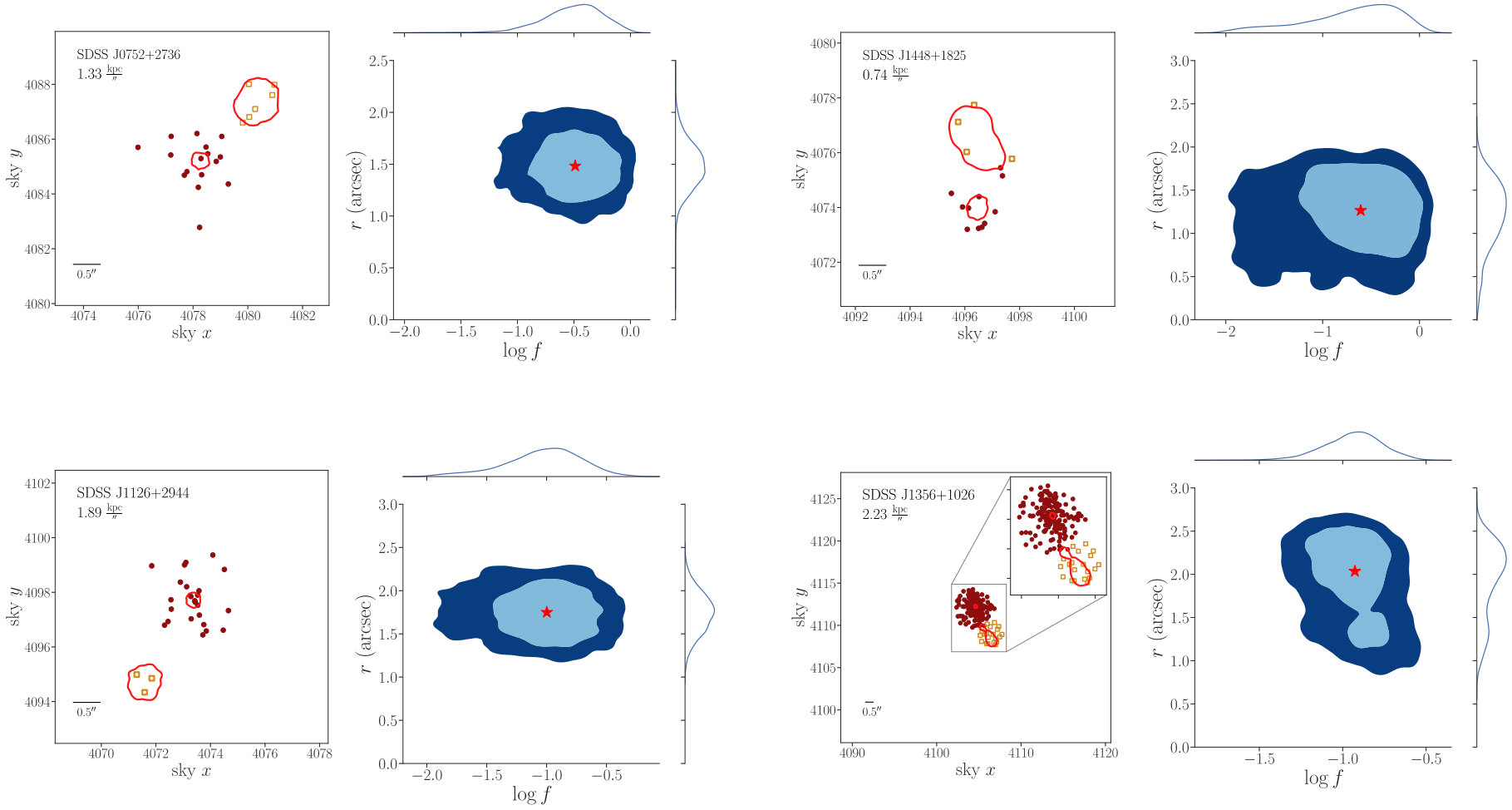
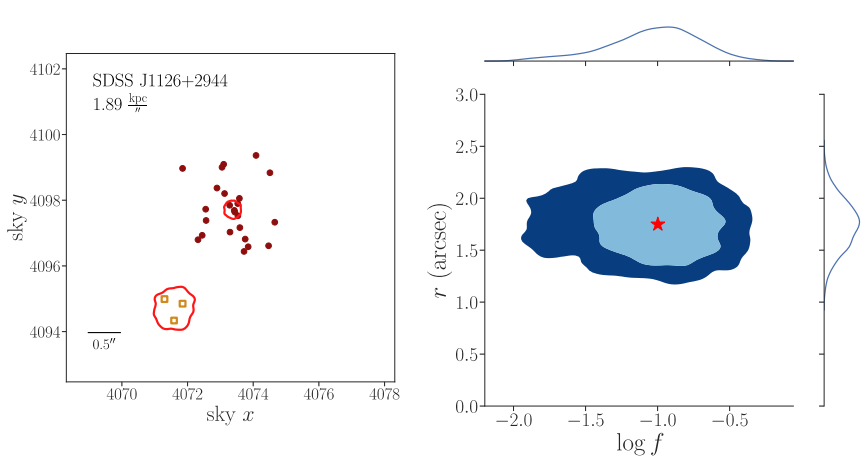
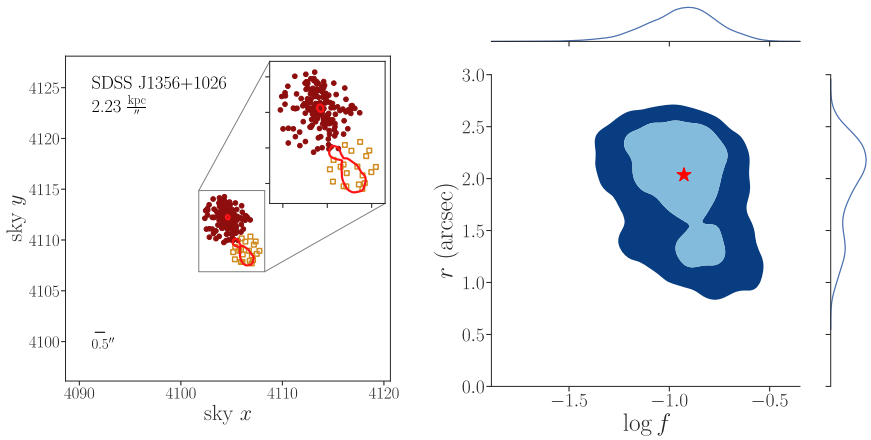


Foord et al. 2019, in prep.

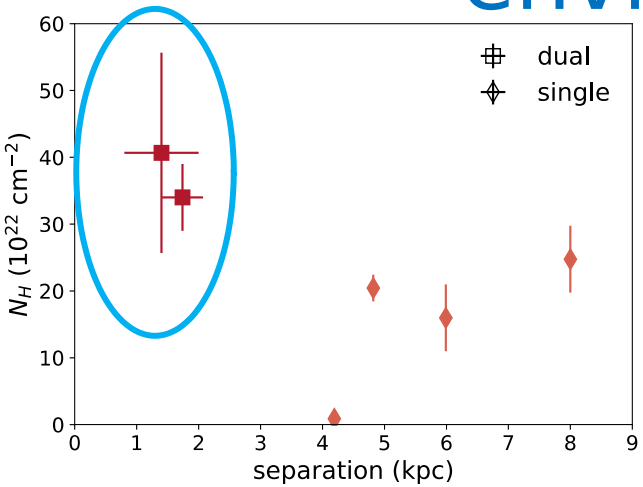
We've discovered 2 systems that have secondary X-ray point sources with $L_{2\text{-}7,\ unabs} > 10^{40}$ erg s^{-1}





Foord et al. 2019, in prep.

Complementary multi-wavelength observations give insight to preferential environments



Possible Environmental Preferences:

Dual AGN systems may prefer closely-separated, gas-rich, systems

Foord et al. 2019, in prep.

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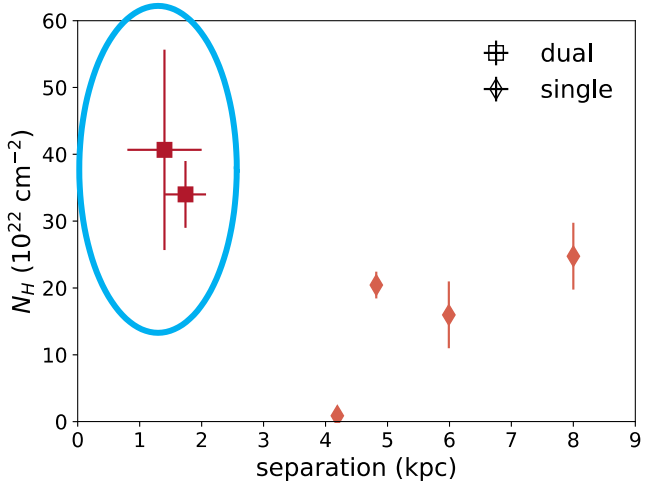

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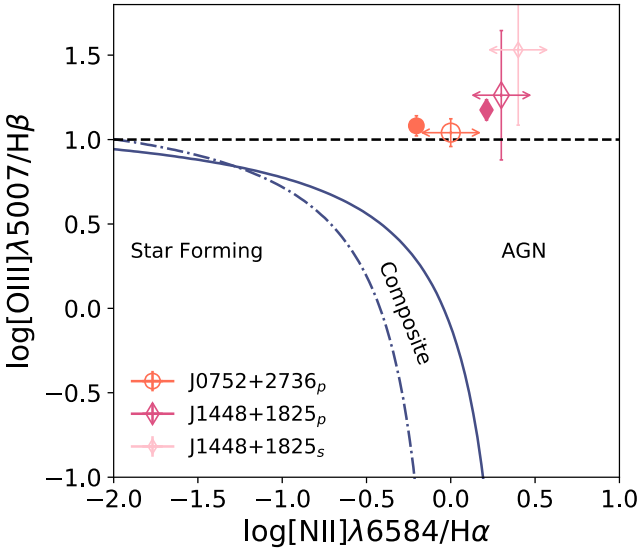

Baldwin, Phillips & Telervich (BPT) diagnostics:

* Using available long slit data, we look at log [O III]/Hβ

* Follow-up IFU observations will allow for a better understanding of possible contamination

Foord et al. 2019, in prep.

Take-away Points & Future Work

Take-away points:

- Very few dual AGN have been found & confirmed to date!
- BAYMAX (Bayesian Analysis of Dual AGNs in X-ray) allows for a statistical and quantitative analysis on *Chandra* observations
- We are starting to find dual-AGN candidates, and will learn more about their preferential environments and properties.

Future:

- We plan to eventually constrain the rate of dual AGN as a function of redshift, using deep archival *Chandra* fields, with many AGNs to analyze.

- BAYMAX is flexible to incorporate any PSF model, and can work with future telescopes such as *Lynx!*