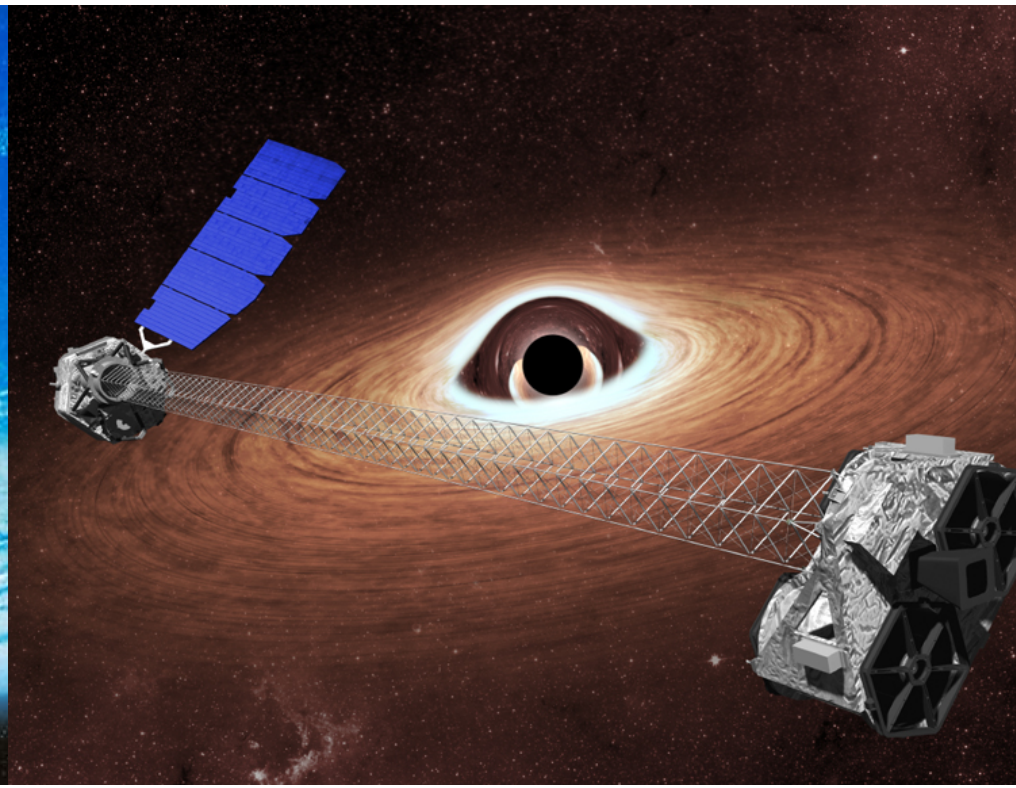
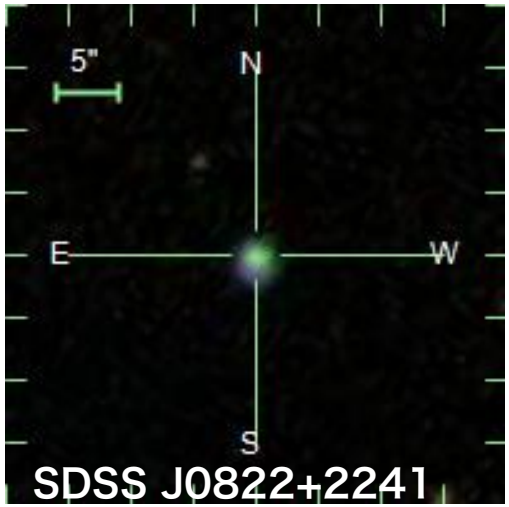




An X-ray study of two Green Pea galaxies

T. Kawamuro (NAOJ)

Y. Ueda (Kyoto Univ.), K. Ichikawa (Tohoku Univ.), M. Imanishi, T. Izumi (NAOJ), A. Tanimoto (Kyoto Univ.) and K. Matsuoka (Ehime Univ.)

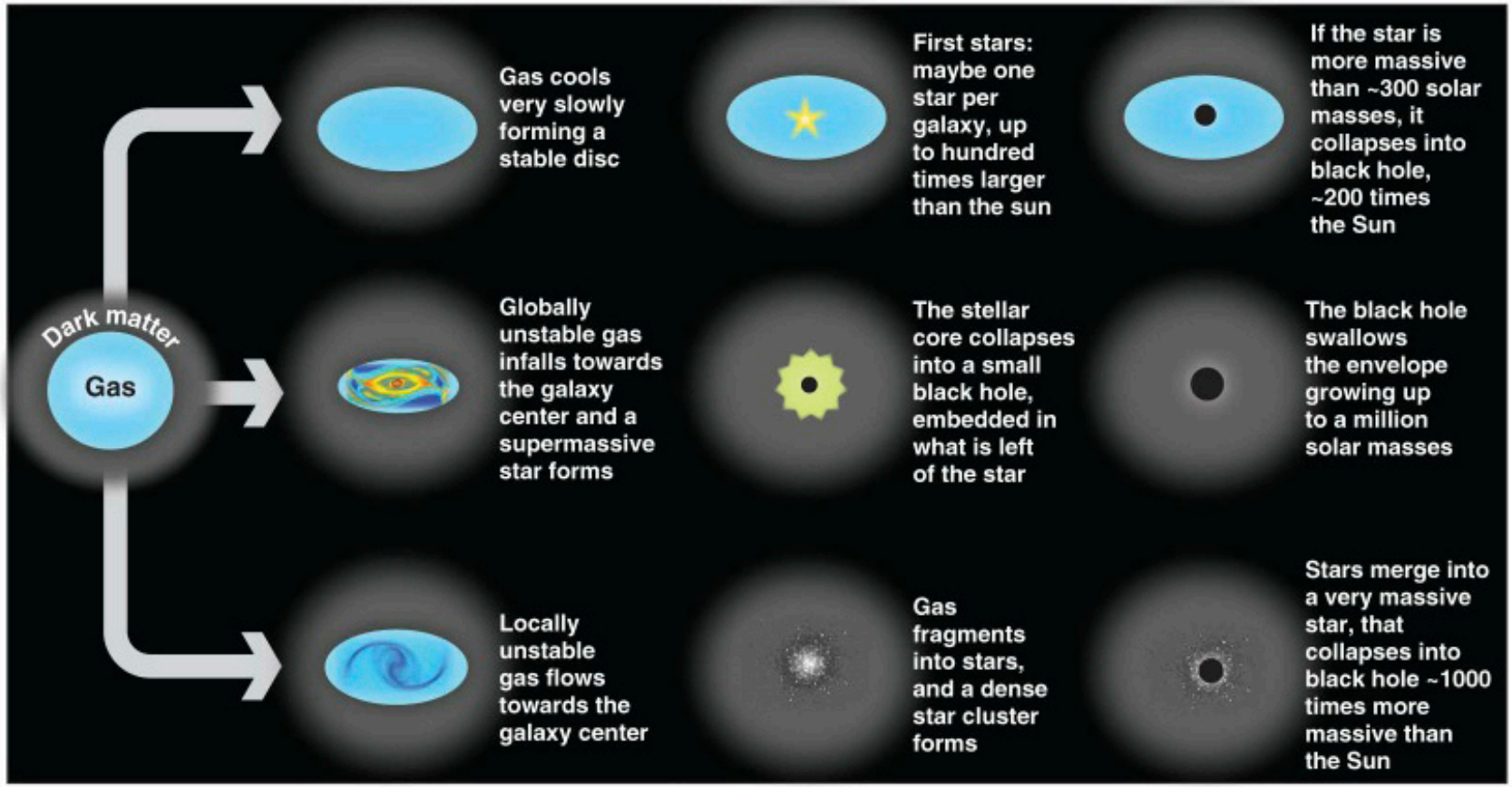
The 6th Galaxy Evolution Workshop

(TK+, submitted to ApJ)

Science BG: Seed black holes for SMBHs

What is the main process that forms seed black holes?

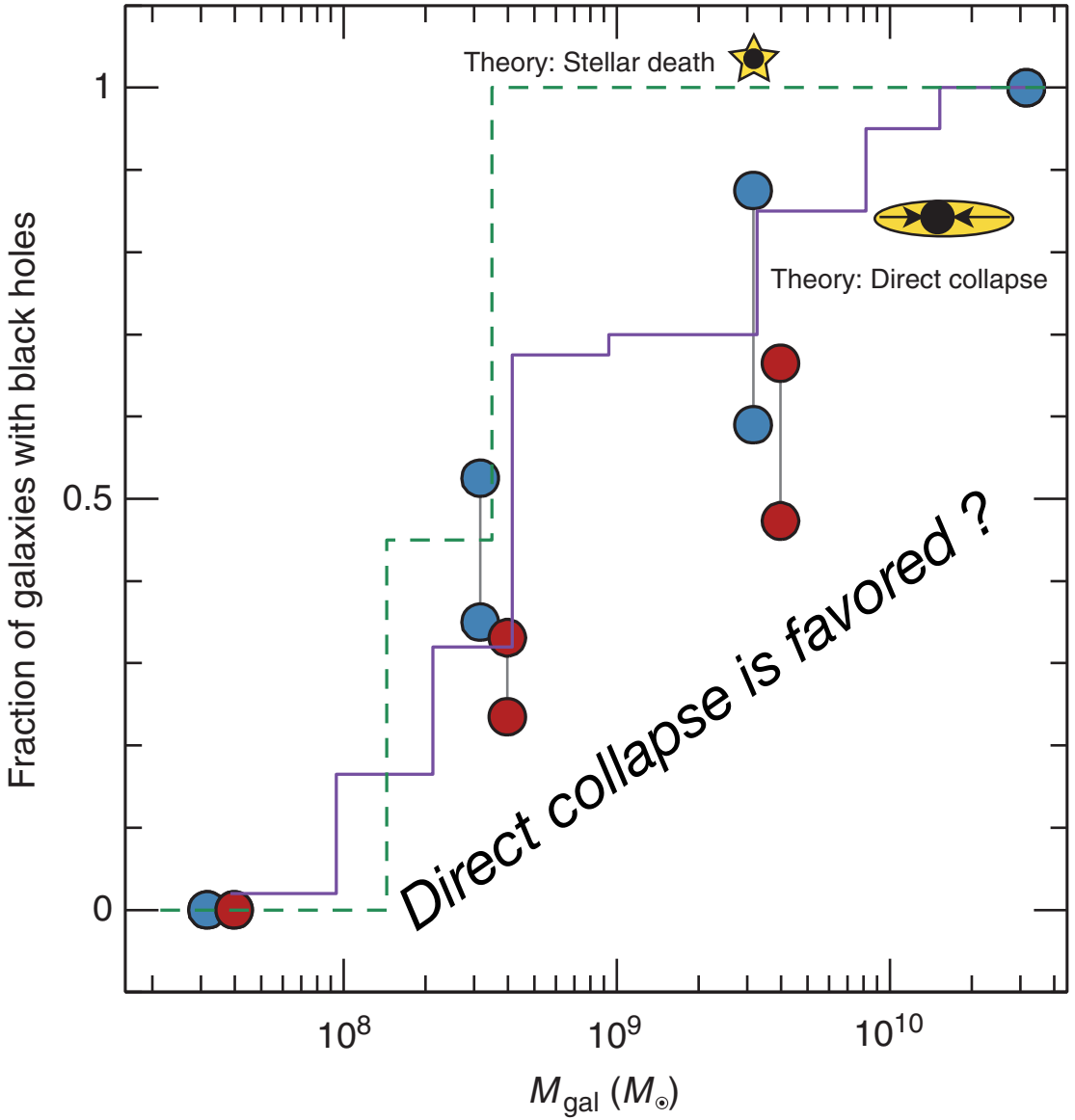
+ The remnant of massive Population III stars
+ The result of the direct collapse of primordial dense gas
+ The end-product of very massive stars formed through stellar mergers in dense star clusters



(http://www2.iap.fr/users/volonter/BHformation.html)

BH occupation fraction

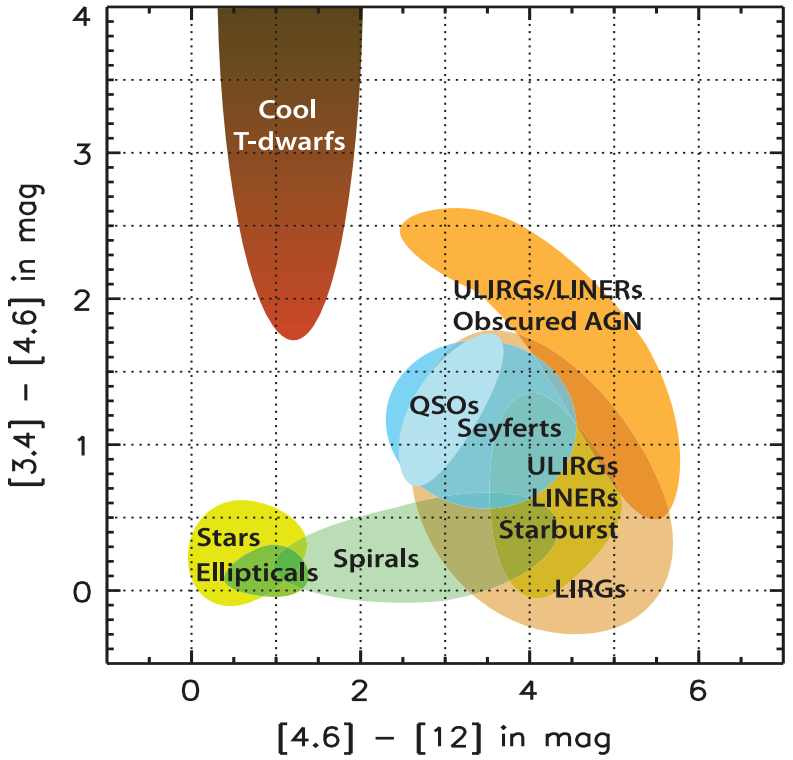
+ The BH occupation fraction has information of seed BHs.
+ The fraction is (#AGN/f_{agn})/#all galaxies (f_{agn} = 0.1: active BH fraction)
+ A lower fraction favors the direct collapse scenario as a primary process.
+ The current sample is biased against heavily obscured systems.

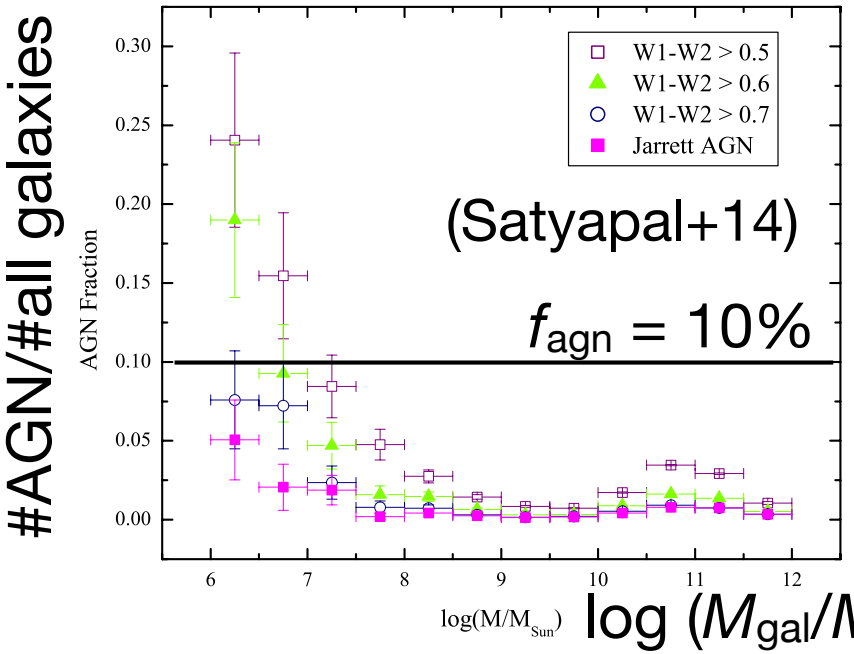


(soft X-ray study by Greene 12)

BH occupation fraction

+ The BH occupation fraction has information of seed BHs.
+ The fraction is (#AGN/f_{agn})/#all galaxies (f_{agn} = 0.1: active BH fraction)
+ A lower fraction favors the direct collapse scenario as a primary process.
+ The current sample is biased against heavily obscured systems.
+ MIR diagnostics studies suggest high AGN fractions of > 10%, thus the occupation fraction > 100%!?
+ Hard X-ray observations are crucial for drawing a robust conclusion.

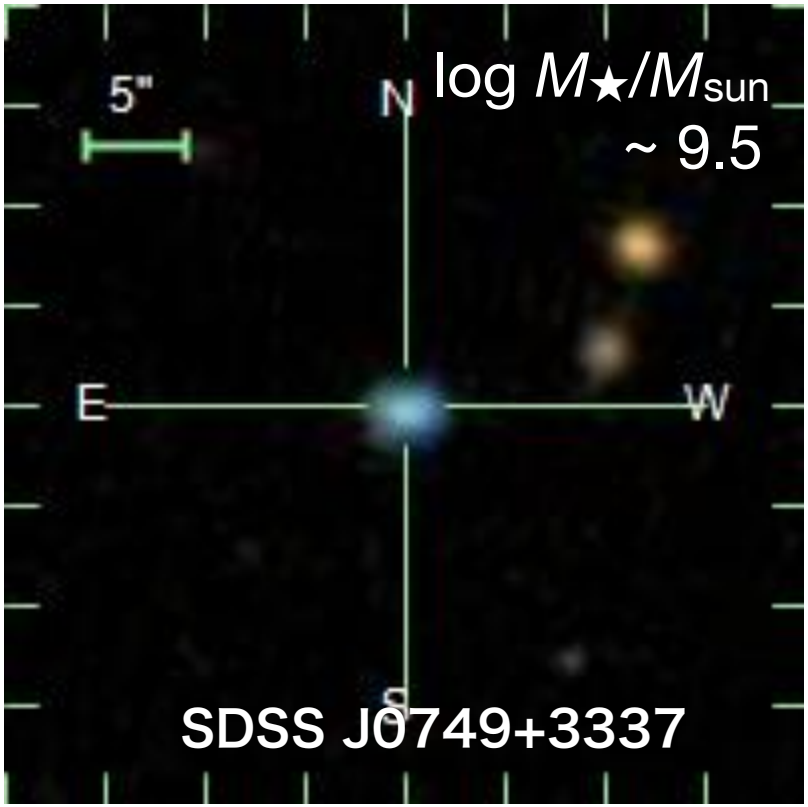


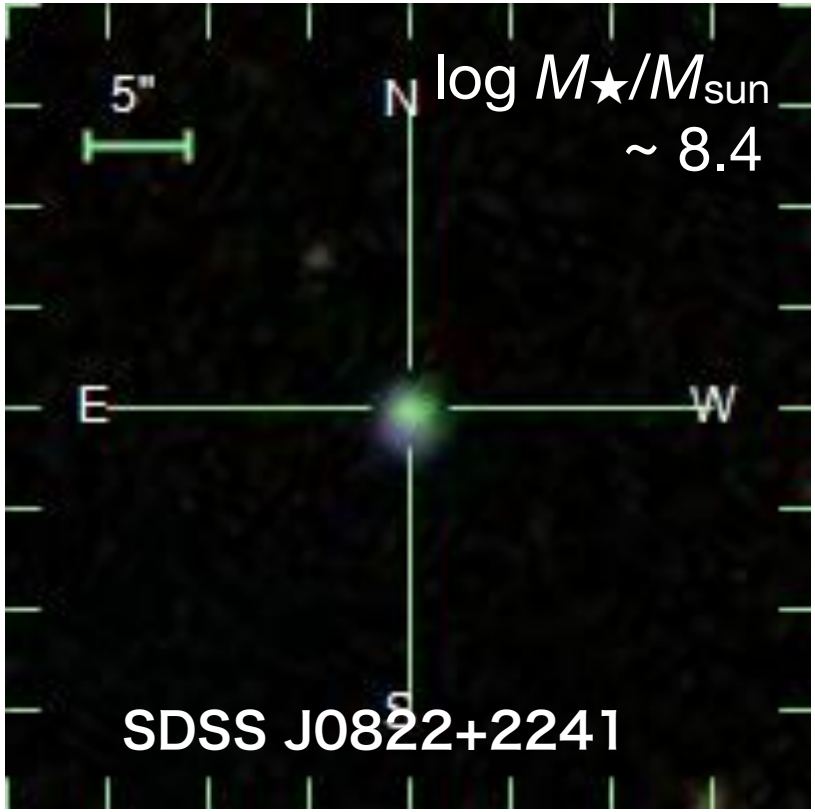


Green Pea galaxies

+ Green Pea galaxies were identified in an SDSS catalog, and their appearances are interpreted as strong [O III] emission w/ high EWs. (Cardamone+09).

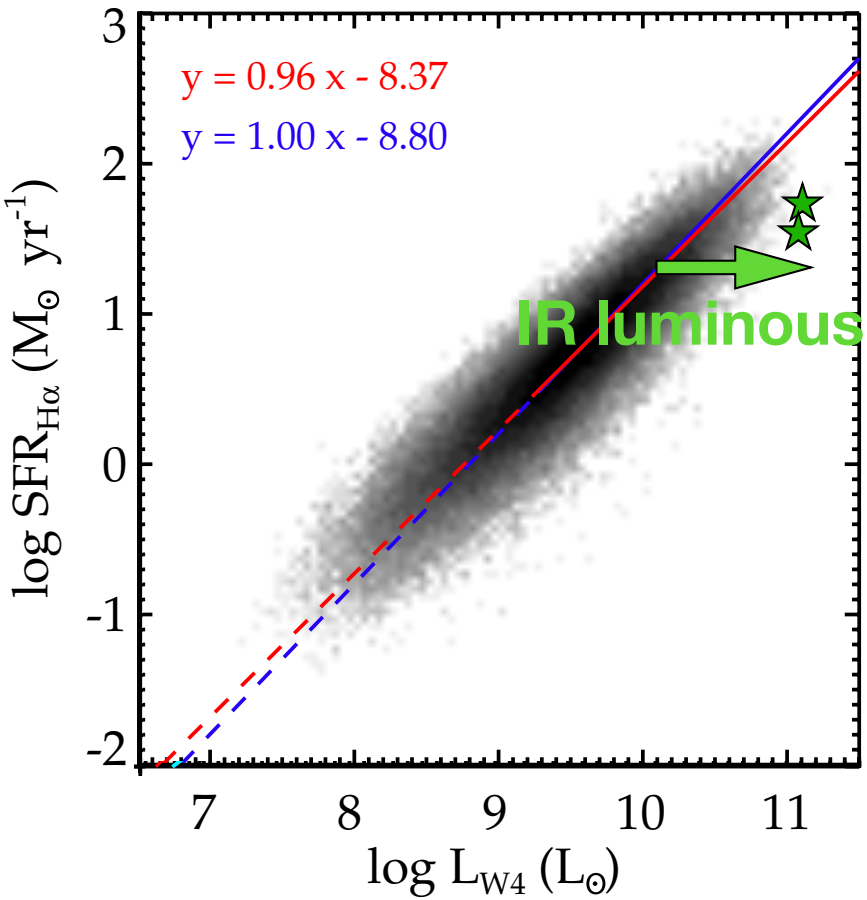
+ They are low stellar-mass and metallicity species, and regarded as those resemble to galaxies in an early phase of the galaxy formation.

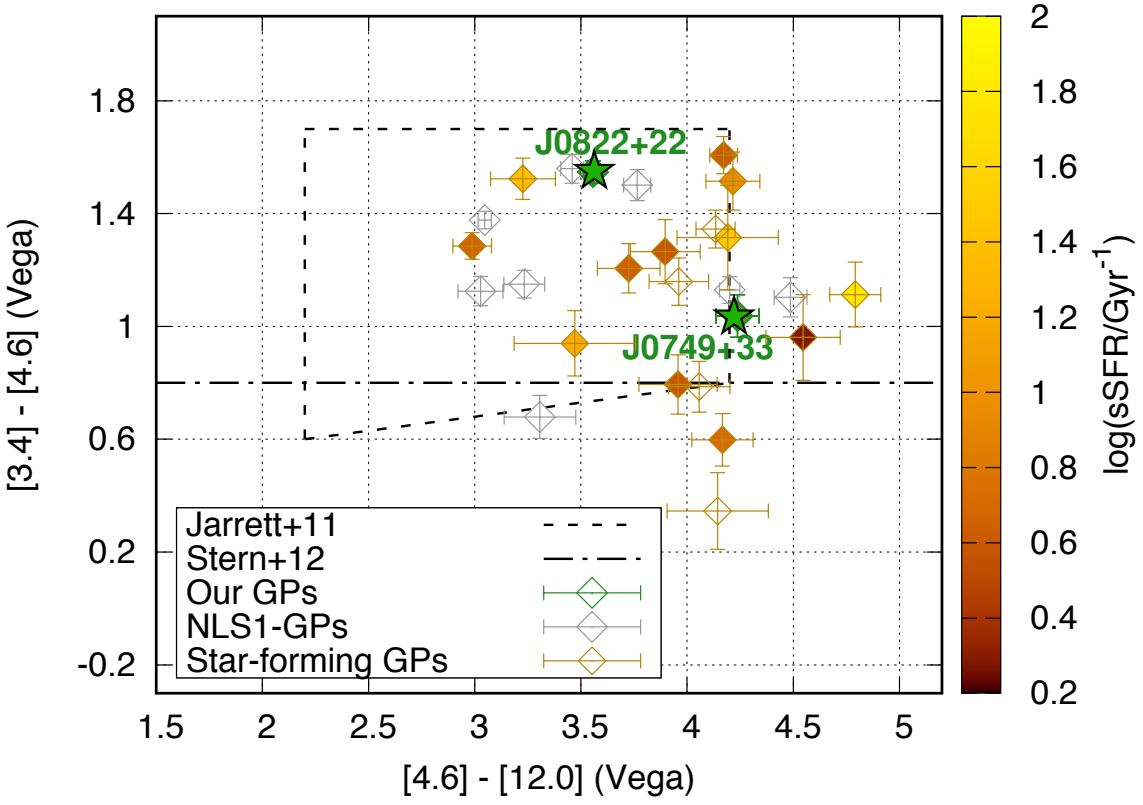




AGN-like MIR properties

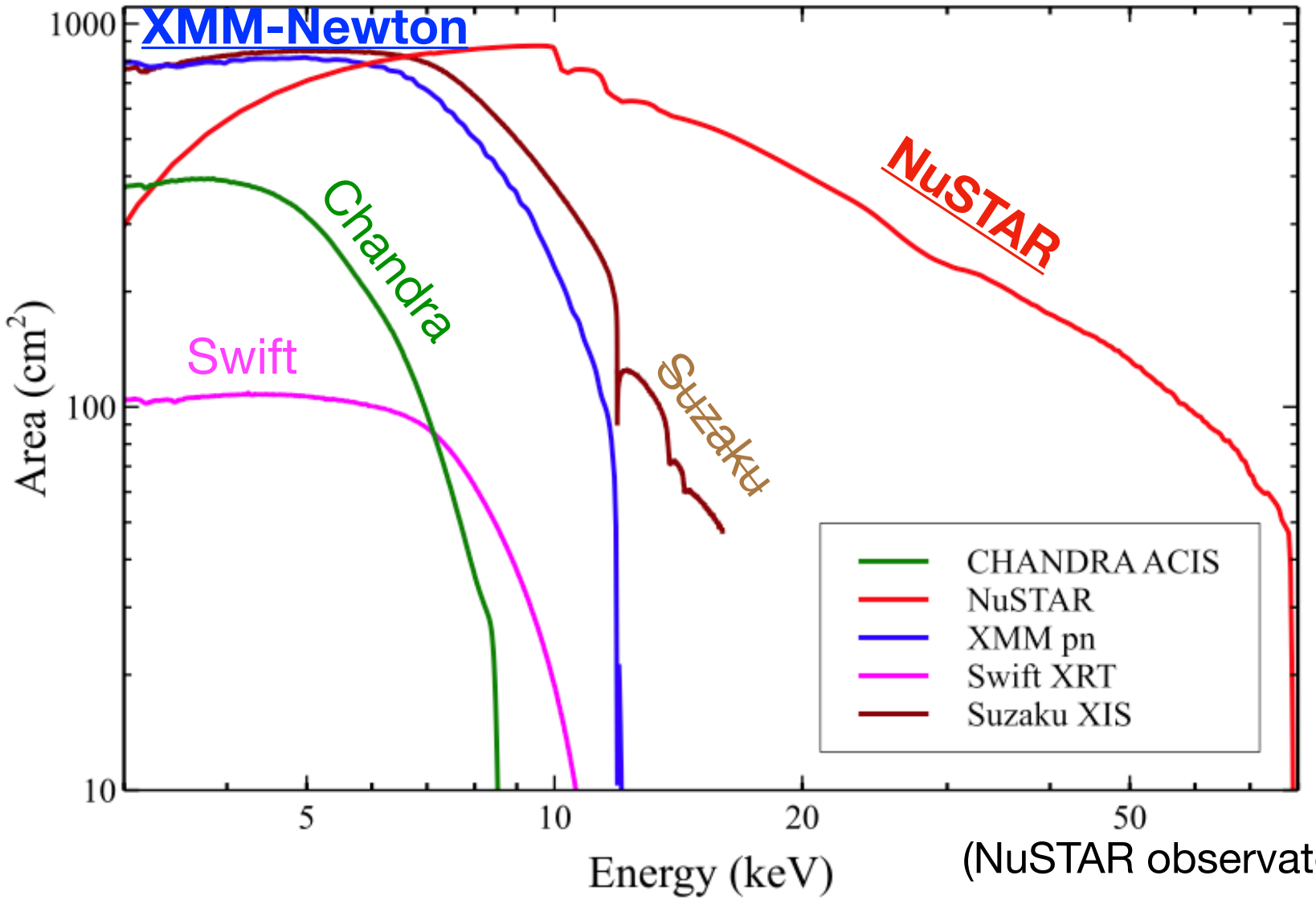
+ The two GPs are consistent with having AGNs in the MIR band.
  - MIR luminosities are higher than expected from the SFRs
    → A further energy source, or AGN?
  - Red colors
    → Hotter dust emission from the AGN torus?





X-ray observatories

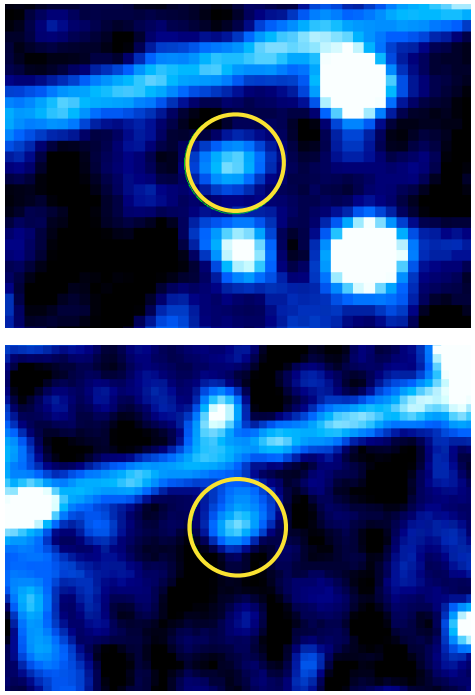
+ Currently, XMM-Newton (< 10 keV) and NuSTAR (> 10 keV) provide high-quality broadband X-ray spectra.
+ We obtained and analyzed NuSTAR and XMM-Newton data for the GPs.

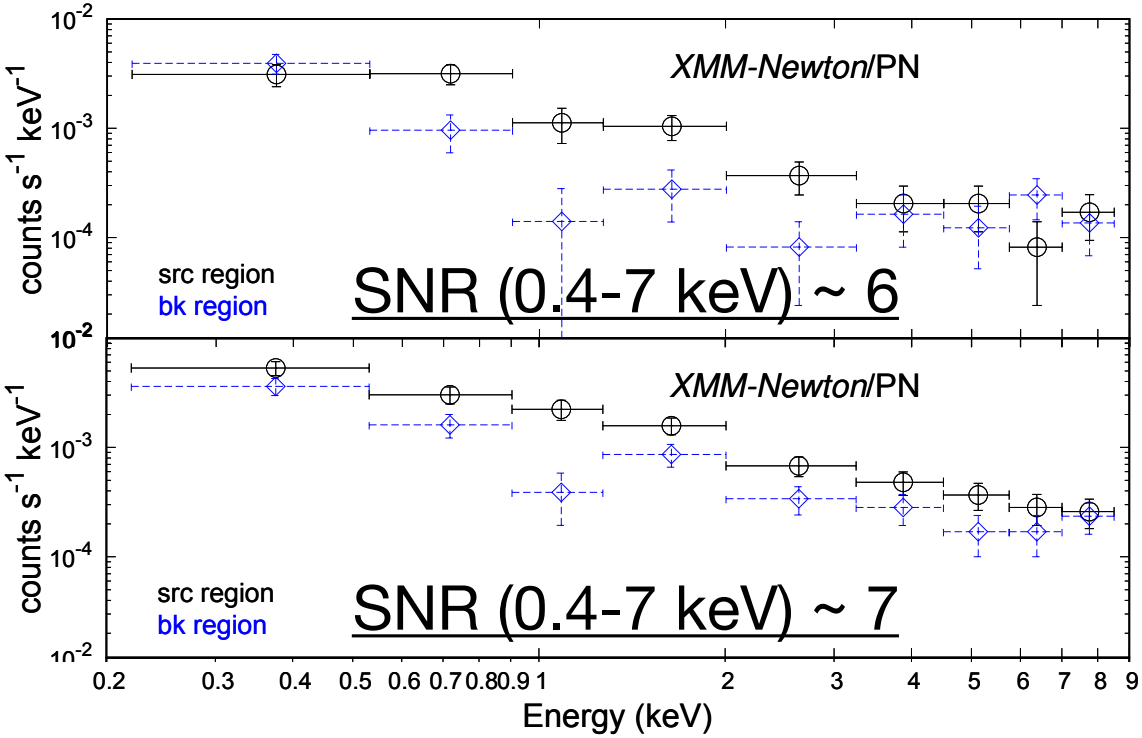


(NuSTAR observatory guide)

Soft X-ray emission from XMM-Newton

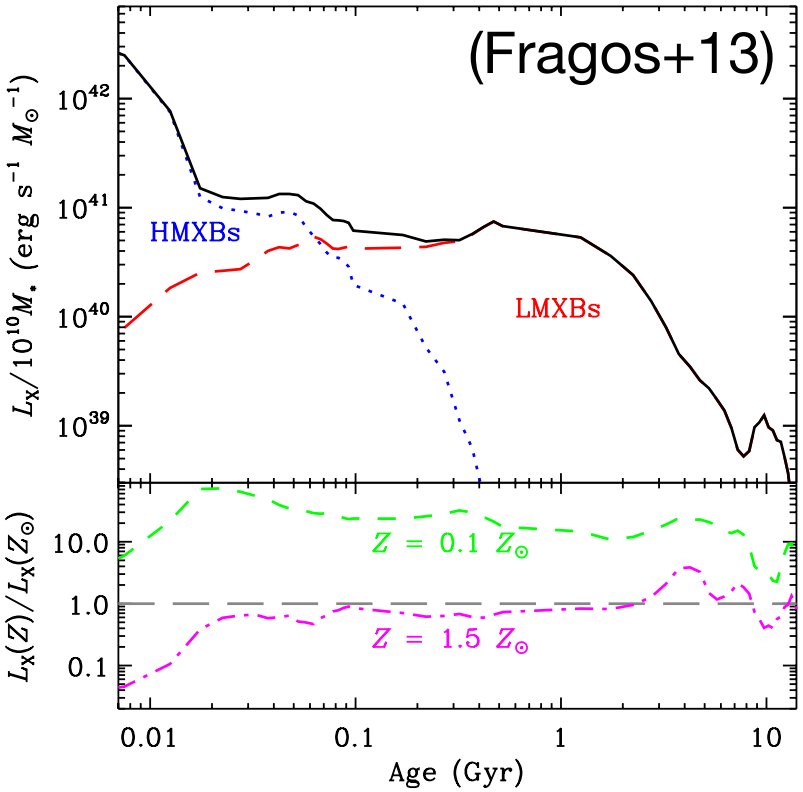
+ Significant soft X-ray emission was detected in both the GPs.
+ X-ray luminosities of ~10^{42} erg s^{-1} are comparable to those of low-luminosity AGNs.

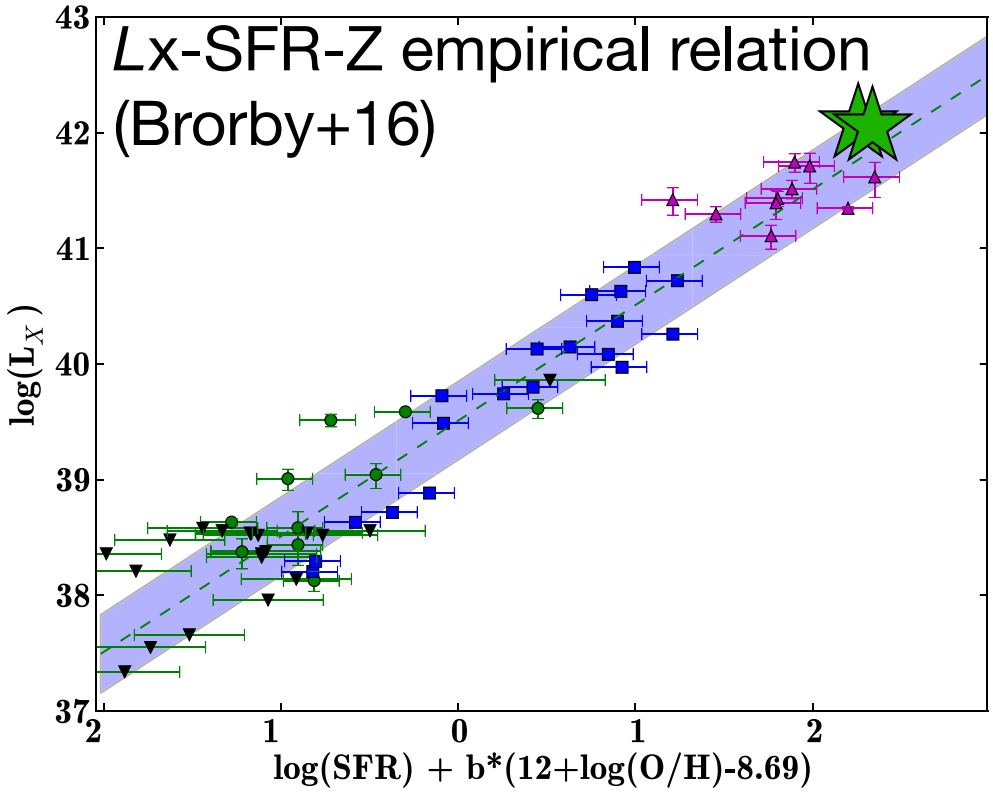




Soft X-ray emission from XMM-Newton

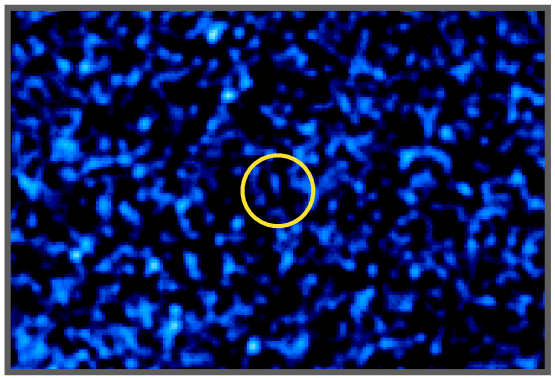
+ Significant soft X-ray emission was detected in both the GPs.
+ X-ray luminosities of ~10^{42} erg s^{-1} are comparable to those of low-luminosity AGNs.
+ ***However***, it may be ascribed to emission from the SF.
  - low metallicity and young galaxies may have enhanced soft X-ray emission from HMXBs.
  - Because of low metal, inefficient outflow leads to the massive XRBs, or X-ray luminous populations (e.g., Fragos+13)

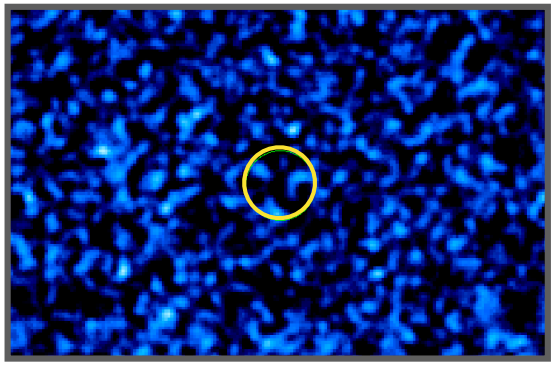


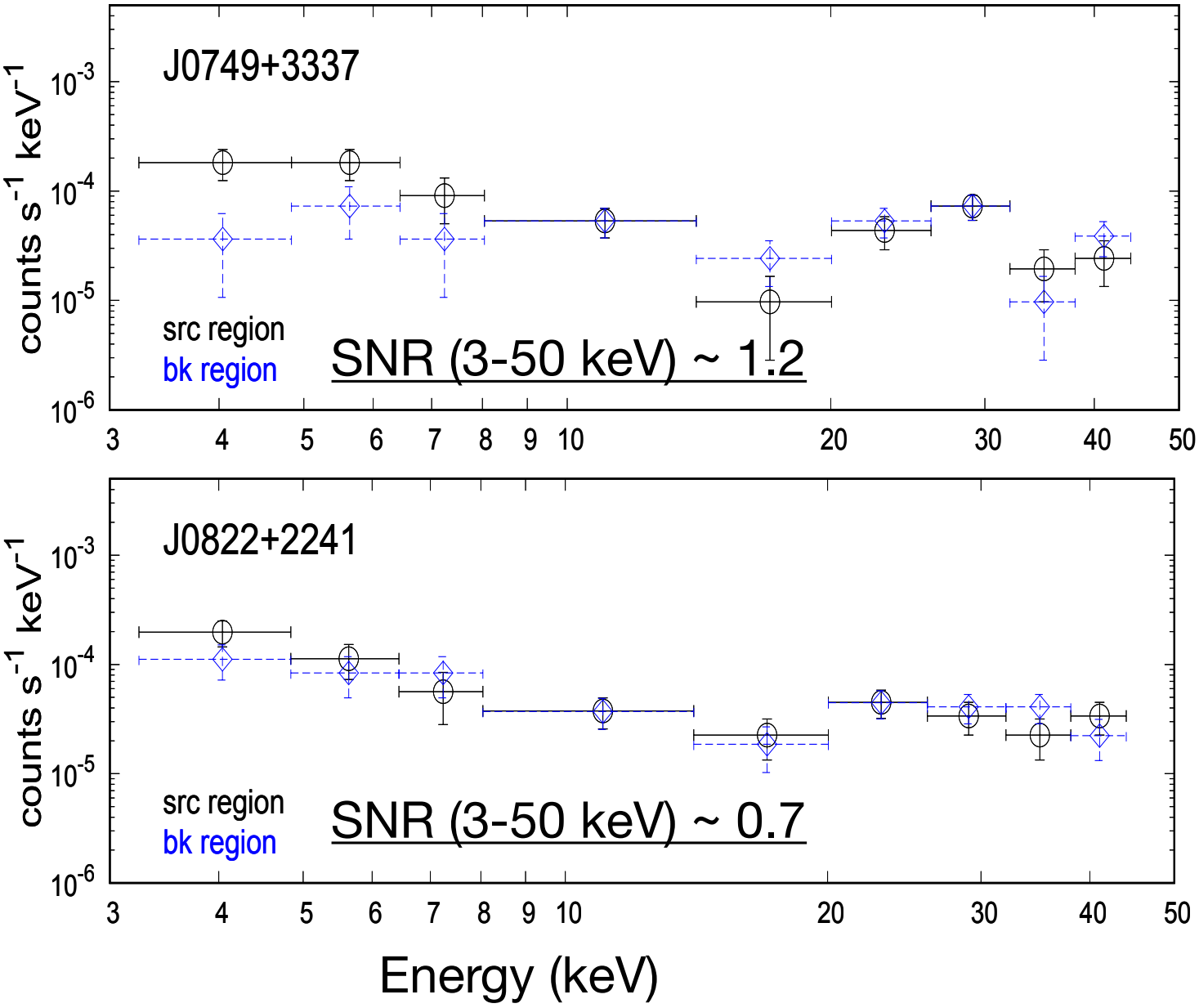


Insignificant hard (> 10 keV) emission

+ Even the most sensitive hard X-ray observatory of *NuSTAR* cannot detect X-rays, direct evidence for the presence of an AGN







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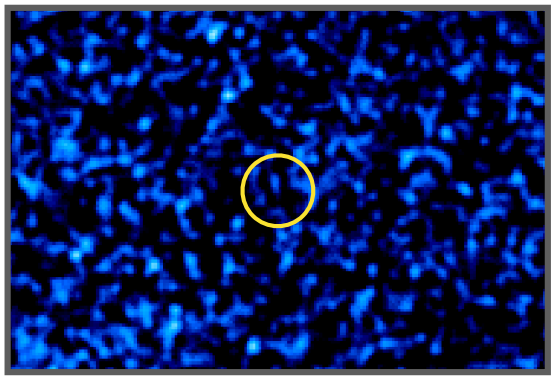

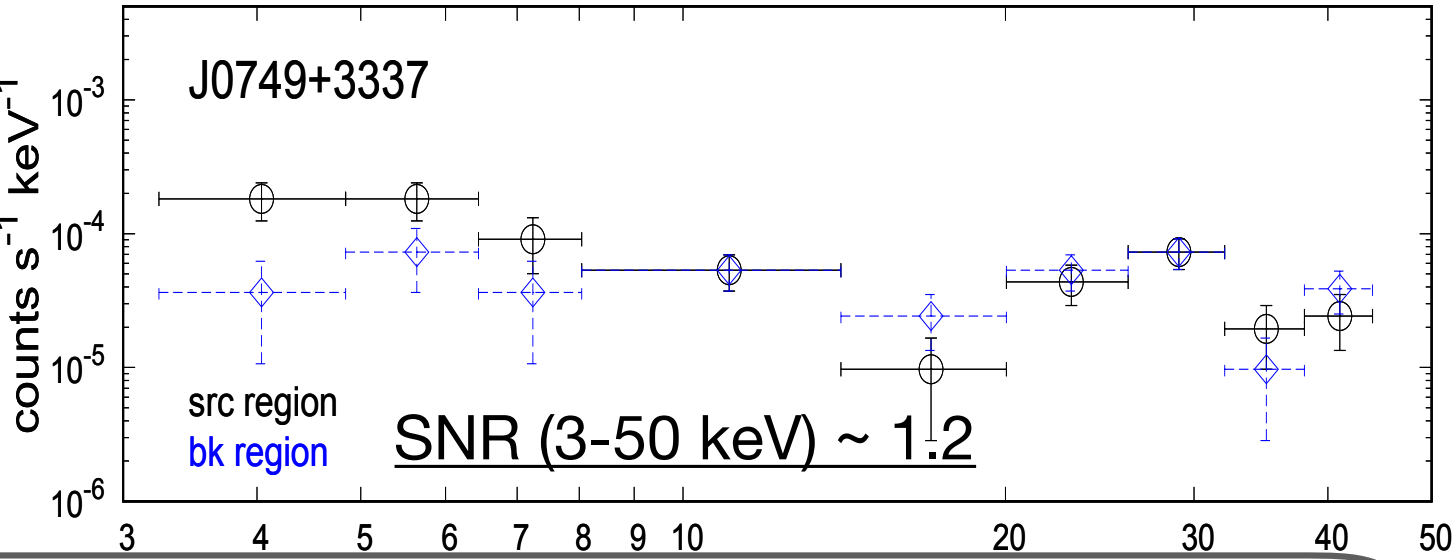

(1) **No AGN exist**, thus suggesting that low stellar-mass have AGN-like MIR properties.

However, …

(2) **Heavily obscured AGNs w/ N_H > 2e+24 may be present**, but cannot be detected even in the hard X-ray band.

Summary

+ The BH fraction is a clue to distinguish b/w the BH seed scenarios. → Need to built an unbiased AGN sample.

+ IR and optical data of representative low stellar-mass GPs are controversial for the presence of an AGN.
→ X-ray observations !

+ We analyzed the first broadband X-ray data of two GPs by using XMM-Newton and NuSTAR.
- Soft X-ray emission was found but may be ascribed to SF.
- Hard X-ray emission was not found.

+ Indeed, two possibilities still remain unfortunately…

(1) **No AGN exist**, thus suggesting that low stellar-mass have AGN-like properties.
We may need to care about this fact in studying such objects.

(2) **Heavily obscured AGNs are present**, but cannot be detected even in the hard X-ray band.