The High Energy X-Ray Probe (HEX-P)
Probing the Dusty Hearts of Dual AGN

Ryan W. Pfeifle[1,2], Peter Boorman[3], Kimberly Weaver[1], Francesca Civano[1], Emanuele Nardini[4], Dominic Sicilian[5], Daniel Stern[3], Javier Garcia[3], Labani Mallick[3], & the HEX-P Team

Overview:

HEX-P is a probe-class mission concept that will combine high spatial resolution X-ray imaging (<10 arcsec FWHM) and broad spectral coverage (0.1-150 keV) with an effective area far superior to current facilities (including XMM-Newton and NuSTAR), to enable revolutionary new insights into a variety of important astrophysical problems. *A fundamental goal of modern-day astrophysics is to understand the connection between supermassive black hole growth (SMBH) and galaxy evolution. Merging galaxies offer one of the most dramatic channels for galaxy evolution known, capable of driving inflows of gas into galactic nuclei, potentially fueling both star formation and central SMBH activity. Dual AGNs in late-stage mergers are thus ideal candidates to study SMBH growth along the merger sequence by coinciding with the most transformative period for galaxies. However, dual AGNs can be extremely difficult to confirm. Hard X-ray studies offer a relatively contamination-free option for probing the dense obscuring environments predicted to surround the majority of dual AGN in late-stage mergers. But to date only a handful of the brightest and closest systems have been studied above 10 keV due to the demanding instrumental requirements involved. In this poster, we present a HEX-P simulation-based study with the Simulated Observations of X-ray Sources (SOXS) software package to address this issue. We demonstrate the unique capabilities of HEX-P to spatially resolve the soft and - for the first time - hard X-ray counterparts of closely separated dual AGNs in the local Universe. By incorporating state-of-the-art physical torus models, we realistically reproduce the broadband X-ray spectra expected for such deeply embedded accreting SMBHs. Hard X-ray spatially resolved observations of dual AGNs – accessible only to HEX-P – will hence transform our understanding of dual AGN in the nearby Universe and will complement next-generation optical and infrared observations from upcoming Extremely Large Telescopes over the next two decades.* ***More information on HEX-P, including the full team list, is available at https://hexp.org.***

Simulations with SOXS and SIXTE

SOXS for simput generation

We simulate AGNs with: 1) An absorbed power law that accounts for Compton scattering and reprocessed emission from a torus (self consistently accounts for Fe K emission); 2) two temperature thermal components to model soft X-ray emission due to star formation; 3) a power law to model scattered AGN emission (0.5%).

AGN Spectroscopic Model

tbabs(borus+ztbabs*cabs*cutoffpl+const*cutoffpl+apec+apec)*

AGNs 1 and 2 have 2-10 keV fluxes normalized to 5.e-14 and 1.e-13 erg/cm^2/s
log(N_H/cm^2) = 22-24 for each AGN
z = 0.05 | θ_{view} = 70° | Covering Factor = 50%
Spectra convolved with spatial point source models to generate a simput file for a given dual AGN pairing.
AGN separations range from 0'' to 50''

SIXTE for event file, image, and spectrum generation

50 ks exposure event files generated for each AGN pairing: HET1 and HET 2, effective 2-camera HET, and LET.
WCS coordinates assigned to event files. Images generated for all three cameras.
Spectra extracted using 10'' apertures for each AGN.

Do you have ideas for how HEX-P would revolutionize your science? Get in touch!

hexp.future@gmail.com
ryan.w.pfeifle@nasa.gov

hexp.org
https://thatastroguy.github.io

@HEXP_Future
@RyanPfeifle

HET and LET Imaging of Dual AGNs

Fig. 1 and 2 show how HEX-P HET and LET imaging will resolve hard X-ray dual AGNs with separations down to ~5''. Source detection algorithms, such as *wavdetect* may be able to detect distinct AGNs with separations 1''< θ <5''.

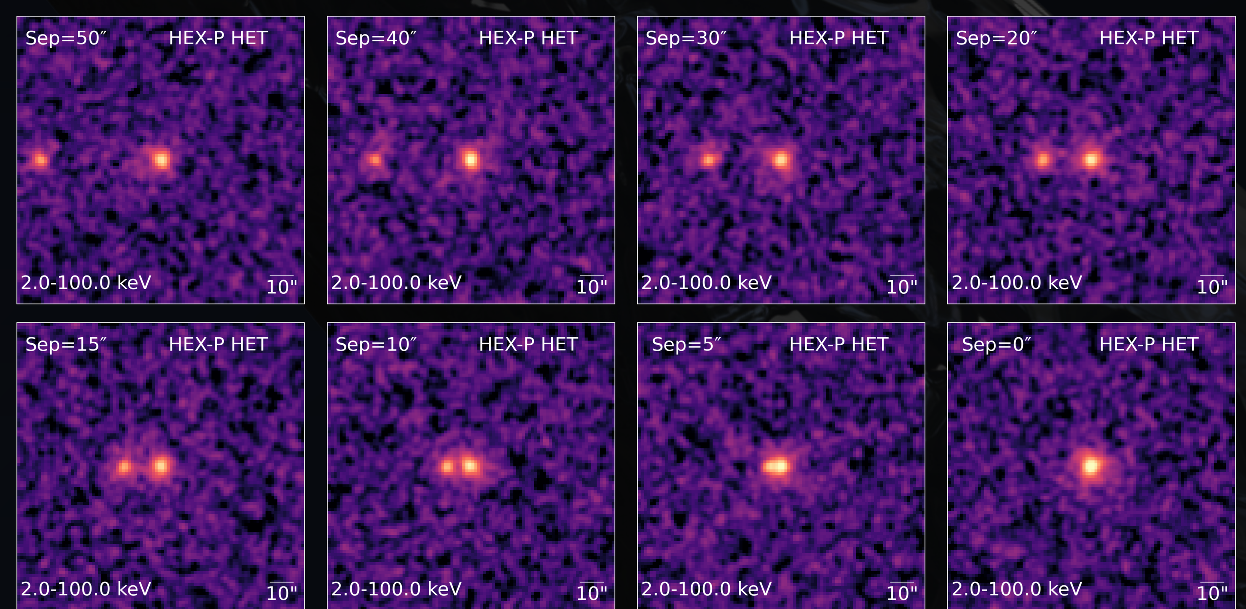

Figure 1: This 8-panel figure shows the effective 2-camera HET 2-100 keV, 50 ks images (1-pixel smoothing), and each panel represents angular separations ranging from 50'' down to 0''.

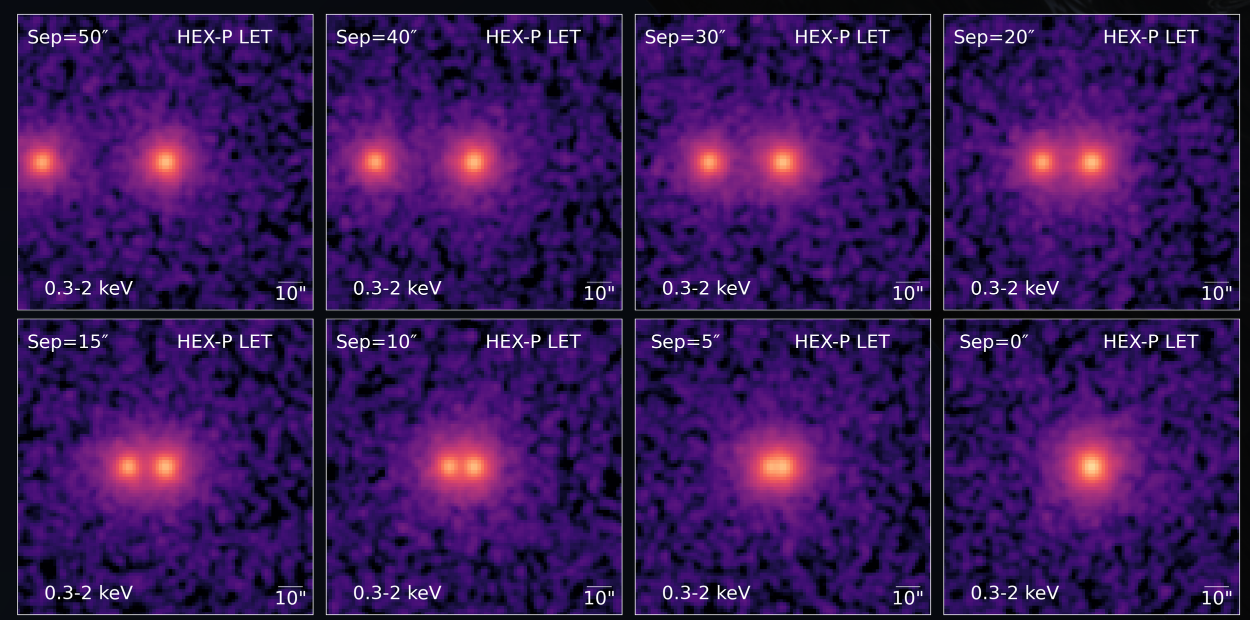

Figure 2: This 8-panel figure shows the LET 0.3-2 keV, 50 ks images (1-pixel smoothing), and each panel represents angular separations ranging from 50'' down to 0''.

A Substantial Improvement over NuSTAR

As Fig. 3 shows, analogous NuSTAR imaging cannot resolve <20'' dual AGNs. AGNs separated by 20'' and 0'' are essentially indistinguishable. The >20'' dual AGNs can be resolved, but these simulations do not account for the NuSTAR background; with background included, the weaker AGN may be undetectable.

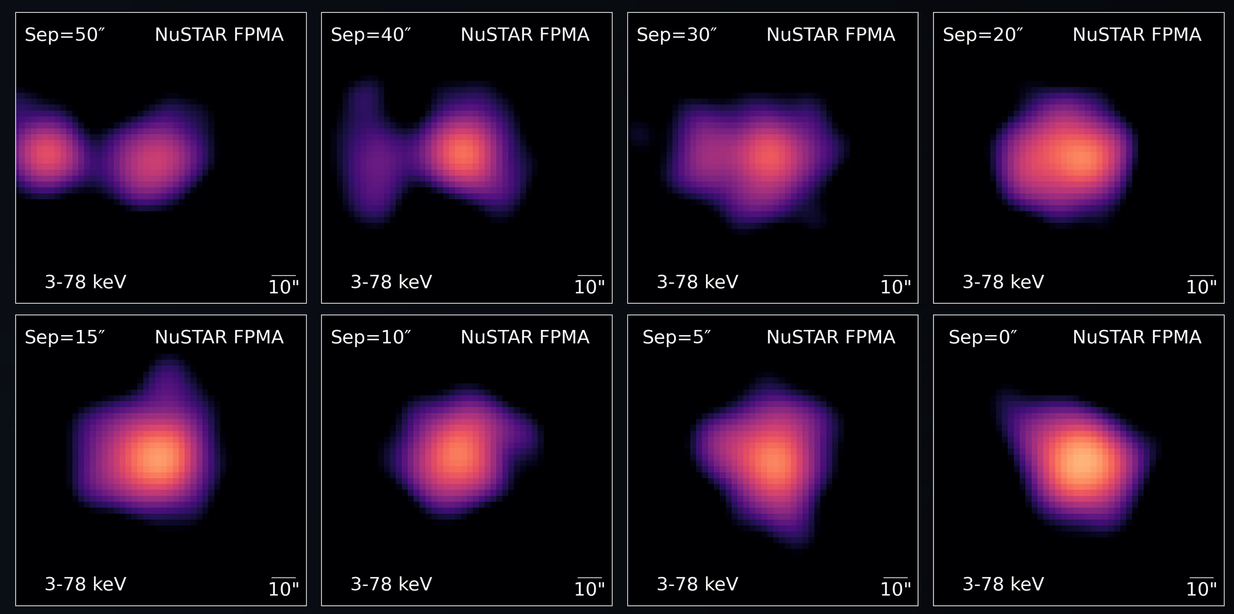

Figure 3: NUSTAR 3-78 keV, 50 ks images (3-pixel smoothing), and each panel represents angular separations ranging from 50'' down to 0''.

Spectroscopic Fitting

Here we show two examples of basic fits to the individual spectra of the two AGNs (separated by 10'').

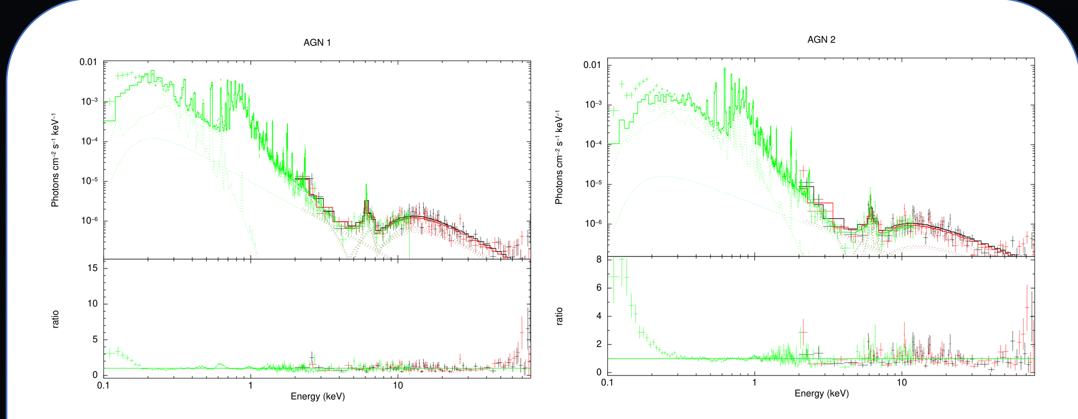

Fig. 4: Basic spectroscopic fits to the two AGNs, where the separation was 10''. Both AGNs in this case were simulated to be Compton-thick with N_H=10^{24} cm^{-2}.

In the above panels, the data were fit with the original input model. In both cases, the photon index, column densities, and other parameters are similar to the inputs, but often over- or underestimated (ex. $\Gamma\approx1.5$ for both, but $N_H\approx1.4\times10^{24}$ cm^{-2} for AGN 1 and $N_H\approx8\times10^{23}$ cm^{-2} for AGN 2). Careful modeling will be required using tools like BXA (Buchner et al. 2014)

Careful Modeling Required for Close Pairs

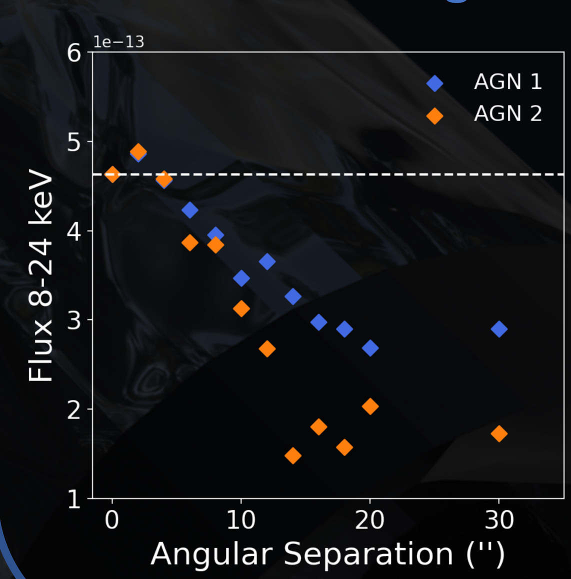

Fig. 5: 8-24 keV observed flux of AGN 1 and 2 as a function of pair separation. Fluxes are derived from spectra extracted using 10'' apertures.

This figure serves as a proxy for spectral contamination. As the two AGNs get closer, they contribute more to each other's observed flux. Notice the large jump in the observed fluxes at 10''-12'', particularly for the weaker AGN. This is expected, given the 10'' apertures, but it demonstrates that the individual spectra will have significant contributions from both AGNs at separations <10'', despite our ability to visually resolve them in imaging.

Conclusions and Ongoing Work

The results of these simulations so far can be summarized as follows:

- The spatial resolution of HEX-P HET imaging will allow us to resolve dual AGNs down to ~5'' (~4.9 kpc at z=0.05)
- In concert with LET and detection algorithms like *wavdetect*, it may be possible to detect the presence of dual hard X-ray sources at separations 1'' < θ < 5''.
- HEX-P imaging will enable broadband studies of dual AGNs via their hard X-ray emission as well as the study of the host stellar populations via the observation of hot thermal components in the soft X-rays, often observed in dual AGNs.

Further simulations will examine spectra that involve varying the viewing angle and covering factors.

HEX-P
HIGH ENERGY X-RAY PROBE

[1]NASA Goddard Space Flight Center, [2]Oak Ridge Associated Universities, [3]California Institute of Technology, [4]INAF-Arcetri, [5]Miami University