Probing the Lifecycle of Nearby Galactic Nuclei via High-resolution X-ray Imaging and Spectroscopy

When was the last AGN on?

How bright was it?

What is the time interval between episodes?

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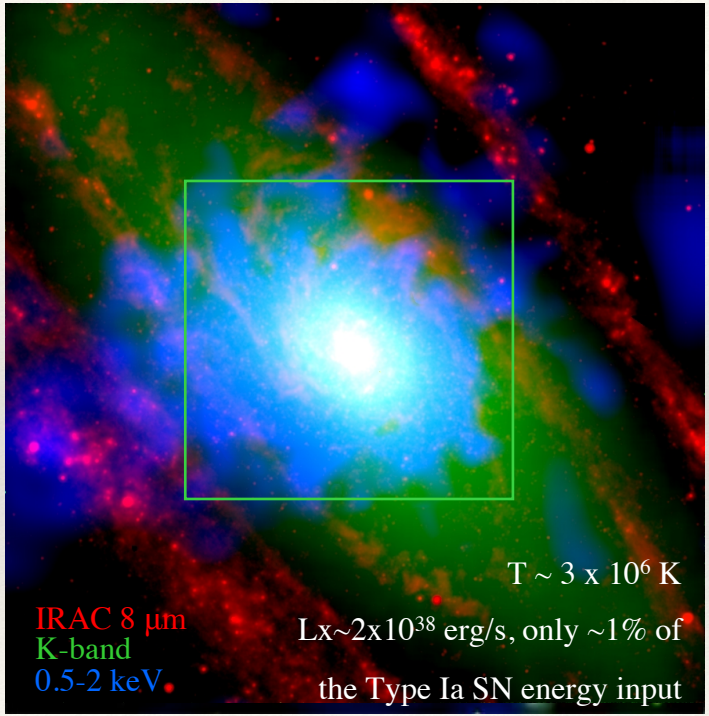
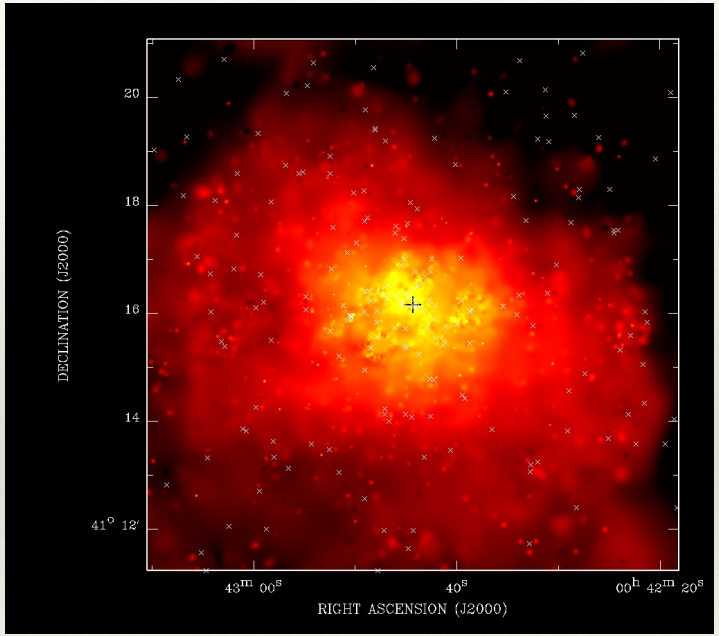
In collaboration with

Shuinai Zhang, Shawn Roberts, Yang Chen, et al

Chandra ACIS images of the M31 bulge

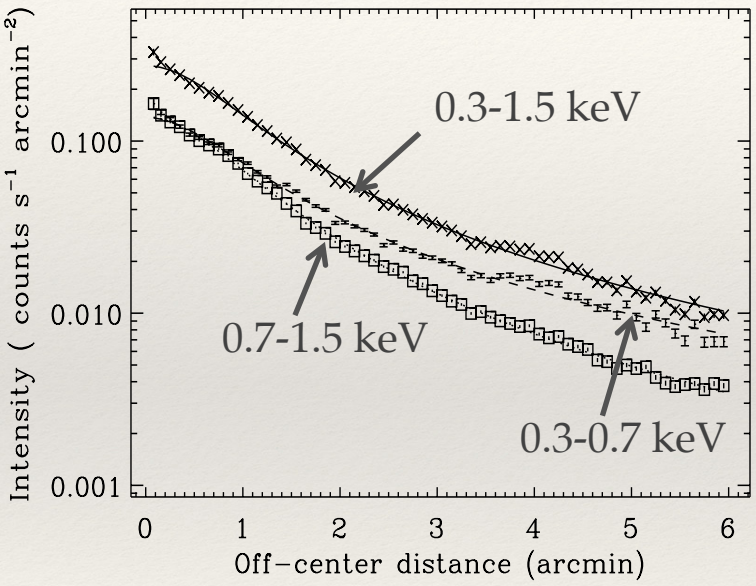


Li & Wang (2007)



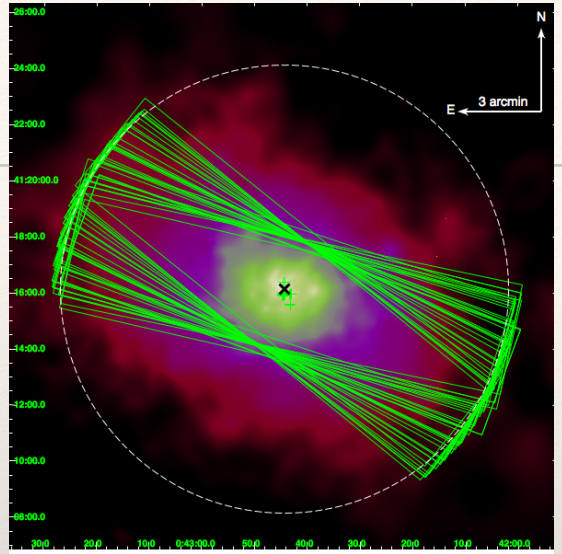
Stacked ACIS-S observations (380 ks total) with (un)detected sources (e.g., including CVs and ABs) removed.

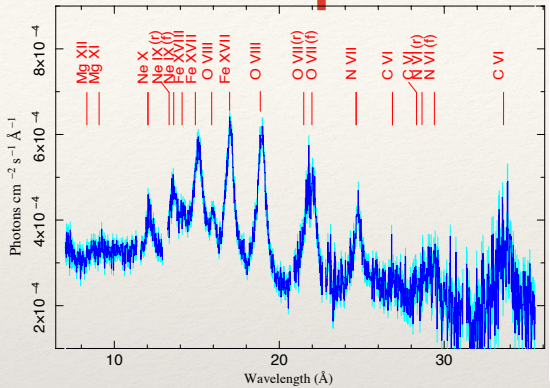
Diffuse soft X-ray radial intensity profiles

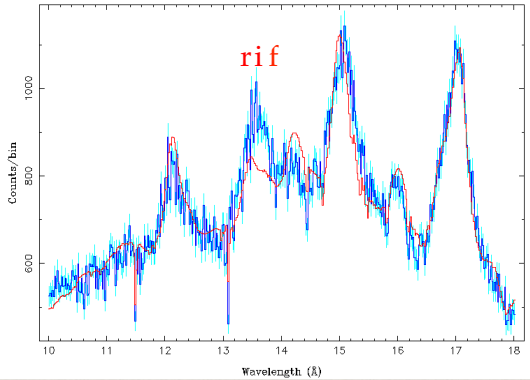


- 0.3-0.7 keV emission is more extended than in 0.7-1.5 keV one → recent central heating and/or resonance scattering (RS) of OVIII and OVII r lines.
- Fit this emission in the 0.3-0.7 keV band with the β-model → the radial density profile of hot plasma, assuming spherical symmetry.

XMM-Newton spectroscopy

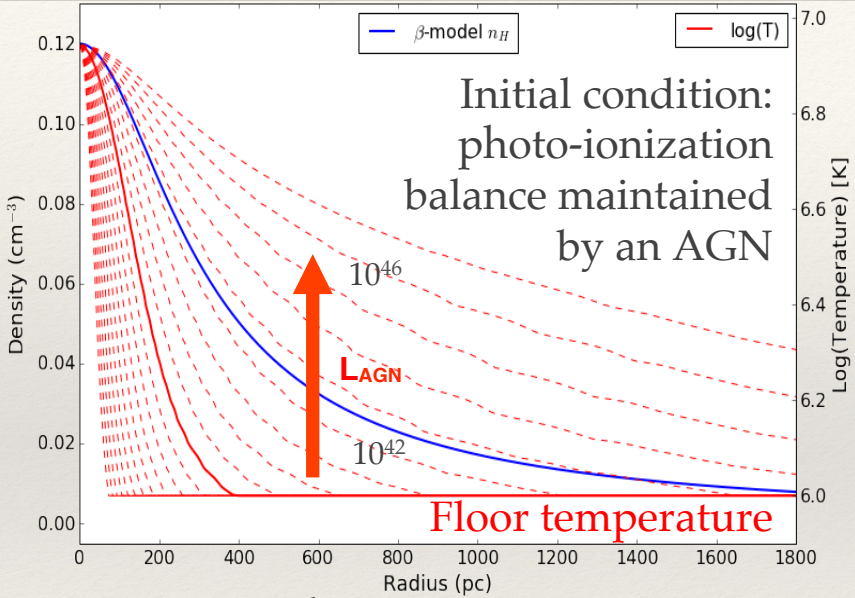


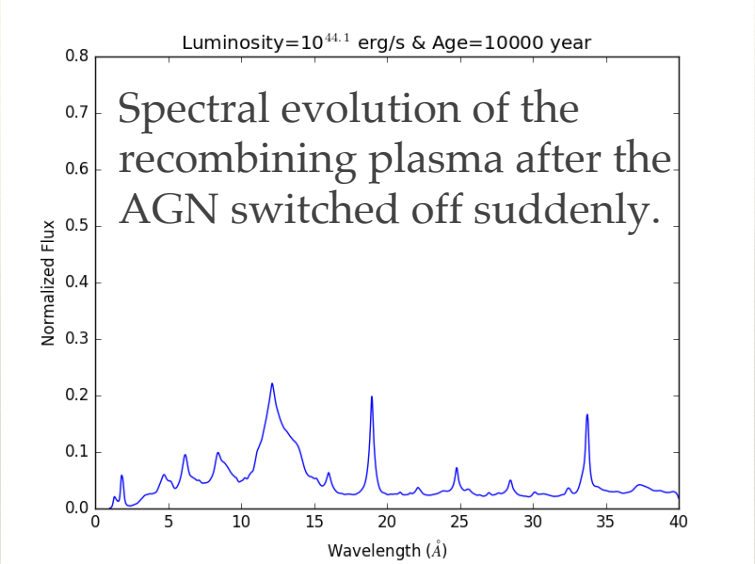




- Stack RGS spectrum from 36 observations (total 766 ks)
- Diverse emission lines → temperature range: kT ~ 0.1-0.7 keV
- Large f/r line ratios of the OVII and NeIX Kα triplets → non-optically-thin (e.g., RS) and/or non-CIE (e.g., recombining) plasma

AGN relic model



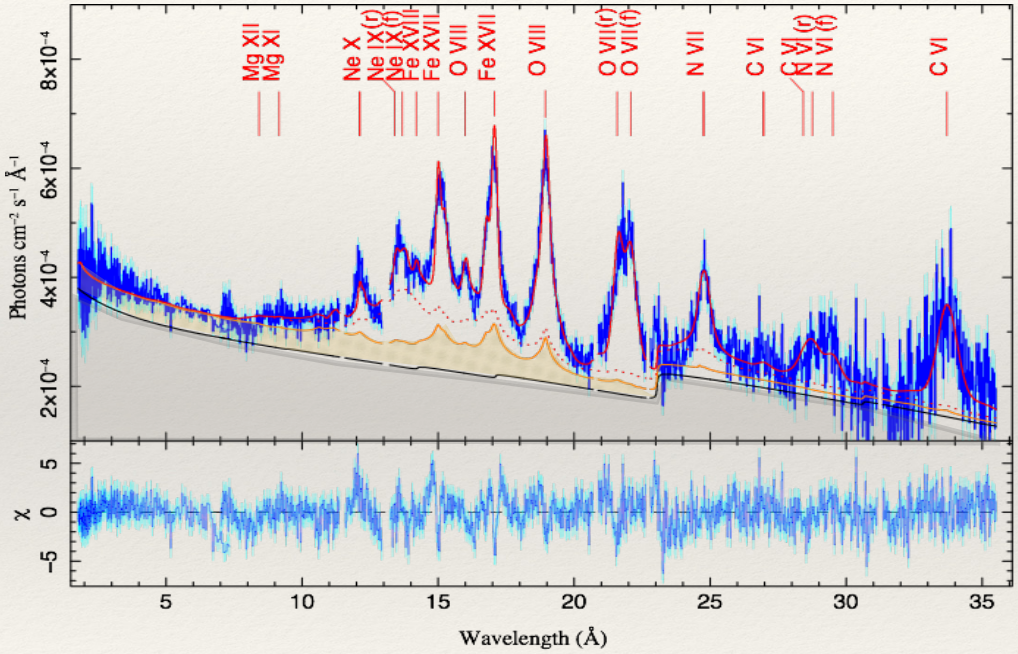


Assuming the β-model density profile; Cloudy → photo-ionization equilibrium of the AGN; AtomDB NEI code → evolution of its relic.

Free parameters: metal abundances, ionizing L_{AGN} and relic age t

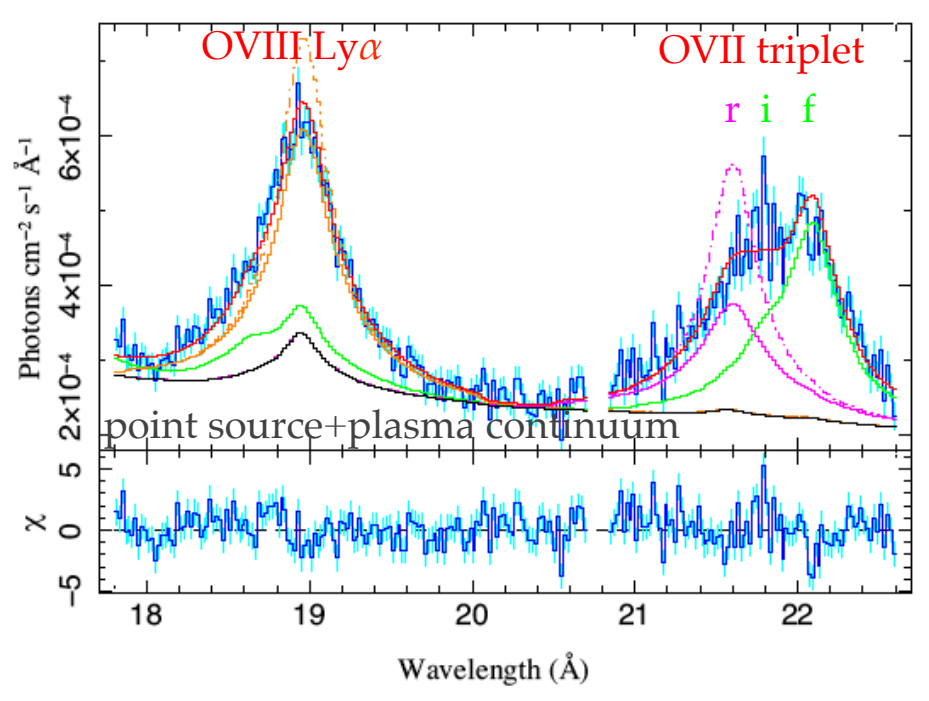
Zhang, Wang, et al. (2017)

AGN relic model fit to the RGS spectrum



- $L_{AGN} \sim 10^{44}$ erg s^{-1}
- t ~ 0.4 Myr
- Abundance: C=0.3, N=0.8, O=0.4, Ne=0.3, Fe=0.9 solar
- Hot plasma spatial extent and resonance line scattering explain the line widths
- The model may also explain extended radio emission observed in the inner bulge

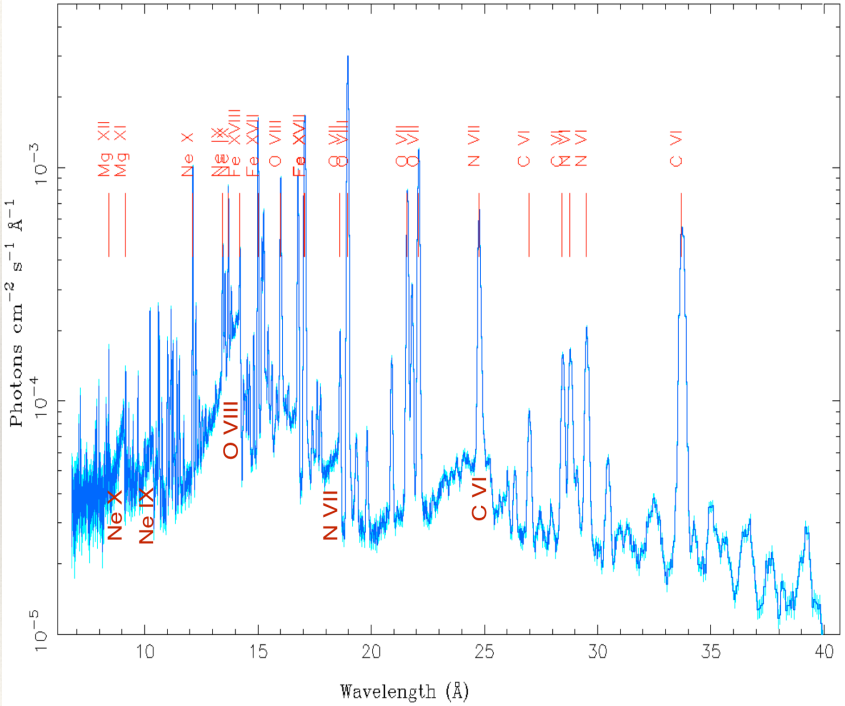
Plasma+RS model of the OVIII/OVII complex



Chen, Wang, et al. (2017)

- RS → spatial and energy broadening of the line emission → RGS line broadening.
- This + limited spectral extraction region → weakening of the line.
- The best-fit of Monte-Carlo simulations to the complex → isotropic turbulent Mach number ~ 0.17, or velocity dispersion 40 ± 4 km s^{-1} for T~ 2.3 x 10^6 K.

Prospects for the circumnuclear medium study

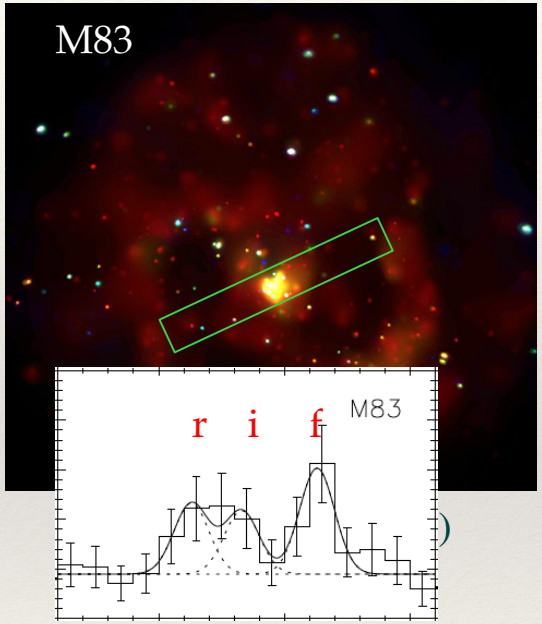


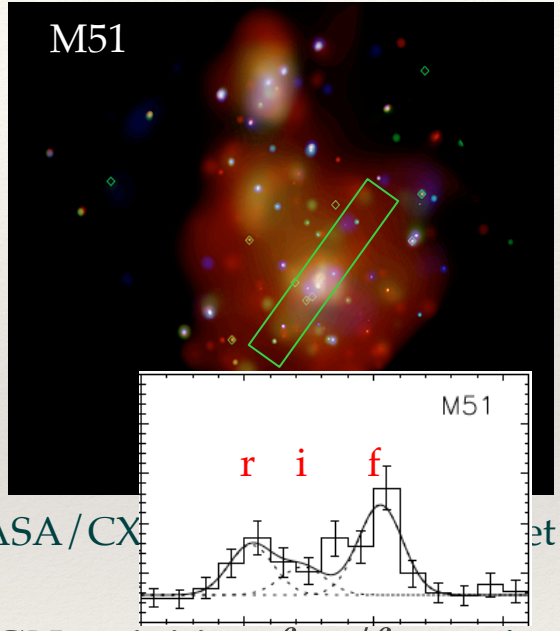
Predicted Athena spectrum of the M31 bulge

- The combination of the high spatial and spectral resolution, as well as the high throughput, as would be provided by *Lynx*, will provide the ultimate tool:
- Significant point source removal
- Spatially-resolved spectroscopy
- Bulk and turbulent motion
- Explore interface physics.

→ Structure and dynamics, as well as ionization and chemical properties

RGS Survey of star forming galaxies: examples





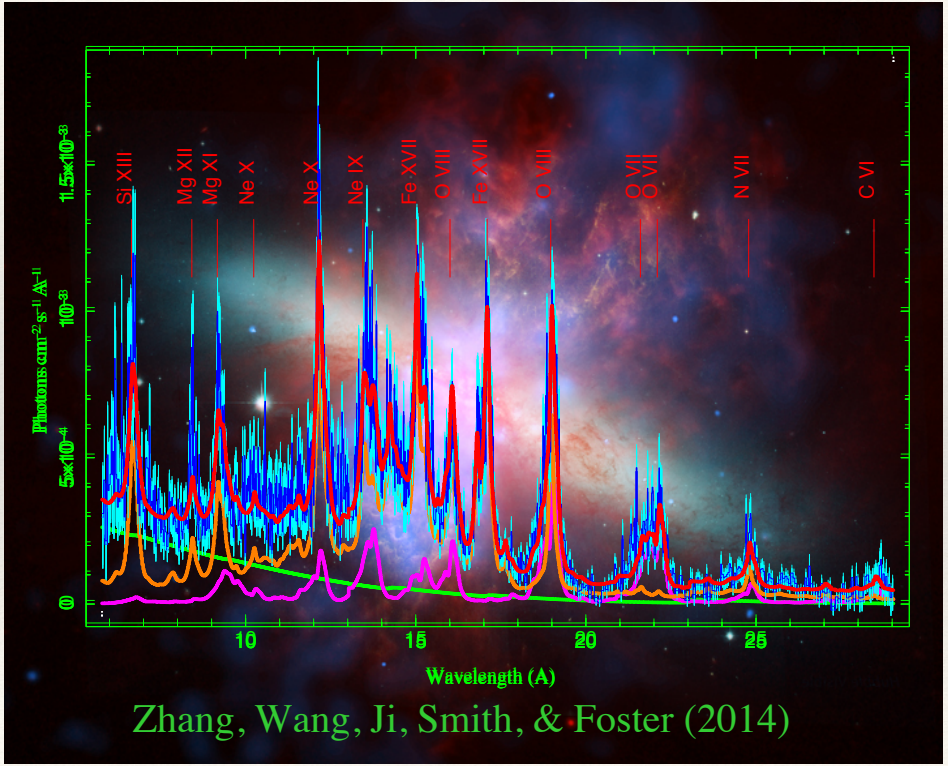
NASA/CX

et al.)

- Little evidence for significant recent AGN activities; $f_{\mathrm{OVIII}}/f_{\mathrm{OVII}}$ ratios are similar to star bursts than AGNs
- Soft X-ray are spatially correlated with star forming regions

Liu, Wang, Mao (2012)

M82: Plasma+CX spectral modeling



Zhang, Wang, Ji, Smith, & Foster (2014)

- Naturally explains the spatial correlation between hot and cool gas tracers.
- CX is proportional to the ion flux into the hot/cold gas interface.
- Accounting for the CX is important to determining the thermal and chemical properties of the hot plasma.

Conclusions

- X-ray spectroscopy can be used to probe AGN relics → AGN history.
- Recombination time scale of hot plasma is > 10^5 yrs in the bulge or longer in outer regions of a galaxy.
- If the time interval between AGNs is < 10^6 yrs or so, the plasma would never reach a CIE state!
- Resonance line scattering and charge exchange also seem to be common processes and can be use to probe the kinematics and interphase physics!