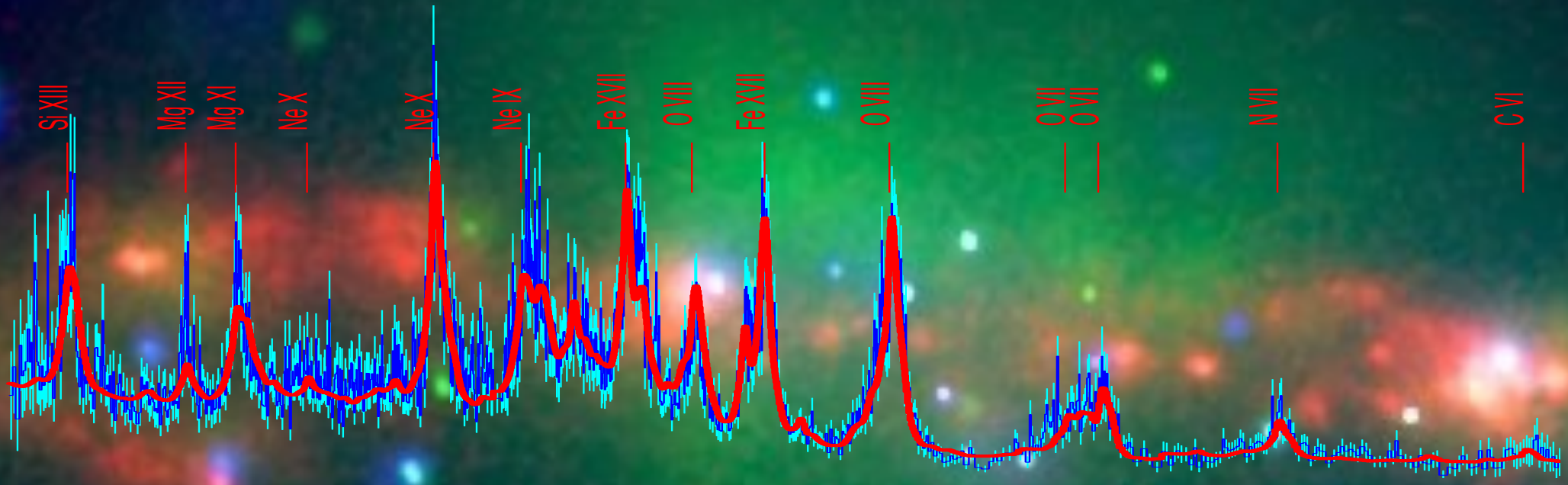
Stellar/AGN feedback in nearby disk galaxies: XMM-Newton/RGS emission line diagnostics



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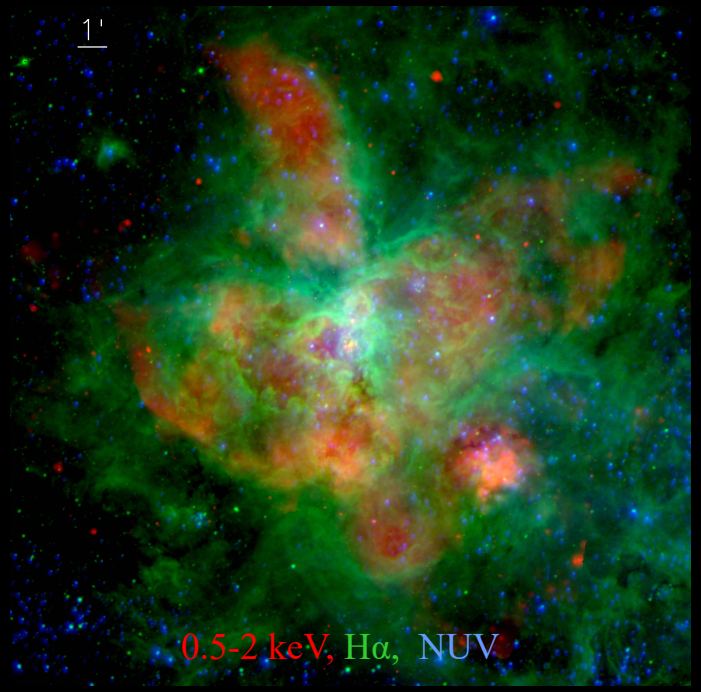
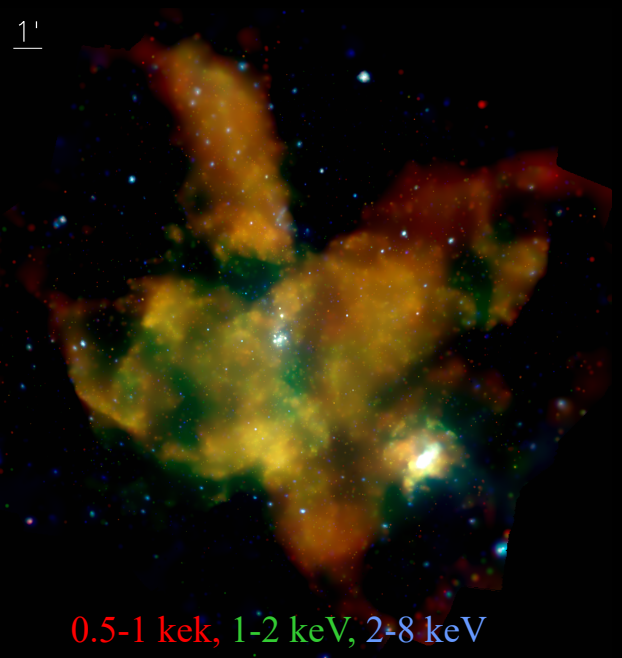
Stellar feedback in 30 Dorado





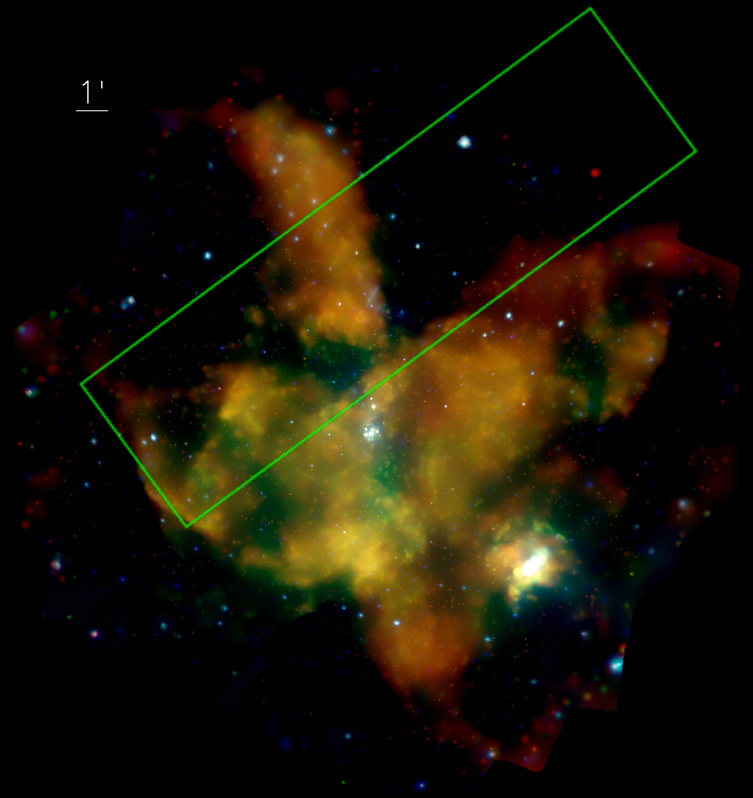
- The brightest HII region in the Local Group of galaxies.
- In the LMC at 50 kpc and with little line-of-sight confusion.
- Powered primarily by the well-studied central OB association.
- The age and IMF are studied in spatially resolved fashion.
- Chemically a closed box.

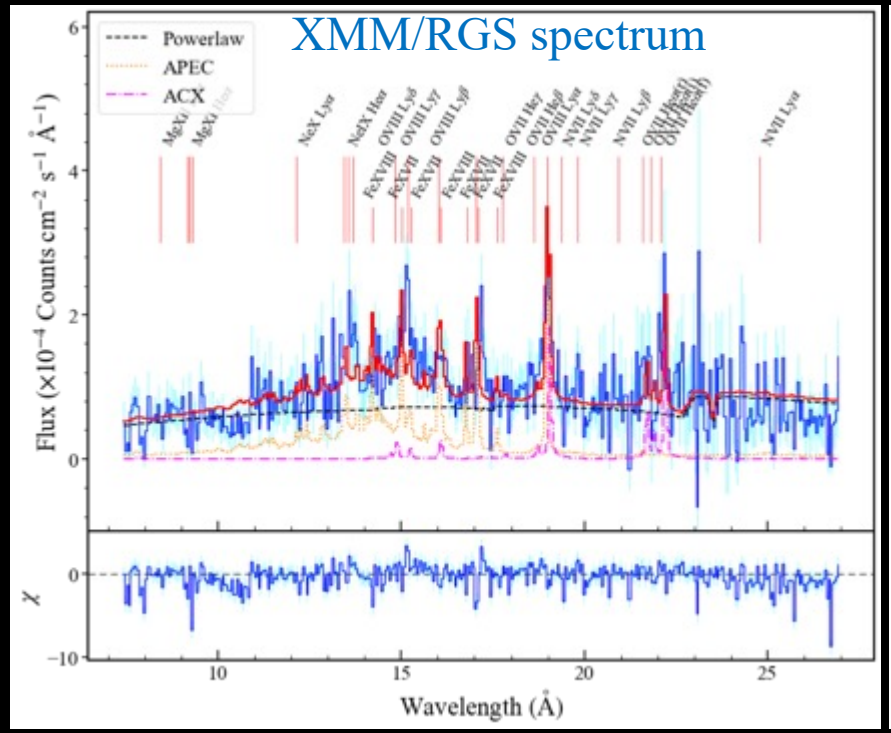
Chandra and Suzaku results:

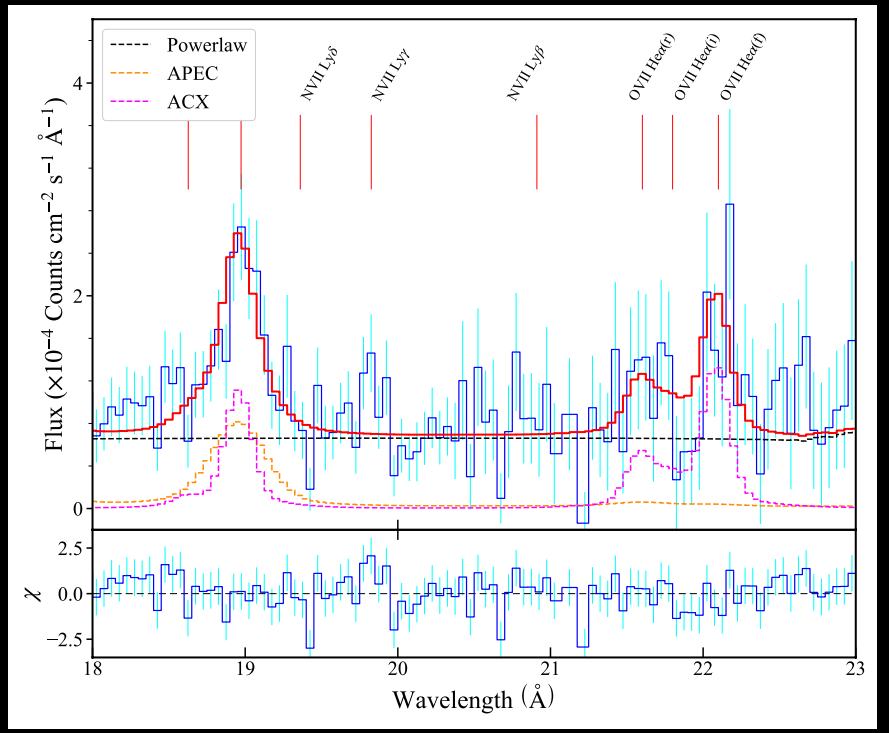
- Hot plasma is not isothermal; a log-normal temperature distribution is a good approx.
- 80% mass-loading from the ISM explains both the mass and the metal abundances of the plasma.
- The thermal+kinetic energies of the nebula is comparable to the mechanical input.
- Evidence for nonthermal diffuse X-ray emission, especially in the central region.

Cheng, Wang.& Lim (2021)

Evidence for charge exchange in 30 Dorado



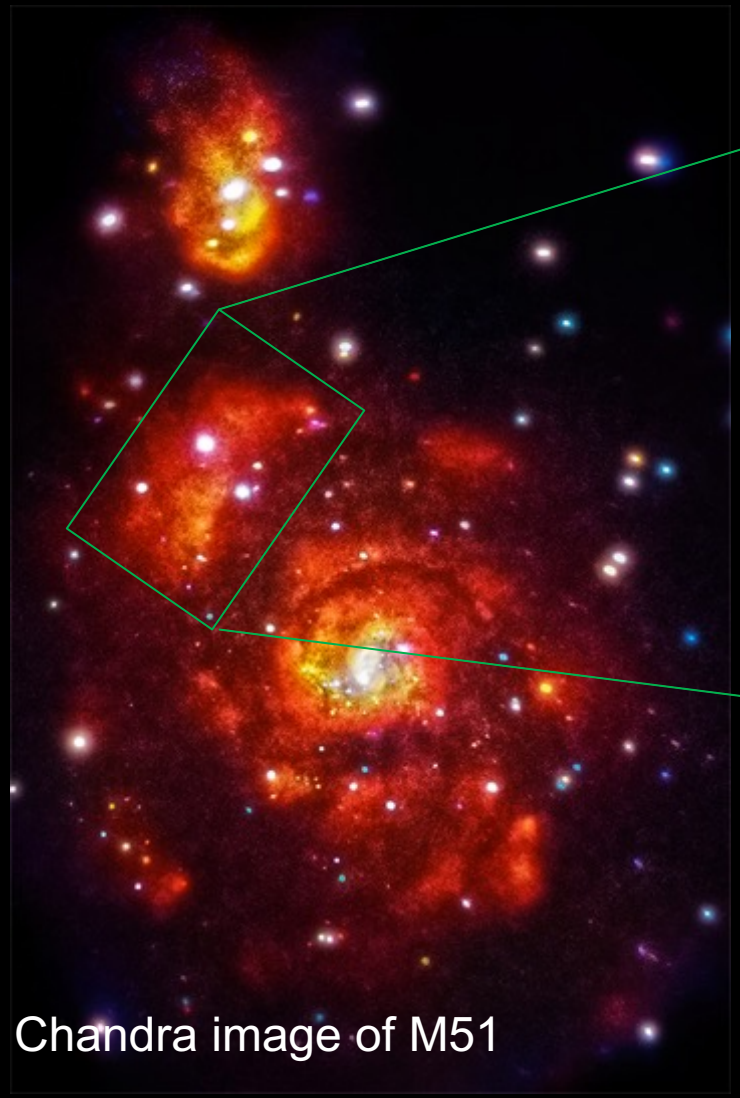




- Large G =(f+i)/r ratio of the OVII Kα triplet is inconsistent with the CIE assumption
- APEC+CX model gives a good fit to this XMM/RGS spectrum

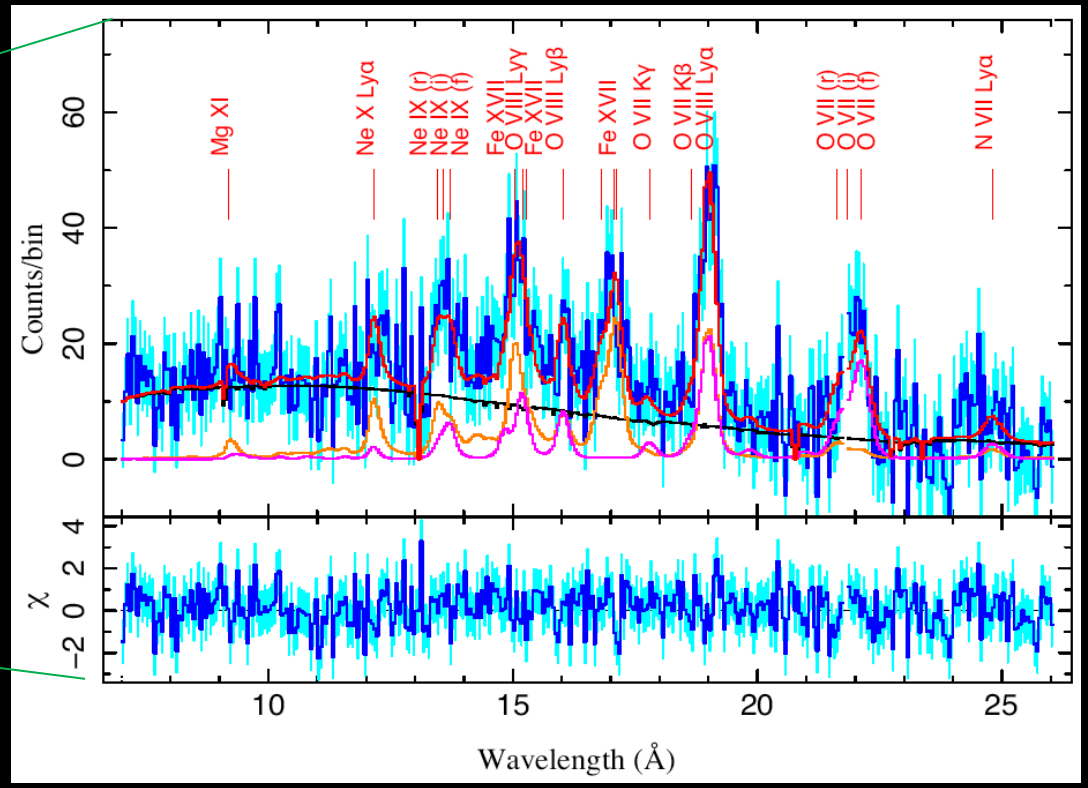
Wang+ 2023 (in prep)

Charge exchange is ubiquitous in star-forming regions



Chandra image of M51

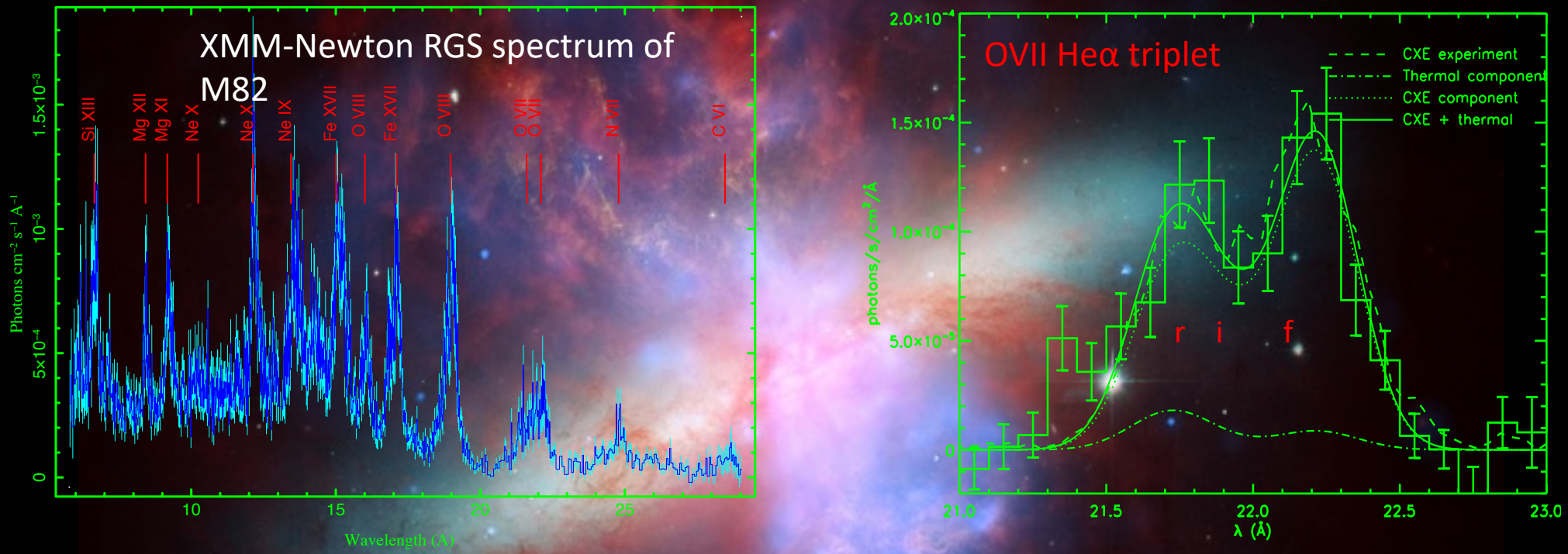
Zhang,Wang+ (2022)



- Large G-ratios of He-like Kα triplets cannot be due to pure CIE plasma emission.
- APEC+CX model gives a good fit to this XMM/RGS spectrum of 210 ks exposure.

Evidence for charge exchange in M82

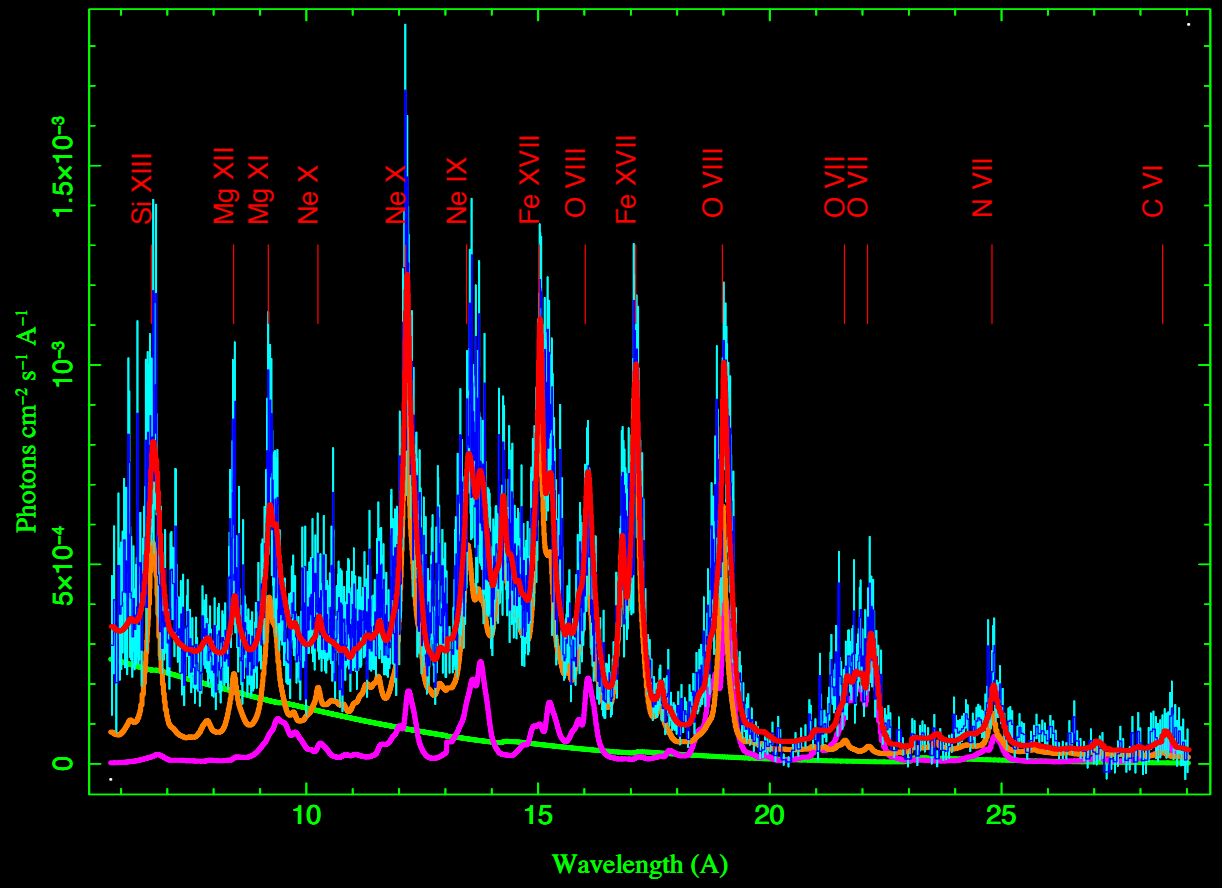
Soft X-ray arises at least partly from the interplay between hot plasma outflow and entrained cool gas, as part of the mass-loading process



G =(f+i)/r ratios of He-like Kα triplets are far too large to be consistent with optically-thin CIE plasma emission.

Liu, Mao, & Wang (2011); Zhang, Wang, et al. (2014)

Thermal plasma + CX modeling of the spectral line emission

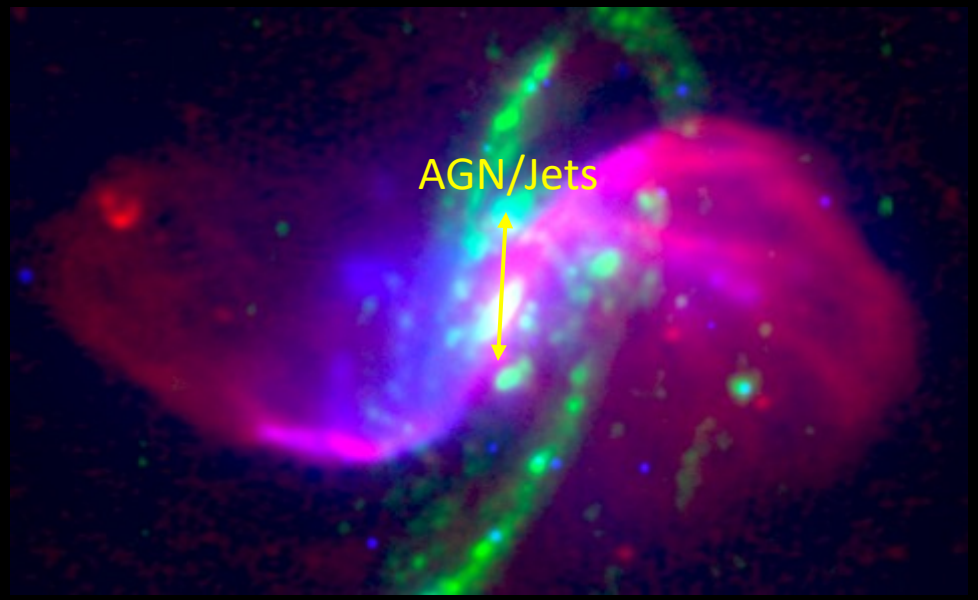


Zhang, Wang, Ji, Smith, & Foster (2014)

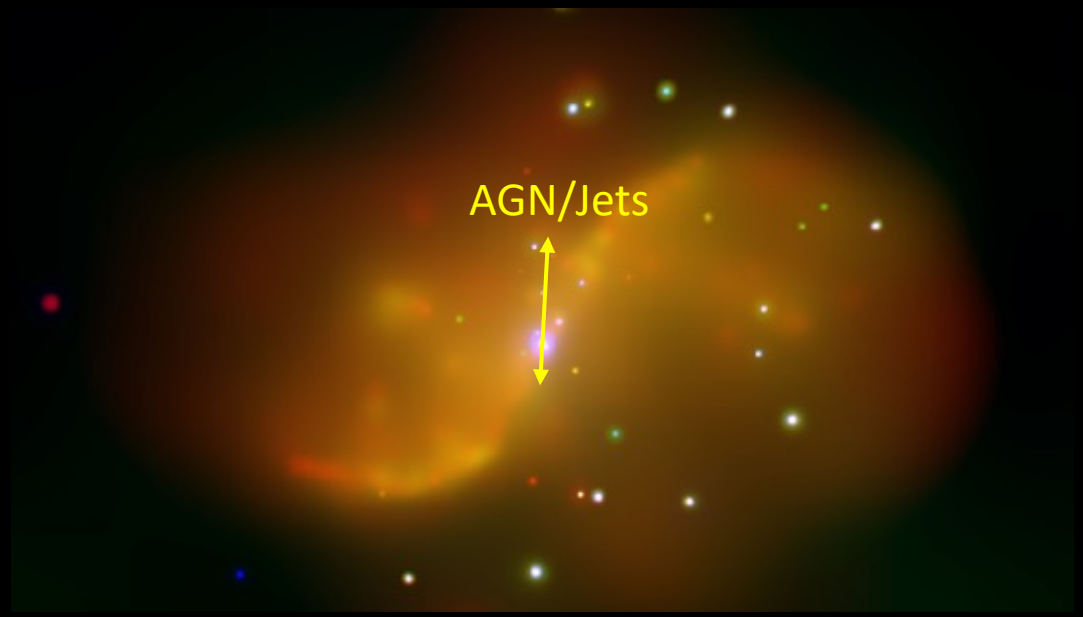
- Explains the spatial correlation between hot and cool gas tracers.
- Accounting for the CX is important to determining the thermal and chemical properties of the hot plasma.
- CX is proportional to the ion flux into the hot/cold gas interface → powerful way to constrain the effective interface area or turbulent mixing and potentially the flow speed.

AGN feedback: bipolar radio and X-ray-emitting bubble-like structure in M106

- At D=7.6 Mpc, it is very similar to our Milky Way Galaxy, in terms of the overall mass and SFR. But there is little gas and star formation in the central region.
- Synchrotron radio bubbles; B-field ~4-300 μG from centers to edges.
- The bipolar structure energetically resembles the Fermi/eROSITA bubbles (~10^{57} erg), but ~2x smaller (+-8 kpc off the galactic disk) or ~4 x younger (~ 0.8 Myr).



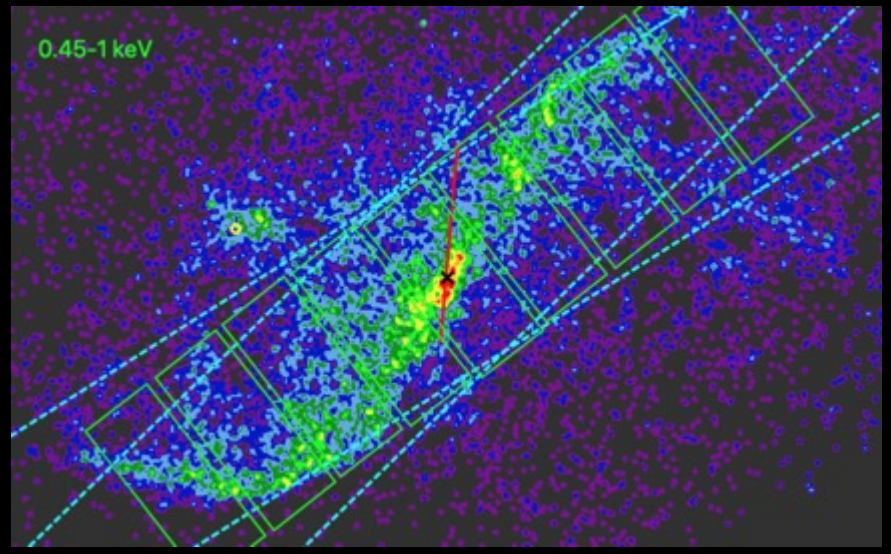
144 MHz FUV 0.4-1 keV

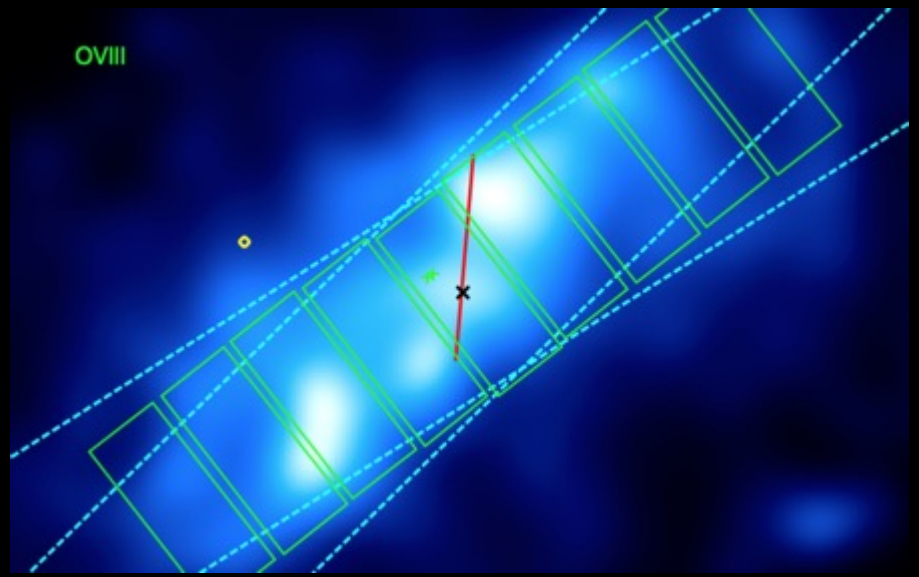


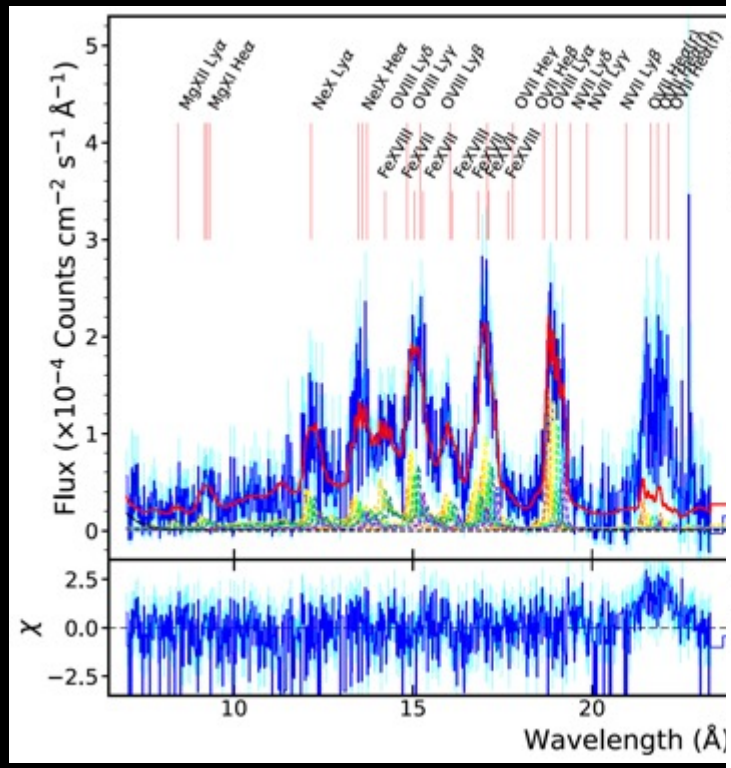
0.4-1 1-2 2-7 keV

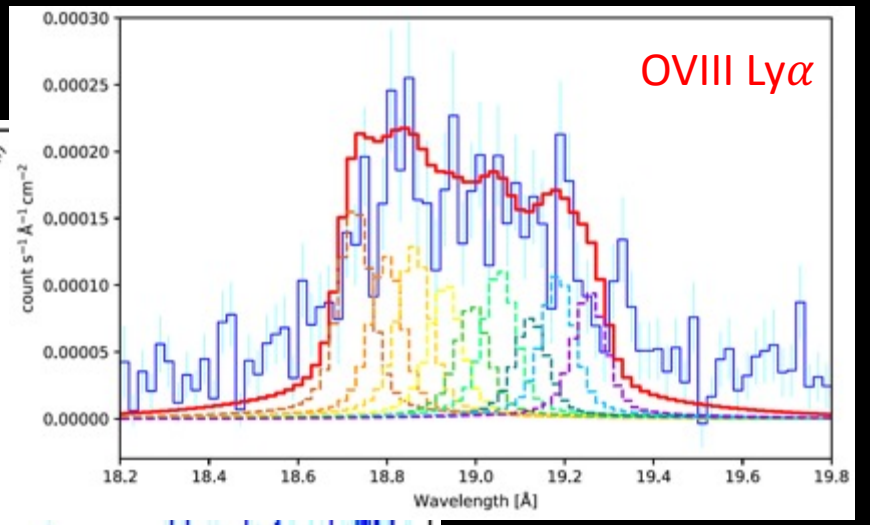
Zeng, Wang, & Fraternali (2023)

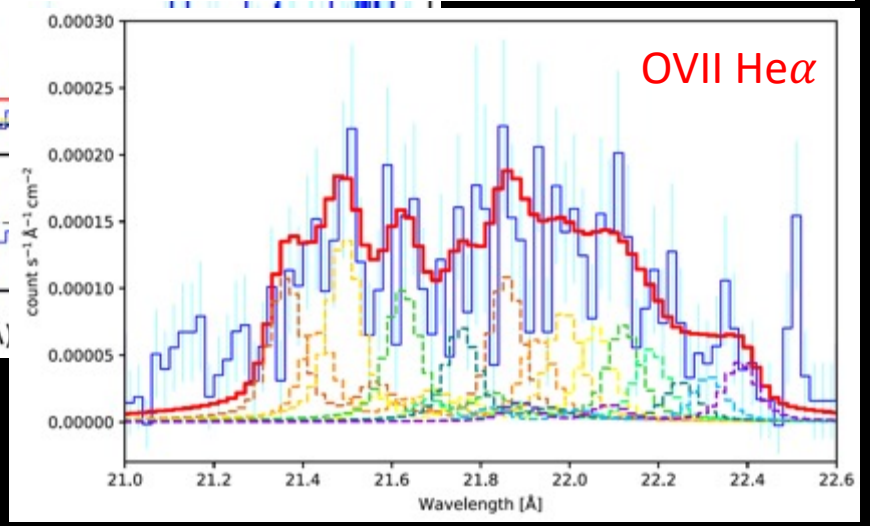
Spatially resolved X-ray spectroscopy with RGS data of the anomalous arms





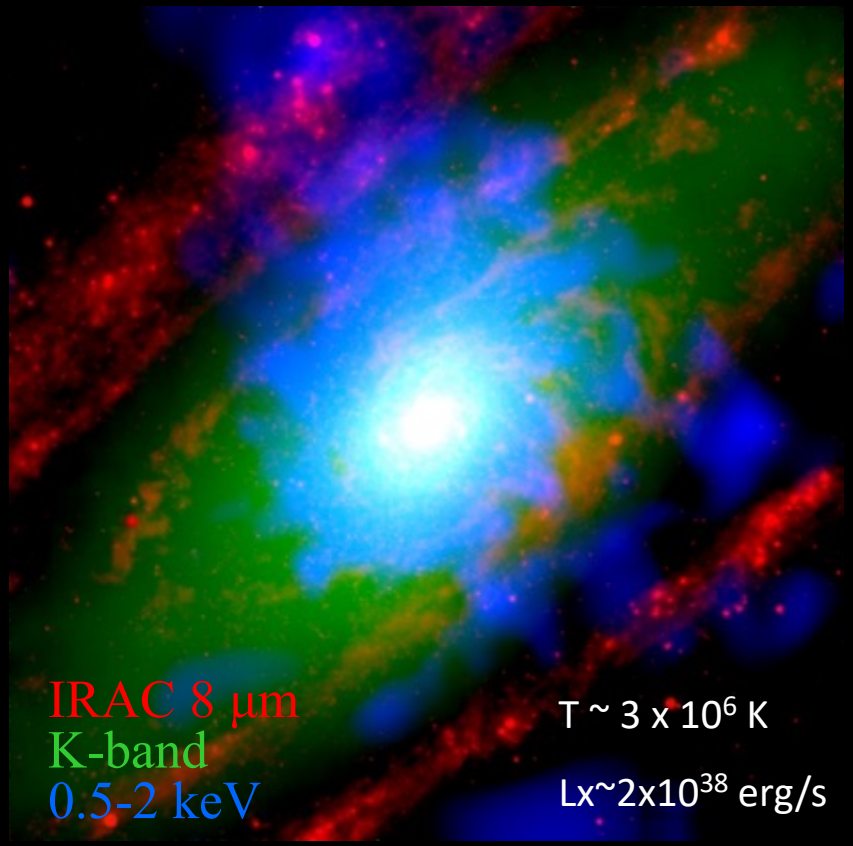






Zhang, Wang+ (2023 in prep)

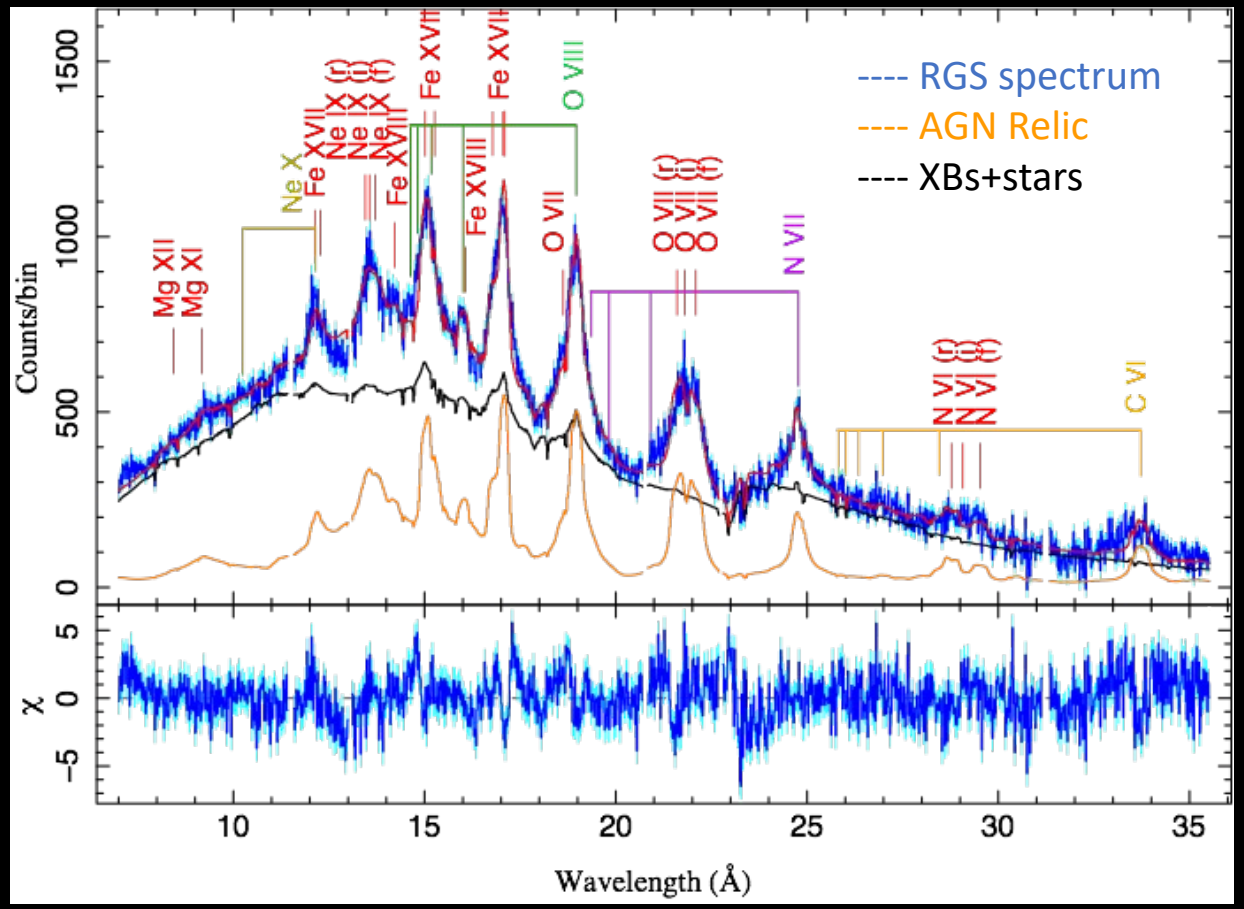
Non-CIE X-ray emission: an AGN relic in M31



The bulge contains little cool gas and no recent star formation

Li & Wang (2007)

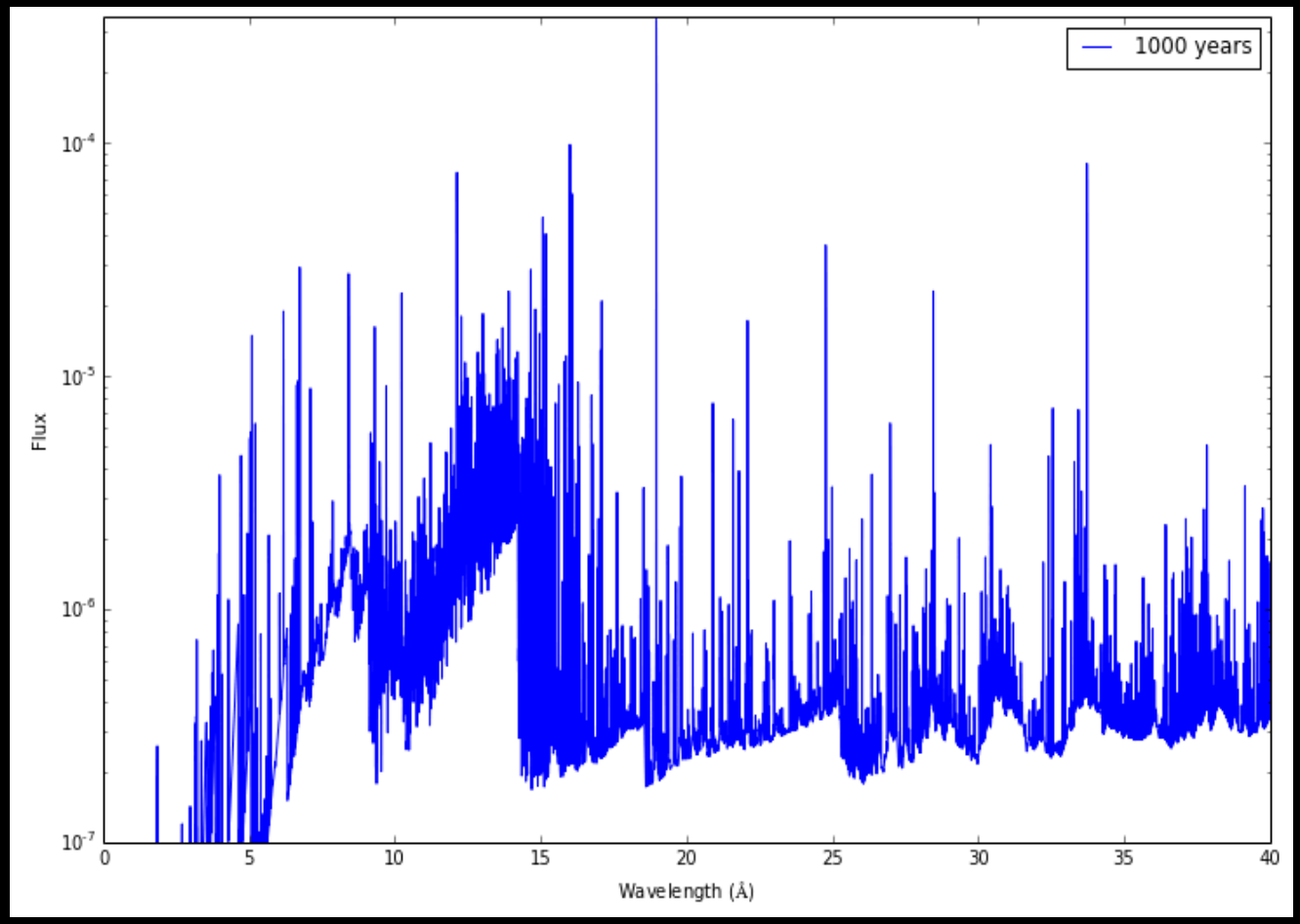
X-ray spectroscopy of an AGN relic in M31



- G =(f+i)/r ratios of Kα triplets of He-like ions are too large to be consistent with optically-thin CIE plasma.
- Also unexpected are high Lyβ/Lyα for H-like N and O and high iron line ratios (Fe XVIII 14.2Å/Fe XVII 17Å and Fe XVII 15Å/17 Å).
- Instead, the spectrum is well explained by the presence of an AGN of Lx~10^{44} erg/s about half Myr ago, which led to over-ionization of the gas.

Zhang, Wang+. 2018

X-ray spectroscopy as a tool to infer the recent AGN history in nearby galaxies



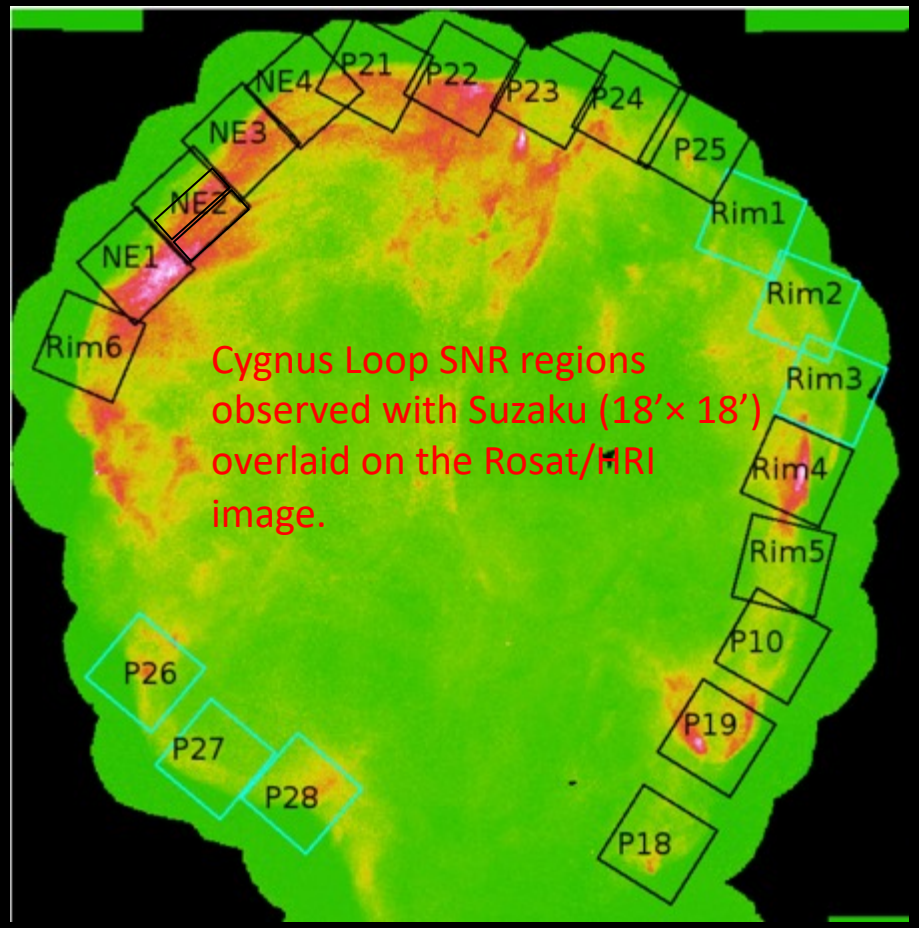
- Recombination continuums (or edges) are key diagnostics of AGN relics.
- Timescale to reach ionization equilibrium can be > time interval between AGN episodes.
- X-ray IFU could map spectroscopic signatures of AGN relics across the ISM and/or CGM!

Zhang, Wang+ (2018)

Summary and conclusions

- Stellar & AGN feedback or its coupling with the ISM/CGM is the weakest link in our understanding of galaxy ecosystem/growth.
- X-ray spectroscopy is essential to the understanding of the feedback:
  - Baryon physics and X-ray emission mechanisms:
    - Thermal, chemical, and kinematic properties of the hot plasma and its heating and/or cooling mechanisms
    - Microscopic physics and radiation process at hot/cool gas interfaces
  - Measurement of AGN feedback
    - Plasma heating by AGN/Jets and outflows
    - Ionization affects of episodic activity
    - Energetics of mechanical outflows

Charge exchange in the Cygnus Loop SNR: OVII Kα triplet centroid as a diagnostic

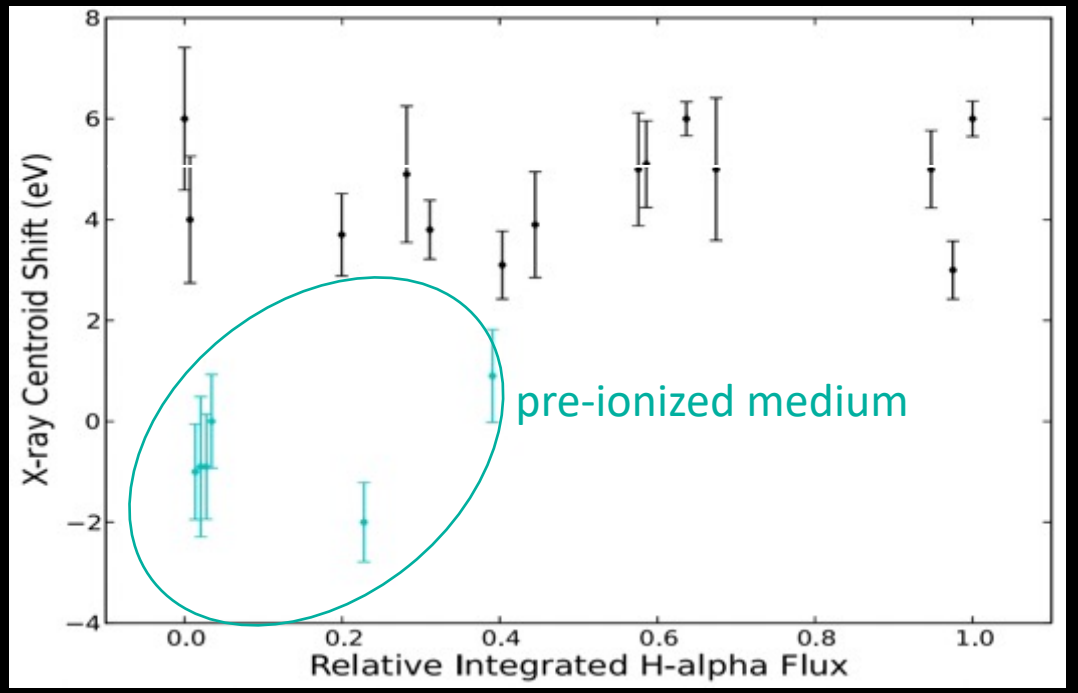


Cygnus Loop SNR regions observed with Suzaku (18'× 18') overlaid on the Rosat/HRI image.

With the large FoV, XIFU can map such large SNRs very efficiently to further probe the CX physics.

Roberts & Wang (2015)

The centroid of the triplet depends on the relative intensities of the R, I, F lines, determined by how the upper levels are populated.



O VII Kα centroid shift between inner and rim regions ($E_{inner} - E_{rim}$) vs. normalized Hα flux density; RGS confirmation by Uchida+ (2019)