X-ray spectroscopy of nearby galactic nuclear regions

1. How intermittent are AGNs?
2. What about the silent majority of the SMBHs?
3. How do SMBHs interplay with their environments?

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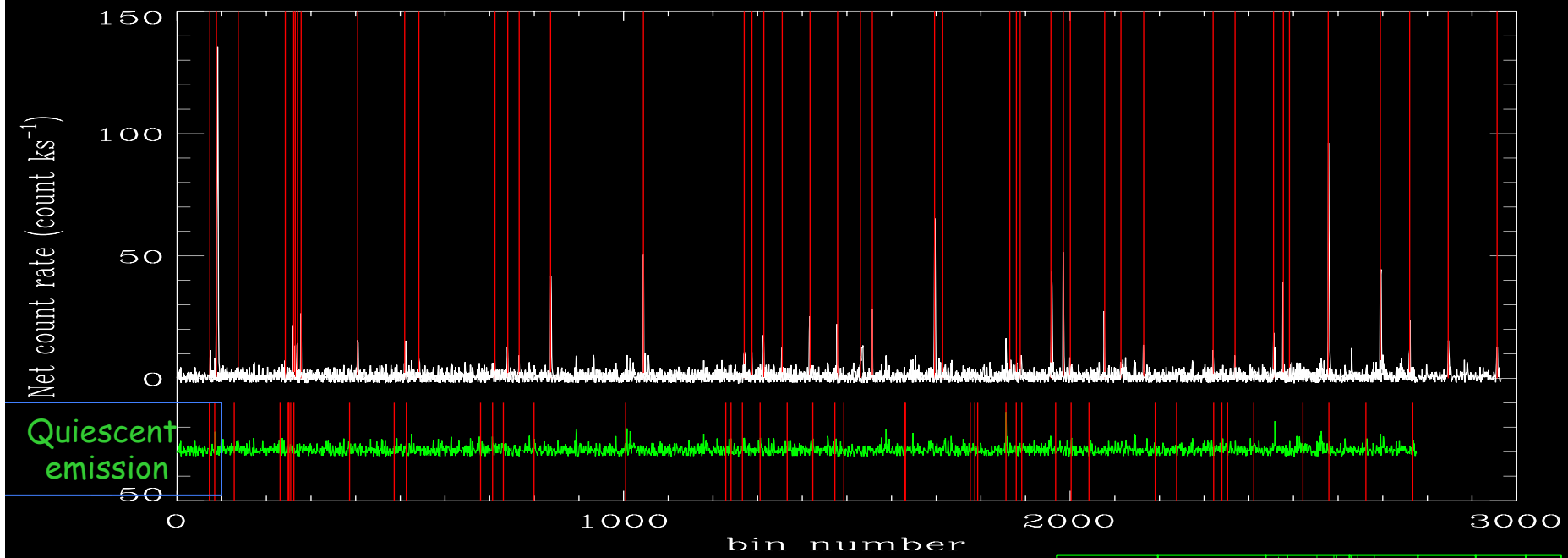
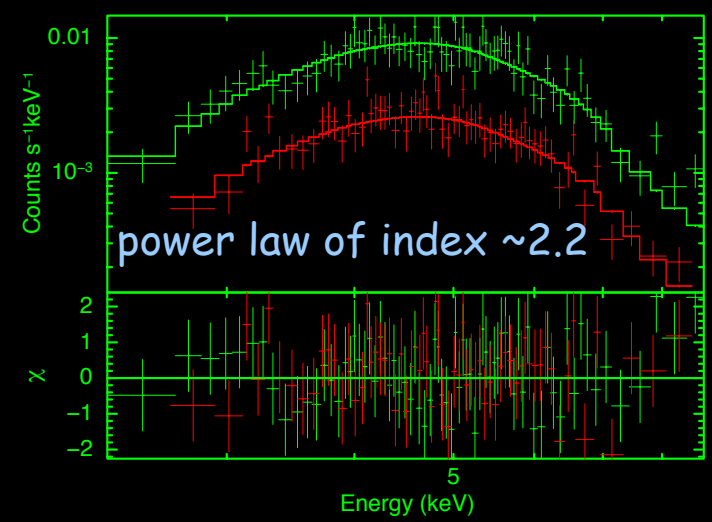
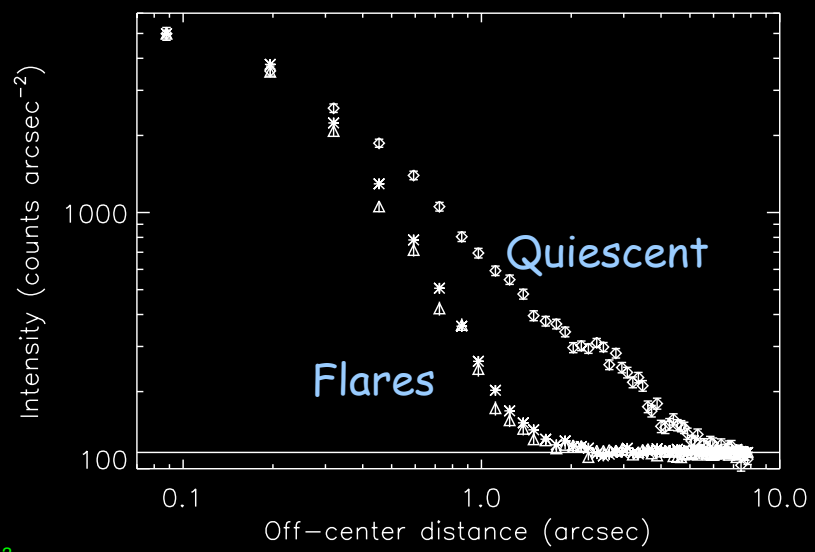
Sgr A*: X-ray flare properties

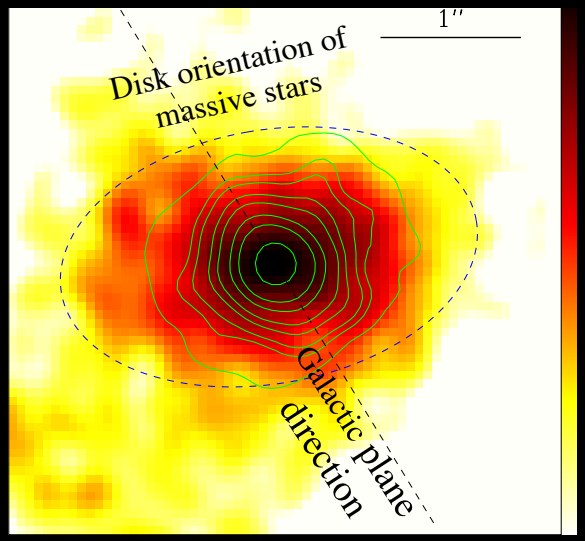


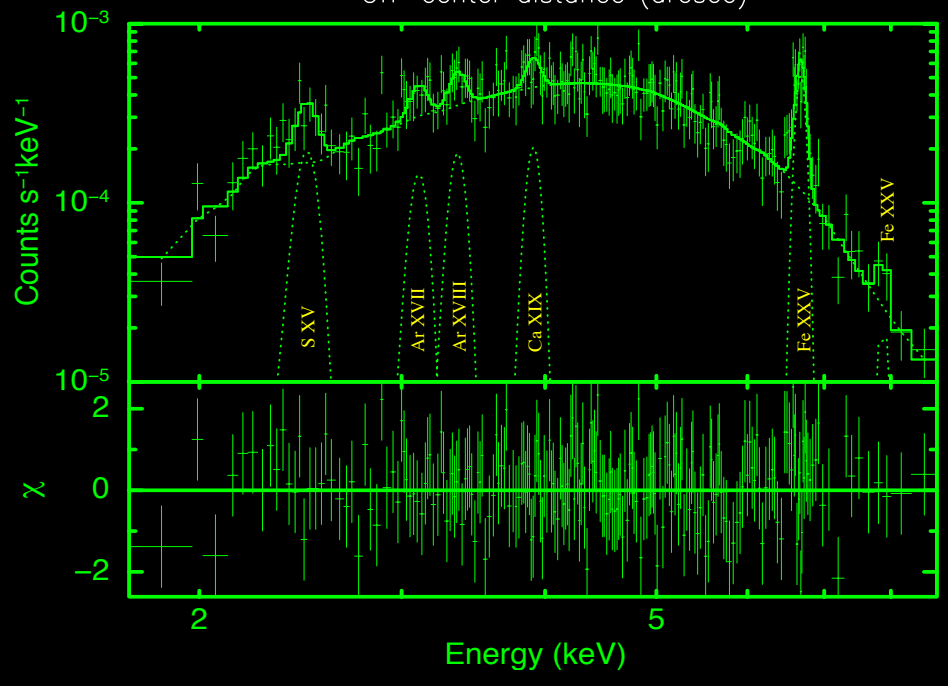
Detected flares have a power law spectrum of index ~ 2.2 and account for ~1/3 of the total X-ray flux of Sgr A* (Wang et al. 13).

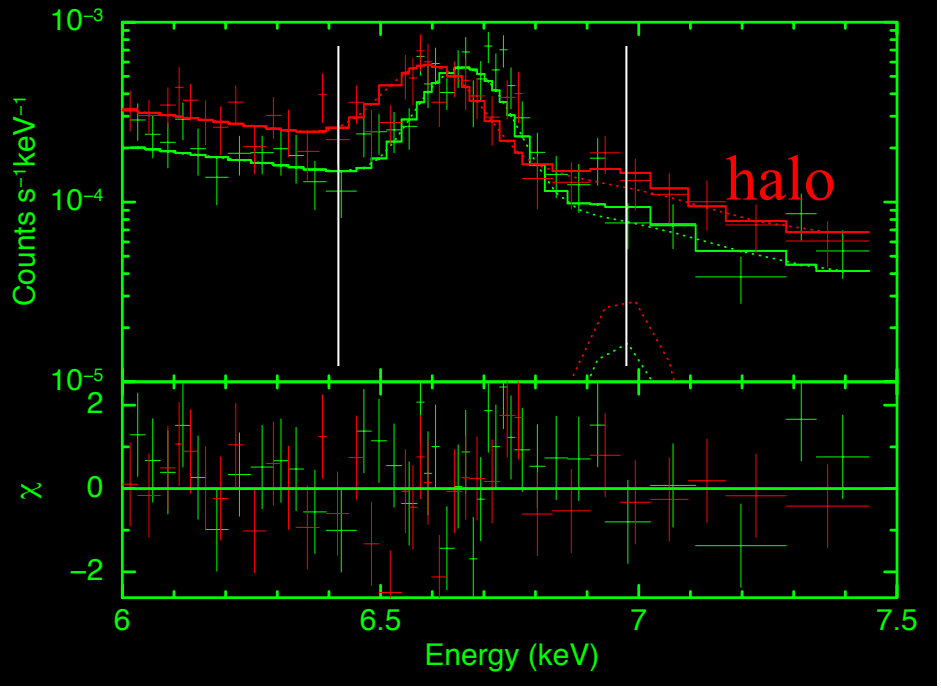


Sgr A*: quiescent X-ray emission

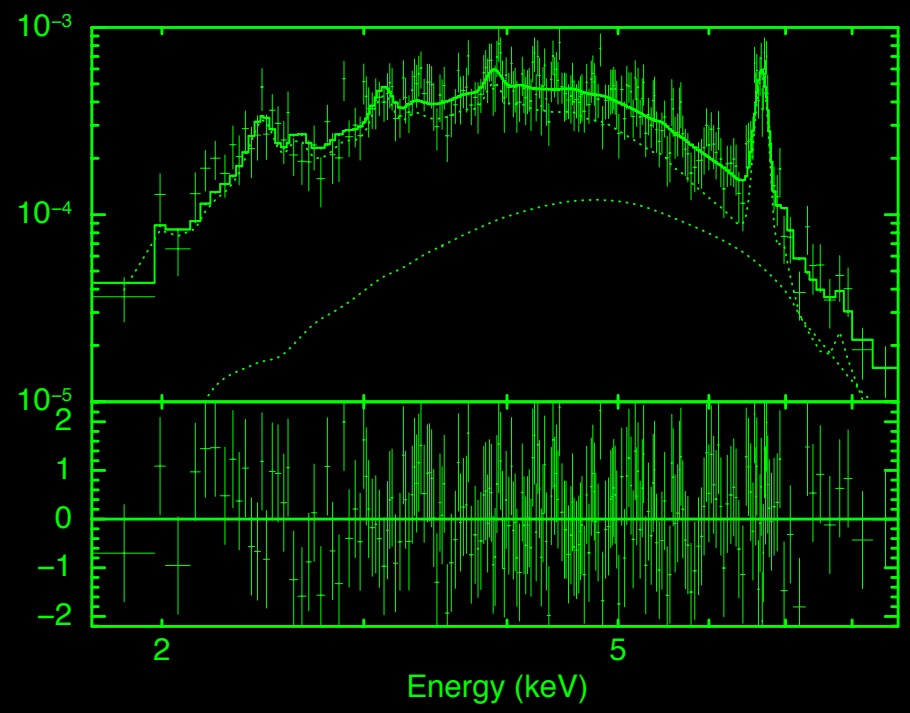








Spectral testing of RIAF solutions

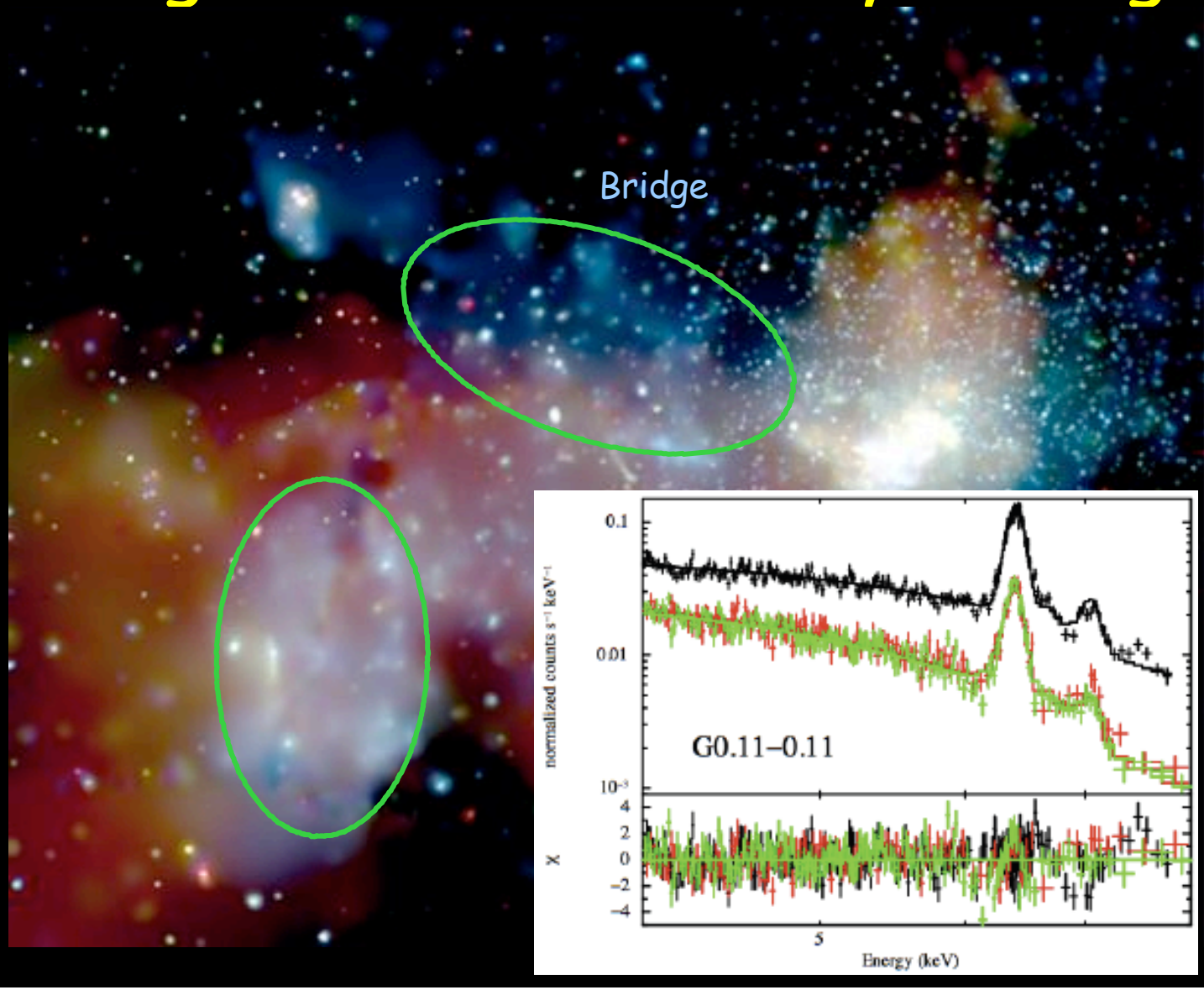


$$T = T_o(r_o/r)^{\theta}$$
$$n = n_o(r_o/r)^{3/2-s}$$
$$\dot{M} = \dot{M}_o(r/r_o)^{s}$$
$$dEM/d\log(T) \propto (T_o/T)^{\gamma}$$
$$(\text{where } \gamma = 2s/\theta)$$

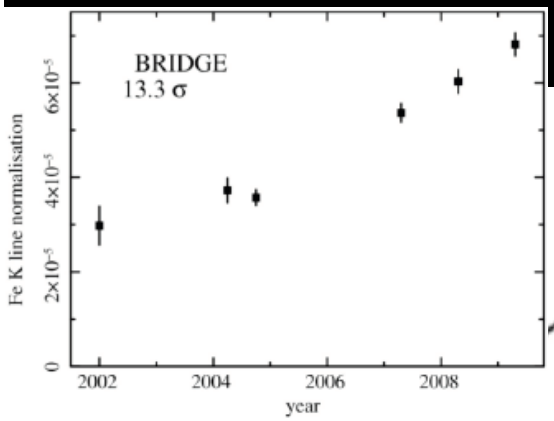
The best-fit s=1.0(0.7-1.2) (for θ~1) is consistent with the exact prediction of the adiabatic inflow-outflow solution (e.g., Begelman 2012); both the fitted abundance and N_H are also as expected.

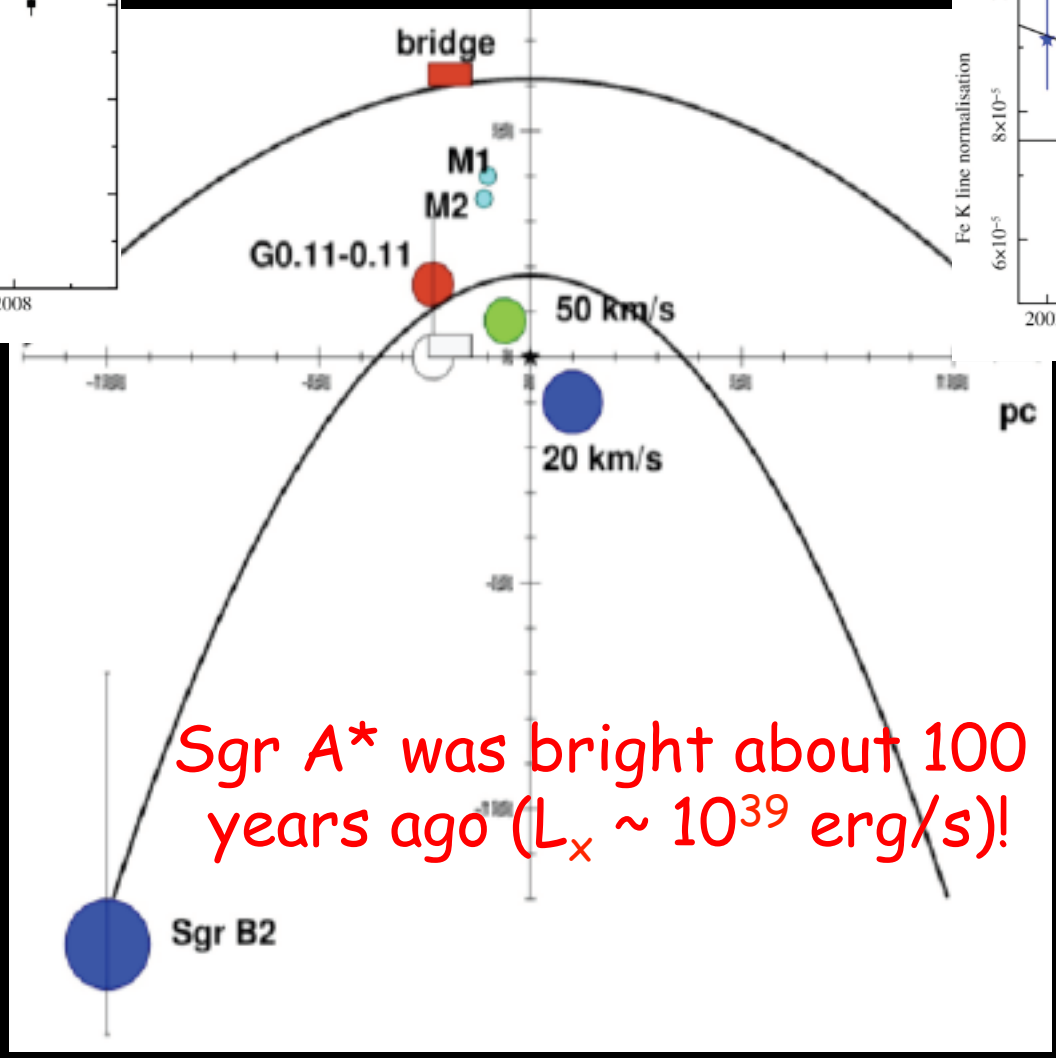
Wang et al. (2013)

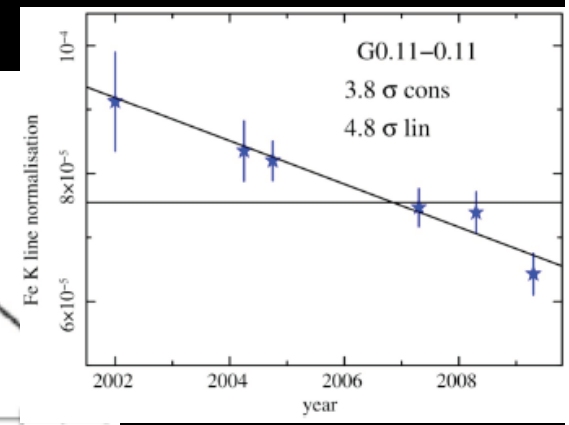
X-ray reverberation: Sgr A* burst ~ 100 years ago



X-ray reverberation: a Sgr A* burst ~ 100 years ago



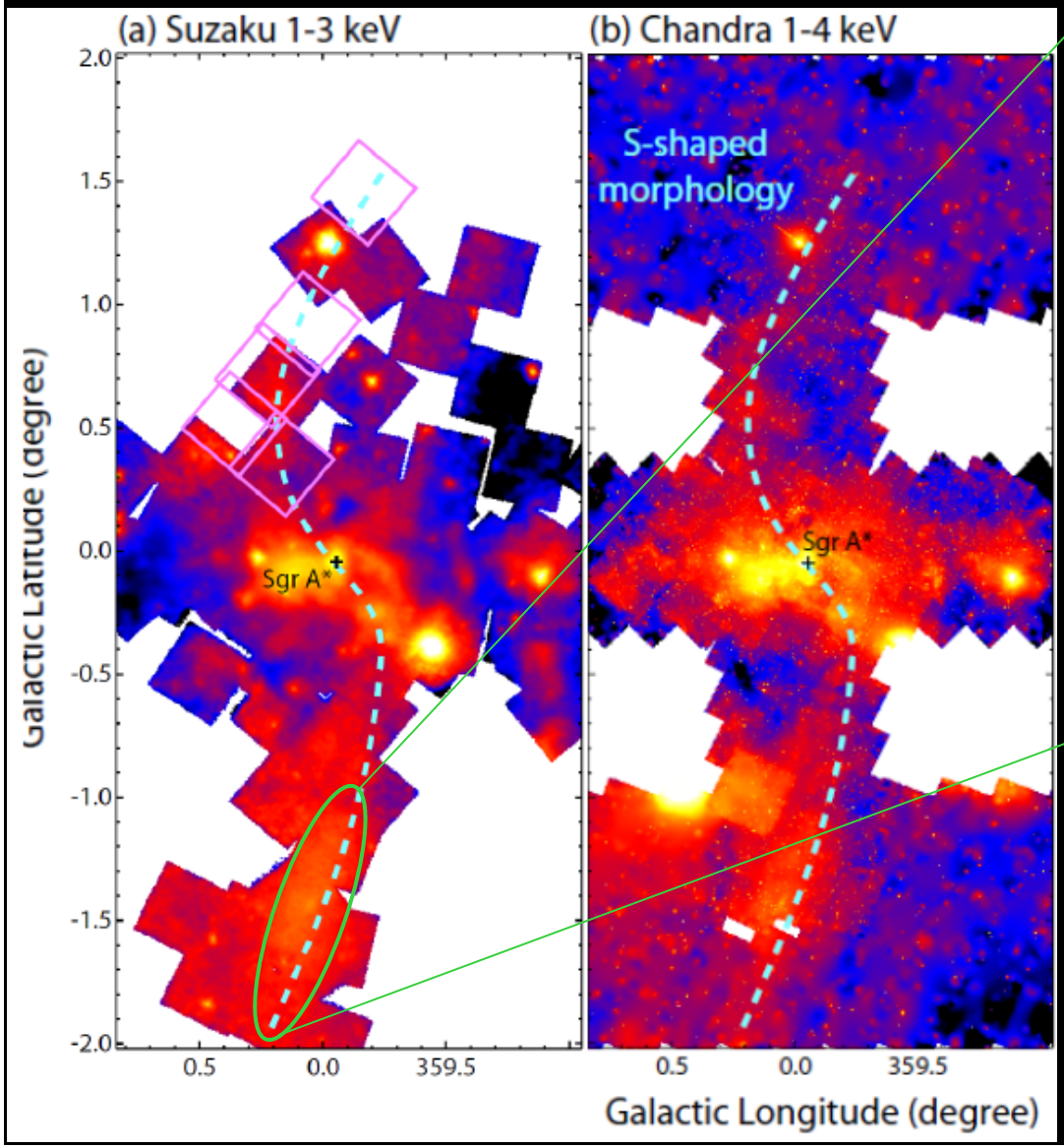


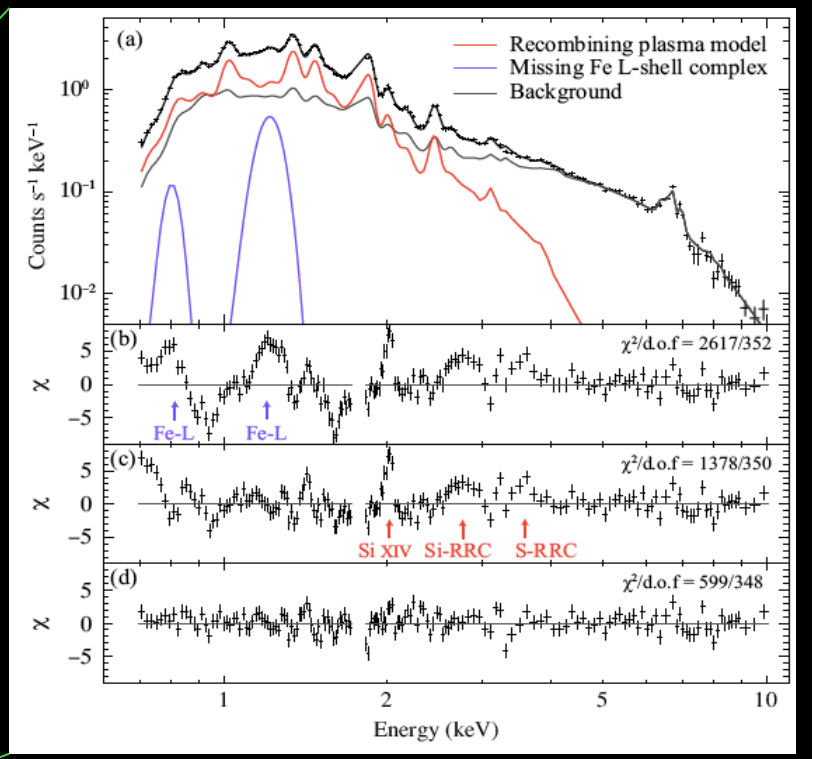


Sgr A* was bright about 100 years ago (L_x ~ 10^{39} erg/s)!

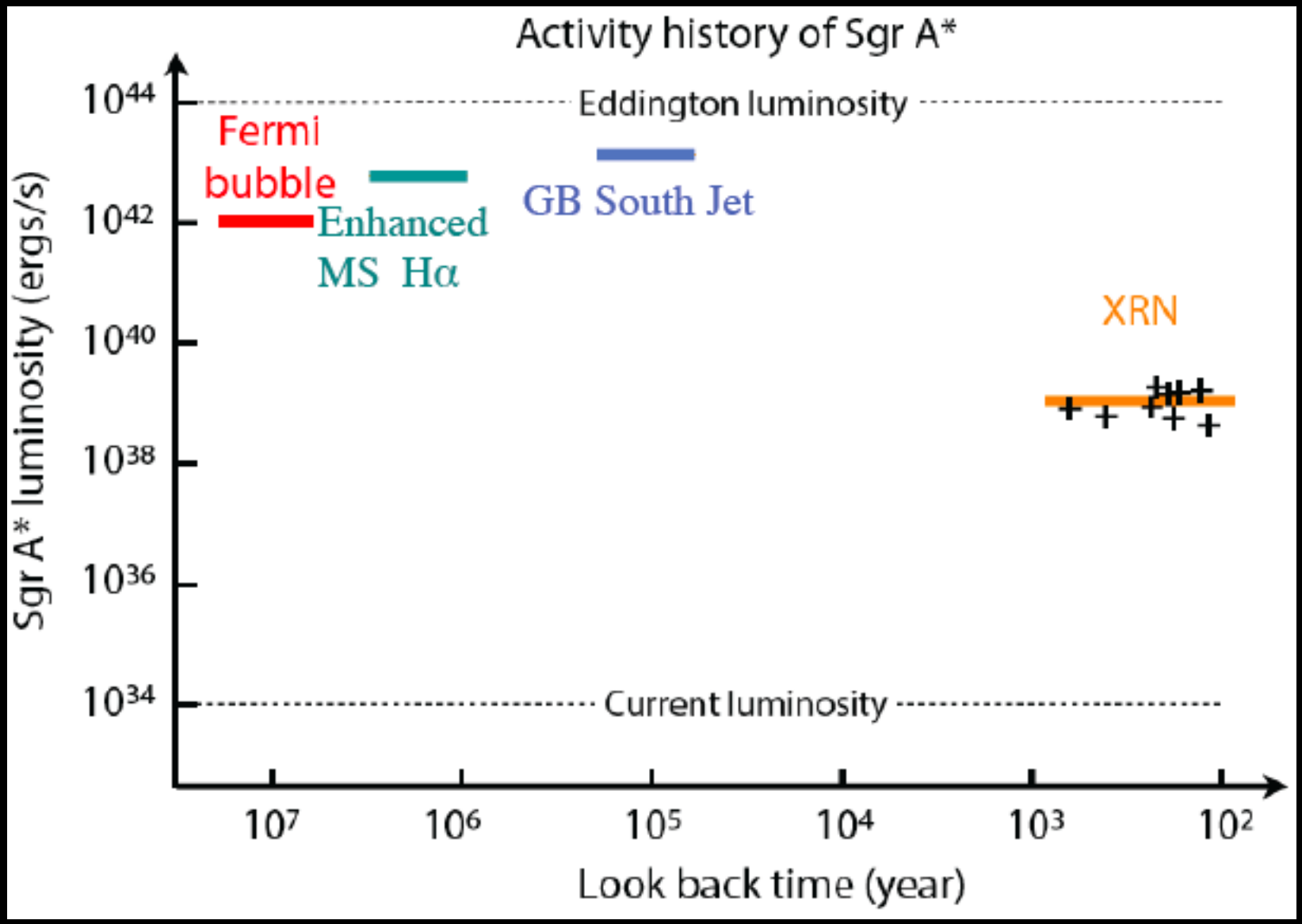
Ponti et al. 2010

Earlier Galactic center activity: Detection of recombining plasma.



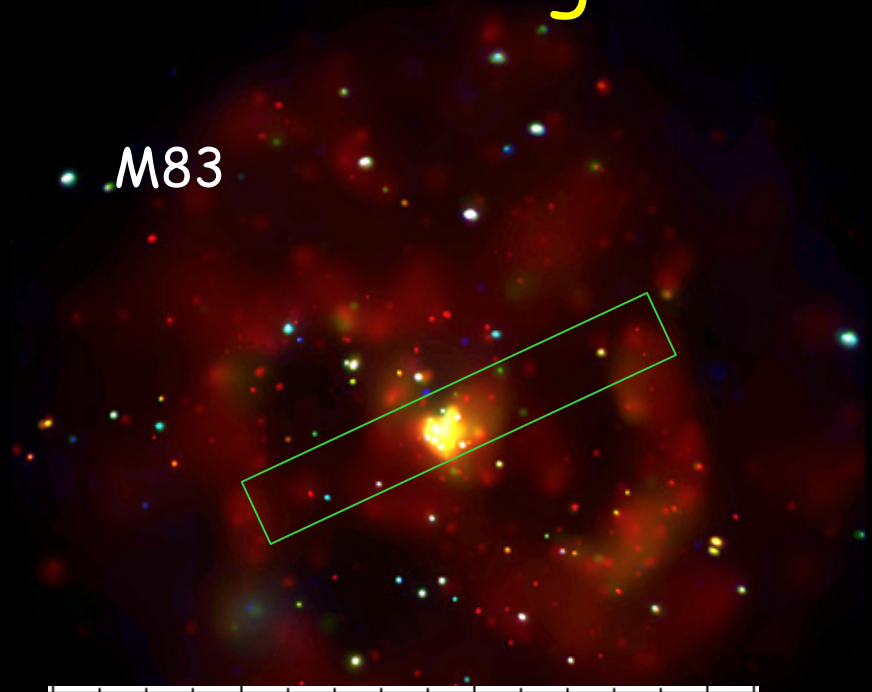


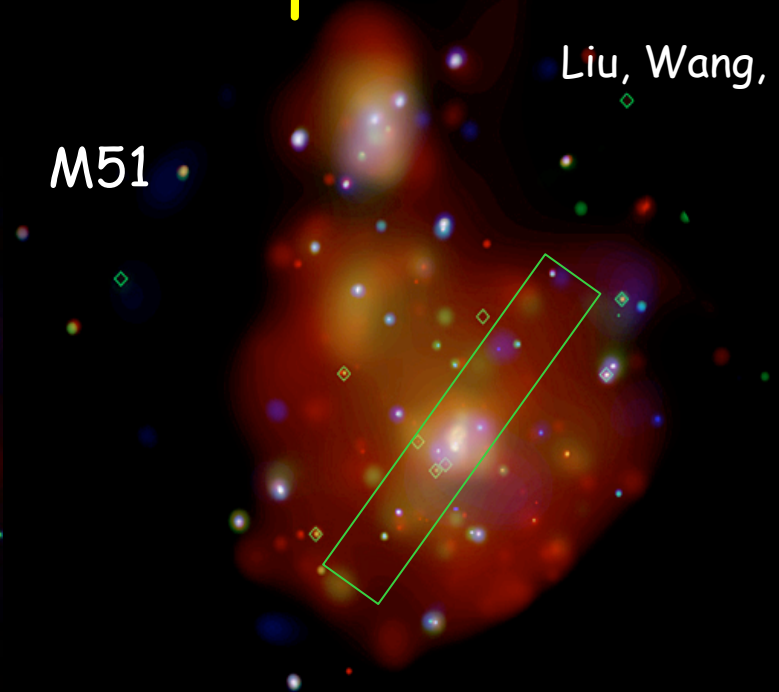
S. Nakashima et al. (13)

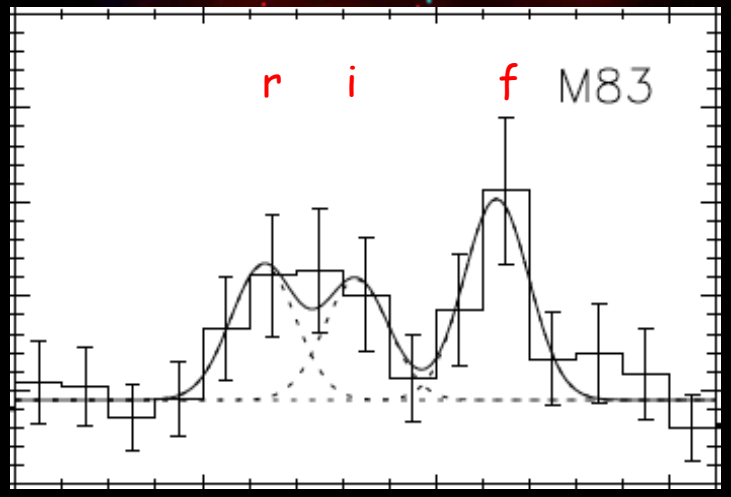

Activity history of Sgr A*
Eddington luminosity
Fermi
bubble
Enhanced
MS Hα
GB South Jet
XRN
Current luminosity
Sgr A* luminosity (ergs/s)
10^44
10^42
10^40
10^38
10^36
10^34
10^7
10^6
10^5
10^4
10^3
10^2
Look back time (year)

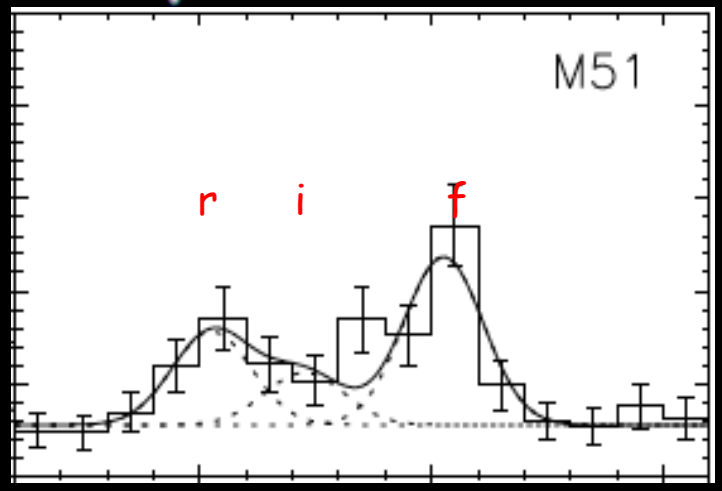
RGS survey of nearby galactic nuclear regions: OVII triplet

Liu, Wang, Mao (12)

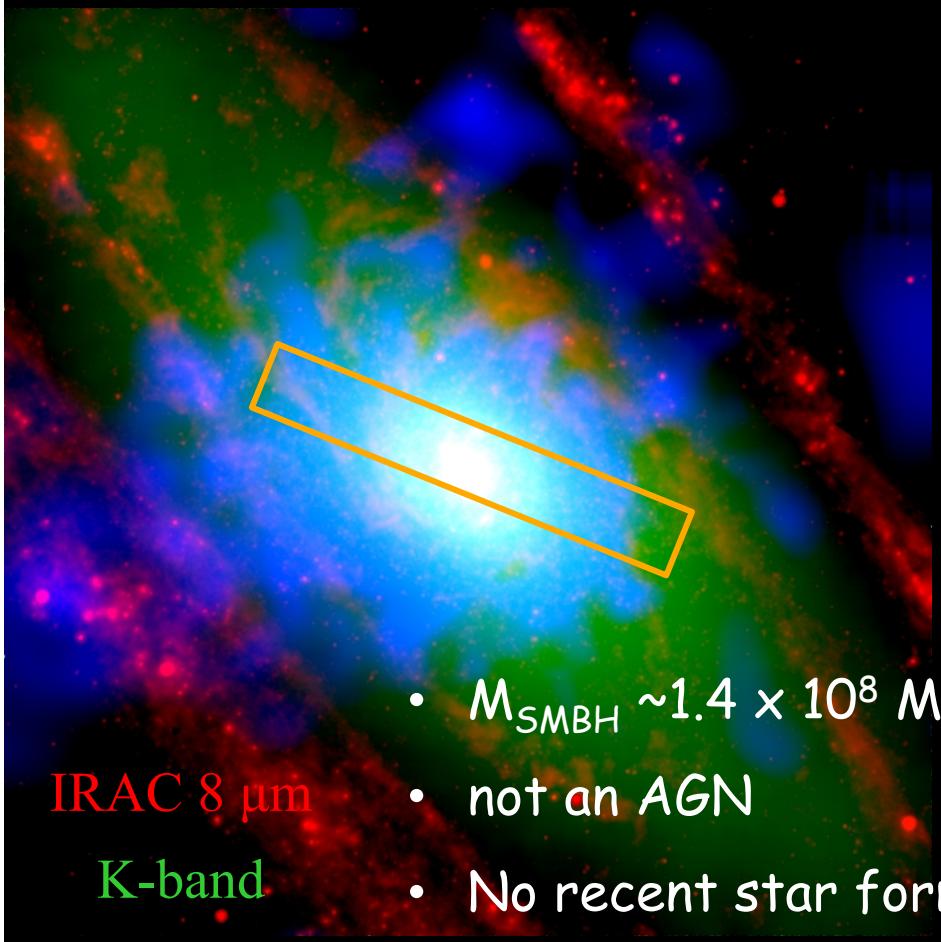




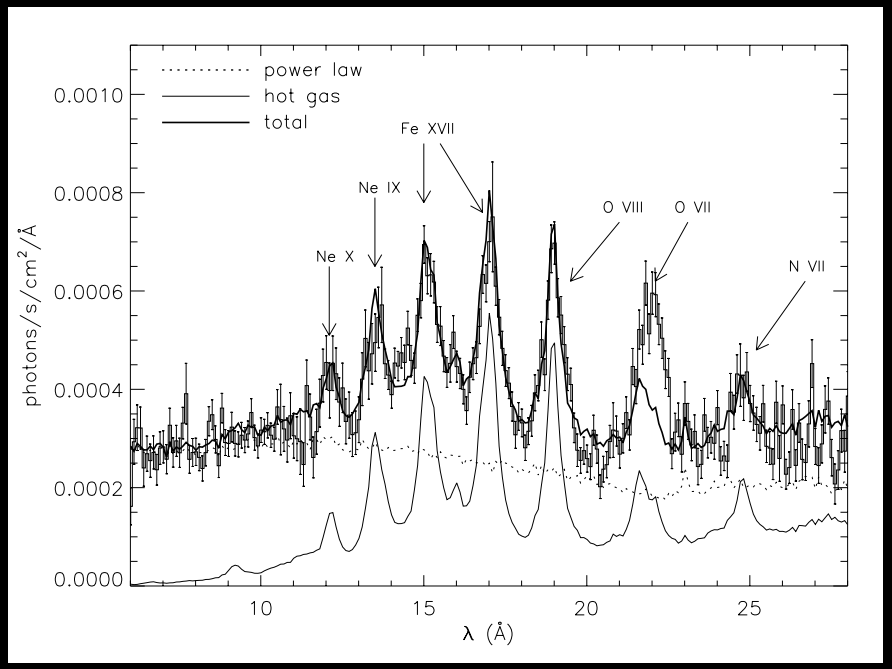




XMM-Newton RGS spectrum of the M31 inner bulge



Li & Wang (07)



- M_{SMBH} ~1.4 x 10^8 $M_\odot$
- not an AGN
- No recent star formation
- Diffuse hot gas: T ~ 3 x 10^6 K; Lx~2x10^{38} erg/s

Strong deviation of the OVII Ka triplet from the thermal model: high G-ratio.

Liu, Wang, Li, & Peterson (10)

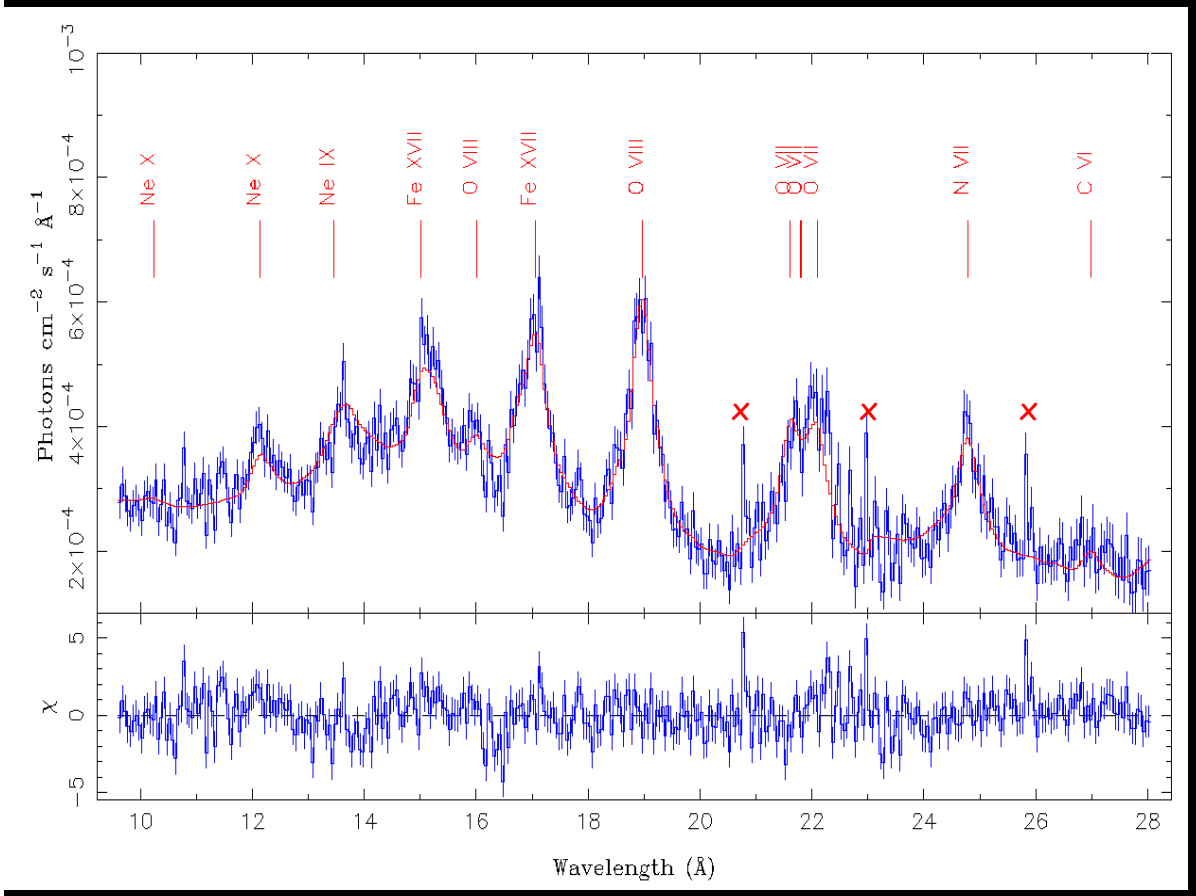
X-ray spectral model of diffuse hot plasma around an intermittent AGN

Compare the model and the RGS spectrum to constrain the parameters: the luminosity of the AGN and time after its turning-off, plus metal abundances.

- Adopt the β–model of the hot gas density distribution, as inferred from X-ray imaging data.
- Set initial ionization state by running Cloudy, assuming a typical Seyfert AGN spectrum .
- Turn off the AGN and calculate the ionization evolution as a function of the time.
- Disperse the 2-D project of the 3-D model into a RGS spectrum.

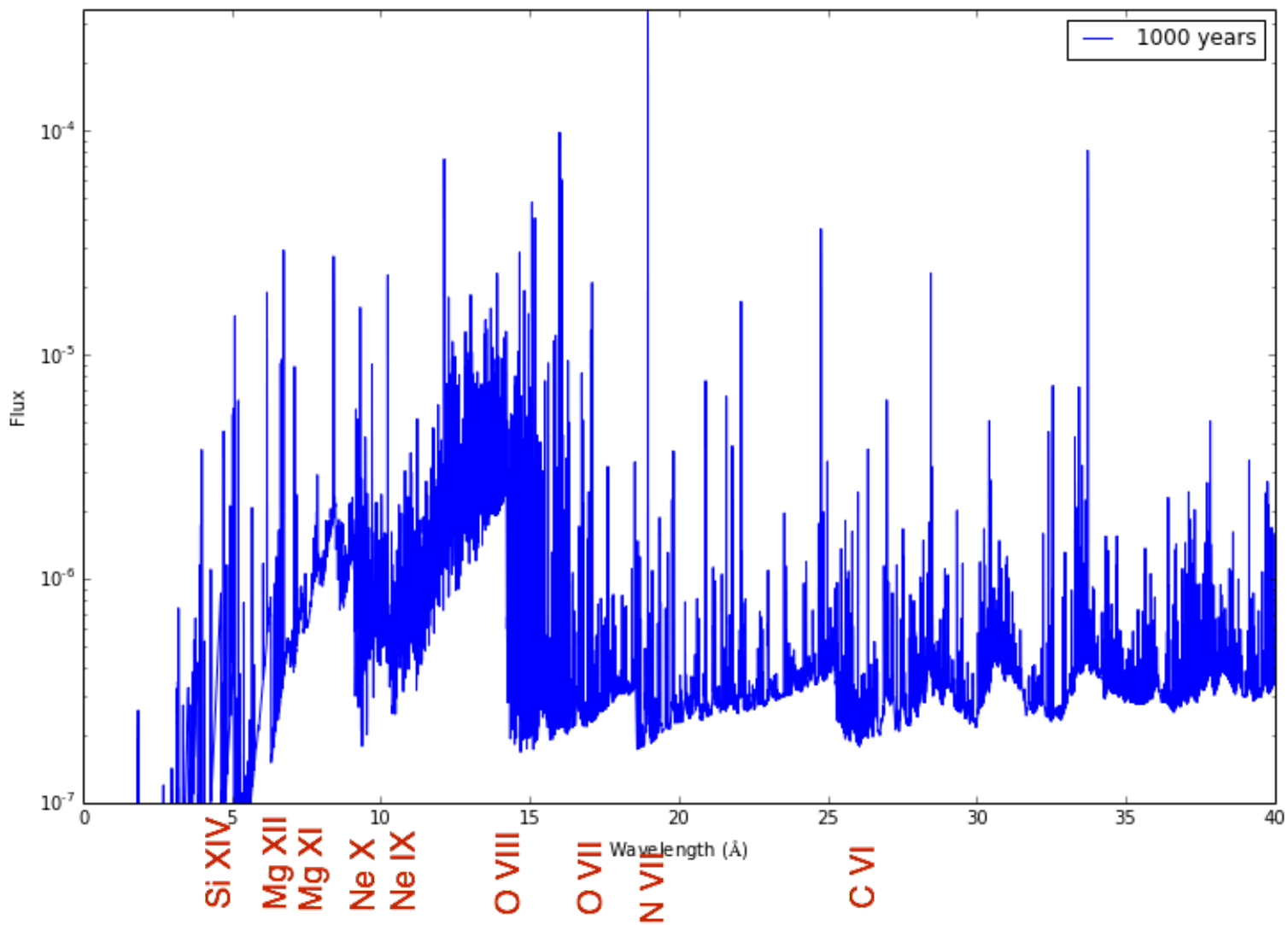
Zhang, Wang, et al. (15 in prep)

Preliminary model fit to the RGS spectrum of the M31 nuclear region

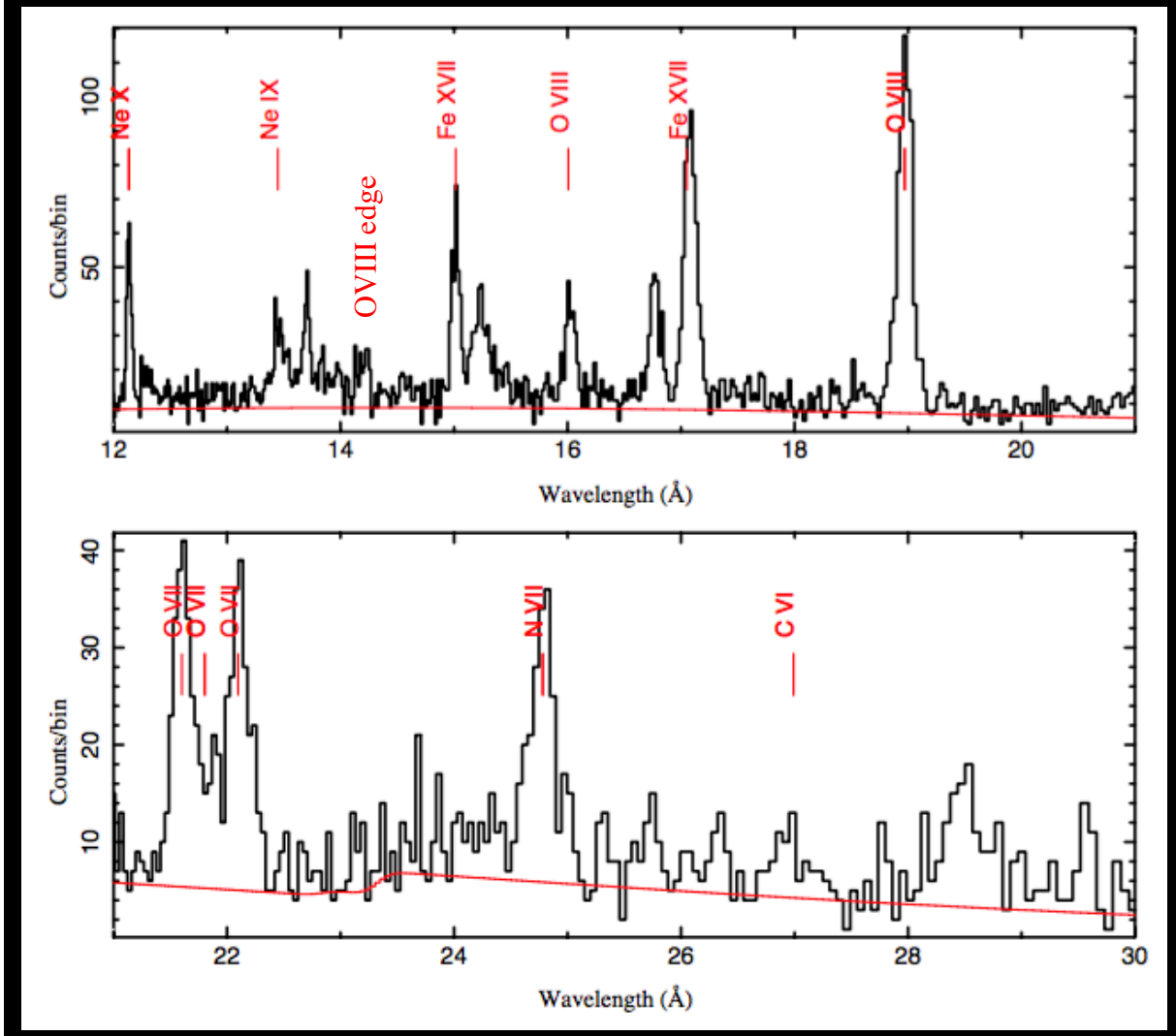


- $L=10^{44.5}$ erg/s
- Time $=4.8\times10^{5}$ yr
- Slightly super solar metal abundances
- Plus a power law of photon index=1.7, representing point-like sources (constrained by X-ray imaging data).

Evolution of the model spectrum

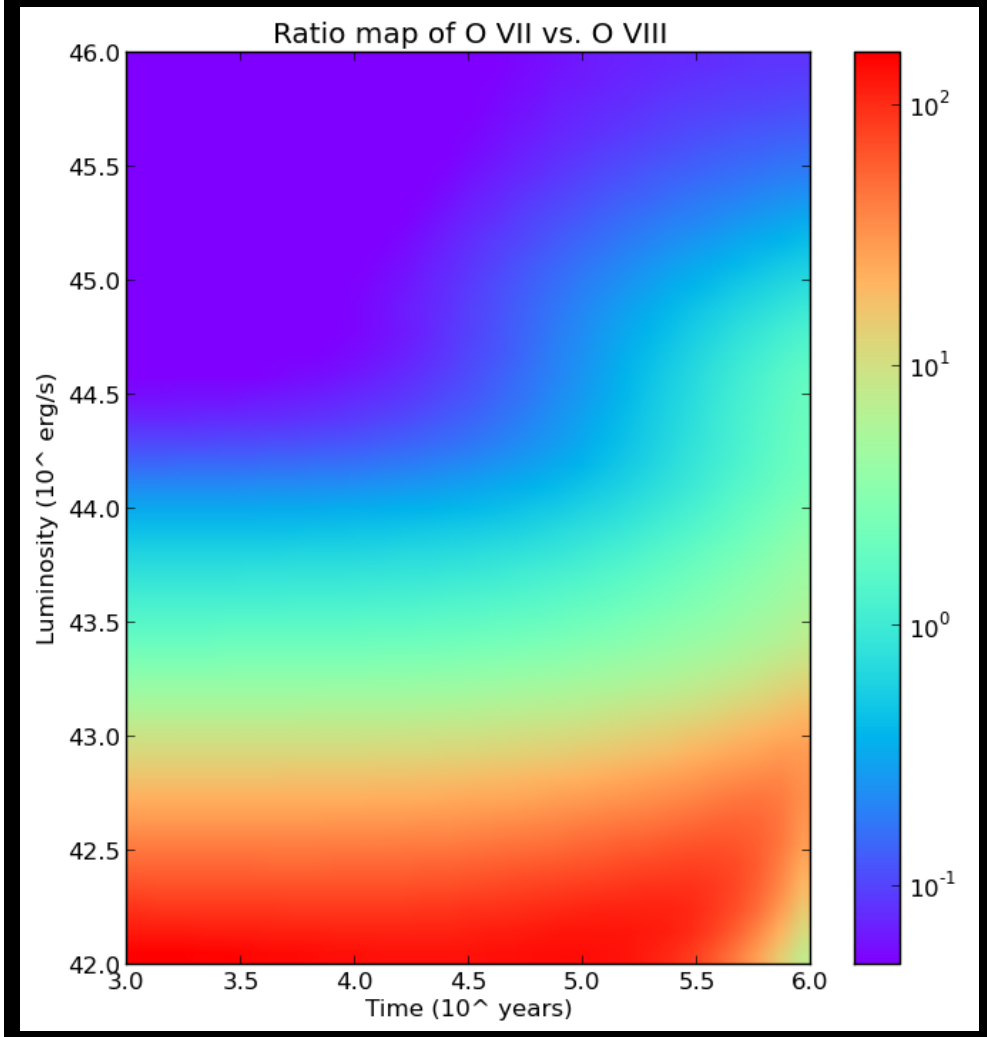


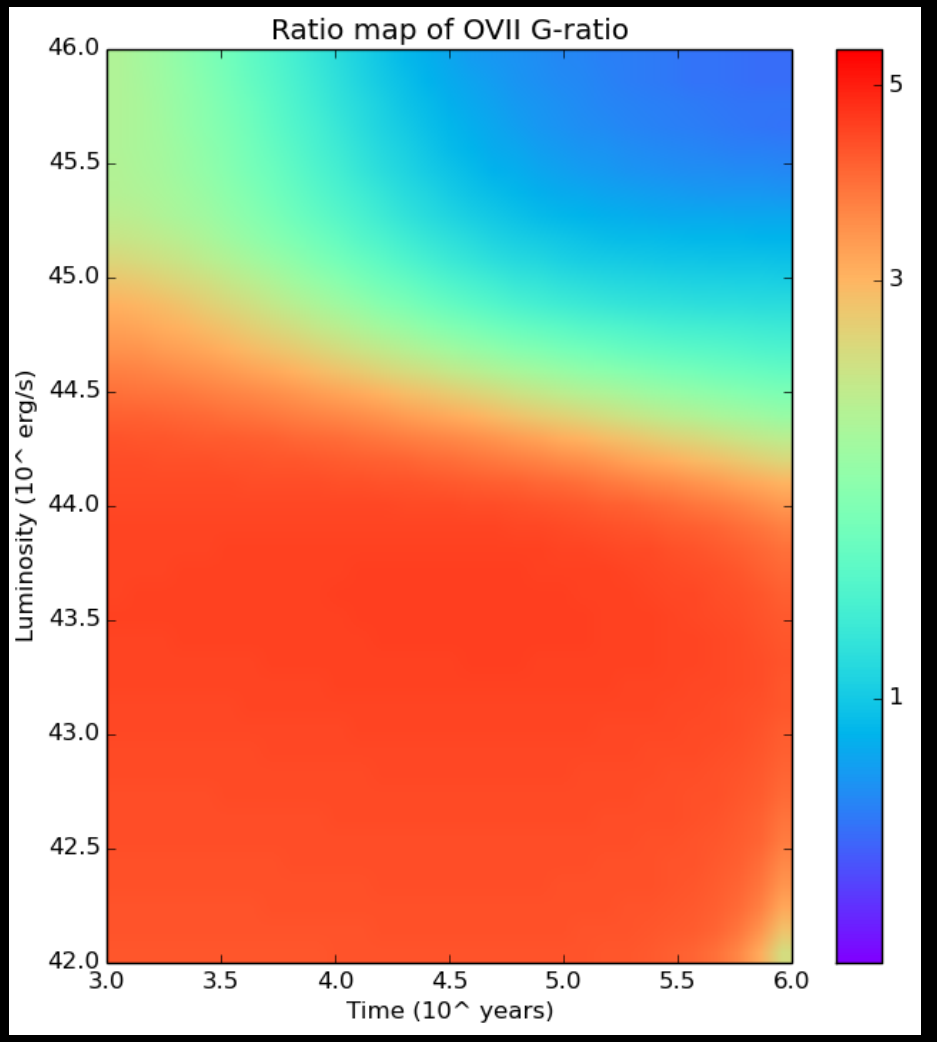
Simulated Astro-H/SXS spectrum of the M31 nuclear region



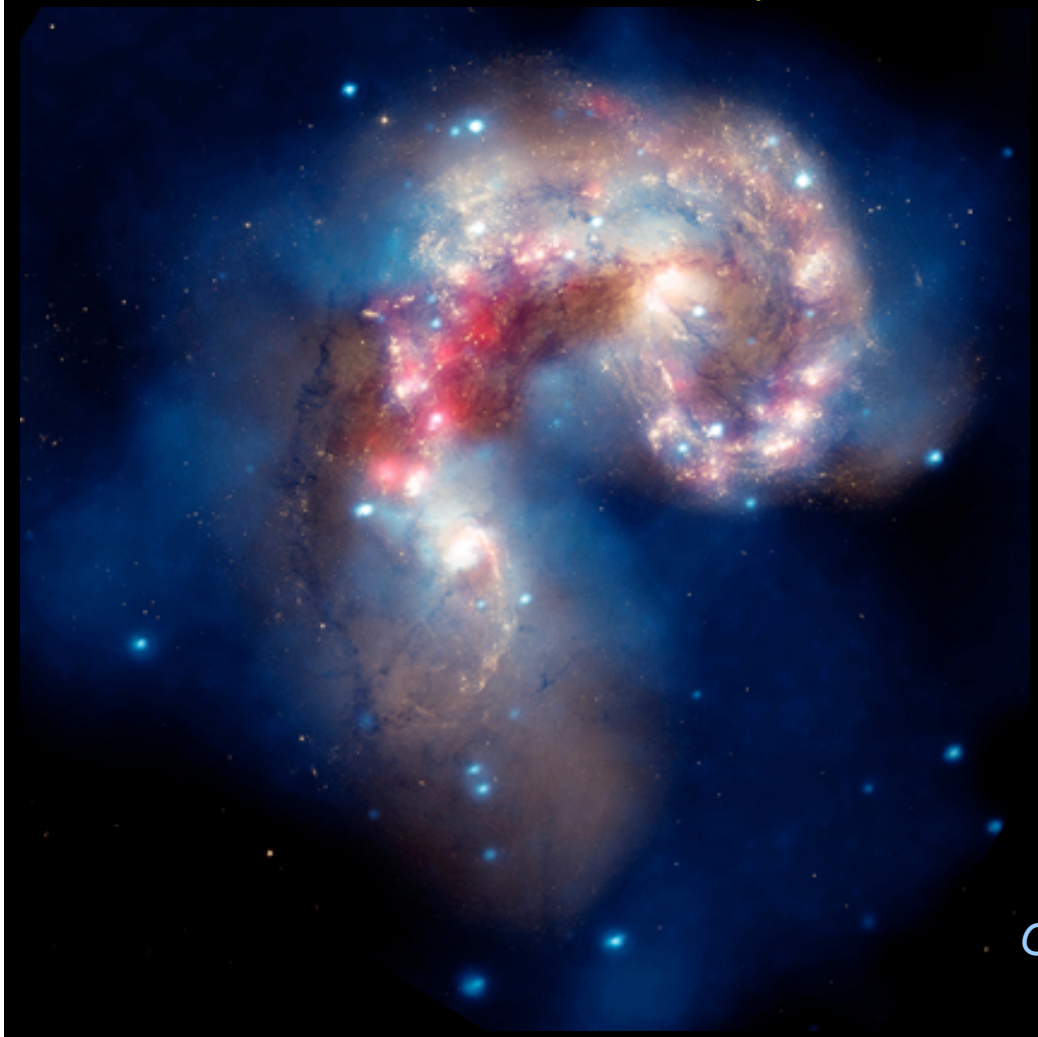
- 50 ks exposure
- Including a power law for point sources
- Multiple triplets and recombination edges can be detected,
- Providing powerful diagnostics of the ionization state and the underlying physics.

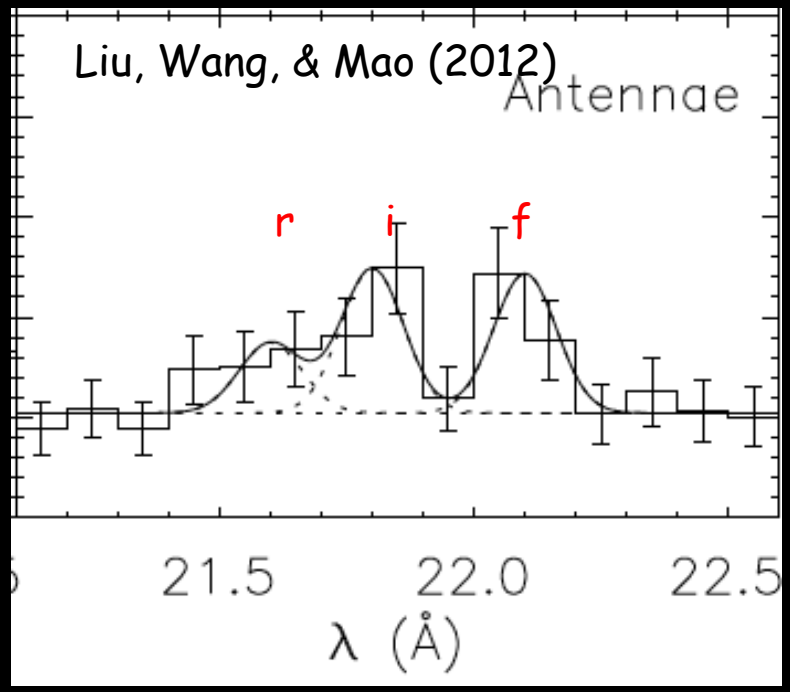
Emission line diagnostics: AGN luminosity and switch off time





OVII Ka triplet: Antennae galaxy





Optical (Yellow), X-ray (Blue), Infrared (Red)

Summery

1. Sgr A* accretes in an inflow/outflow fashion, with > 99% of the initially captured matter ejected in the $r \sim 10^4$-10^5 r_s range.
2. Spatially resolved X-ray reflection studies show that Sgr A* had multi-bursts ~100 years ago.
3. Detection of diffuse recombining plasma indicates that Sgr A* was probably a Seyfert-like AGN about 10^5 yr ago.
4. Non-CIE plasma appears common in nuclear regions of other galaxies. The modeling may allow us to constrain past AGN activities.
5. Diffuse hot plasma in nuclear regions and halos may never be in a CIE state because intermittent AGNs!

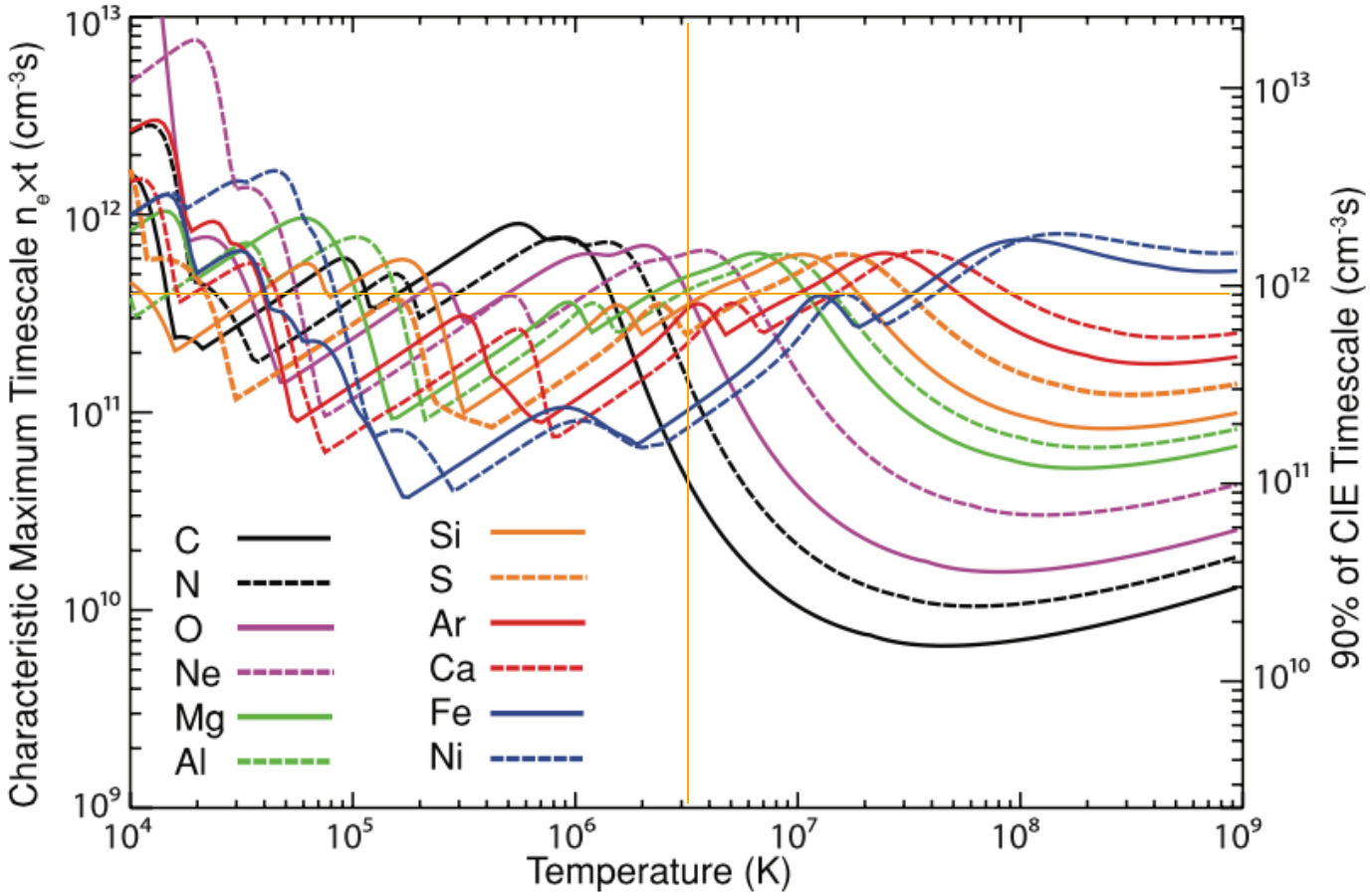


Figure 1. Left axis: density-weighted timescales (in units of cm^{-3} s) for C, N, O, Ne, Mg, Al, S, Si, Ar, Ca, Fe, and Ni to achieve one *e*-folding (e^{-1}) toward ionization equilibrium in a constant temperature plasma. Right axis: density-weighted timescale for all ions to be within 10% of their equilibrium value.

Smith & Hughes (10)

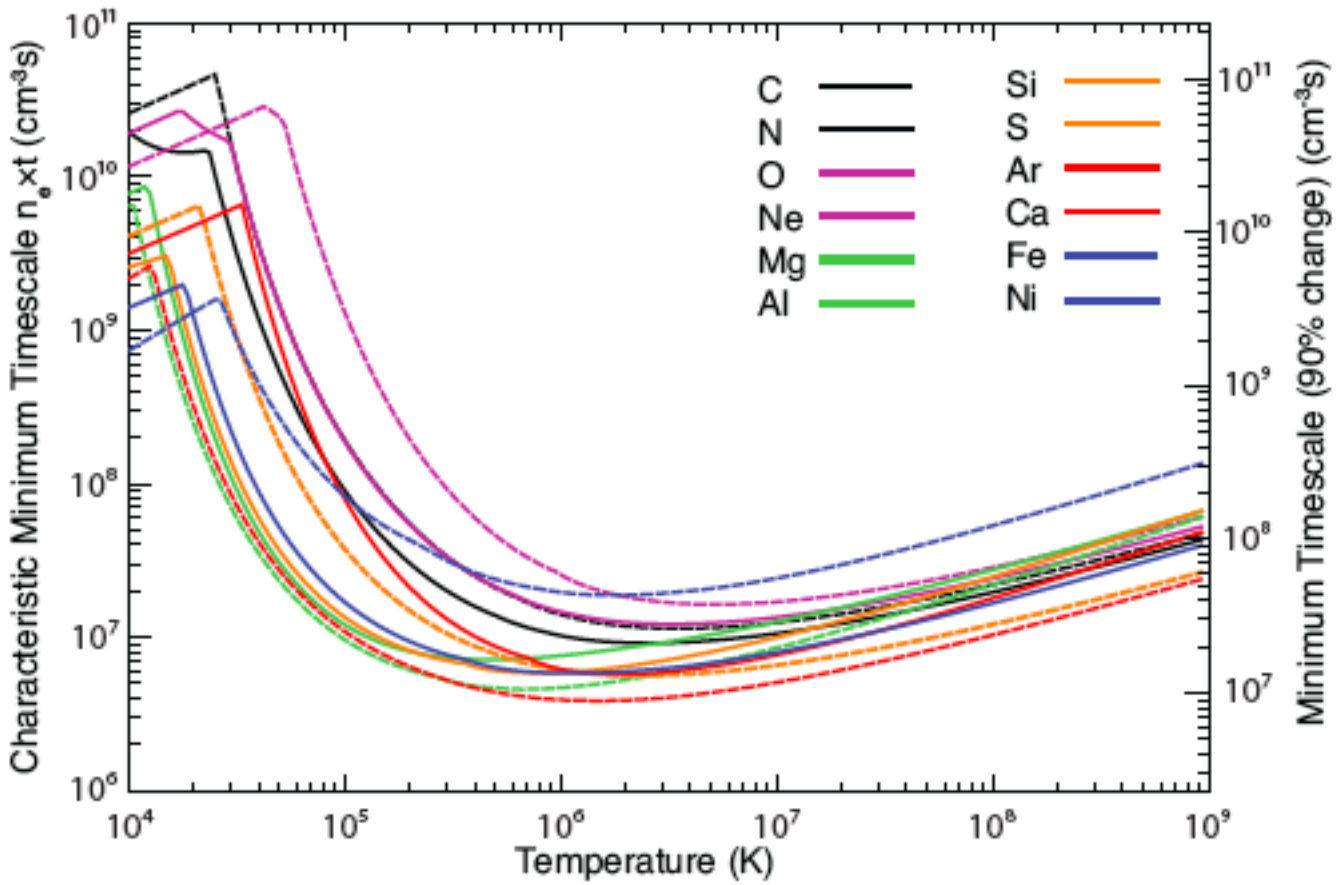


FIG. 2.— [Left axis] Density-weighted timescales (in units of cm^{-3} s) for C, N, O, Ne, Mg, Al, S, Si, Ar, Ca, Fe, and Ni to achieve one e-folding (e^{-1}) of any change in ionization state for an atom in a constant temperature plasma. [Right axis] Density-weighted timescale for an ionization state change of 90%.