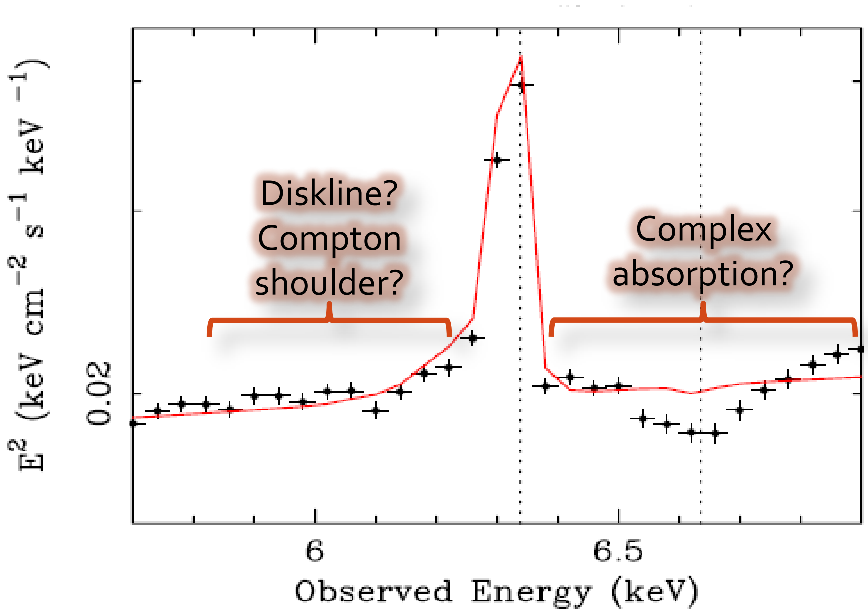
PROBING UNIFICATION WITH HIGH-RESOLUTION SPECTROSCOPY OF NGC 2110

Dan Evans (Harvard), Julia Lee (Harvard), Jane Turner (UMBC/GSFC),
Kim Weaver (GSFC), Herman Marshall (MIT)

Fe Kα Lines and Reflection: AGN Geometry

- The Fe Kα line complex in general consists of a narrow line core, possibly accompanied by broadened emission
- What is the origin of the broad emission?
  - Relativistically blurred diskline?
  - Compton shoulder?
  - Broad line region?
  - Unmodeled absorption?
- If we can deconvolve the contributions from the two, we can probe AGN geometry
- Vital to treat direct+reflected continuum and absorption effects self-consistently



NGC 3783 (Yaqoob et al. 2005)

NGC 2110

Nearby (z=0.0076, D_L=33 Mpc) NELG

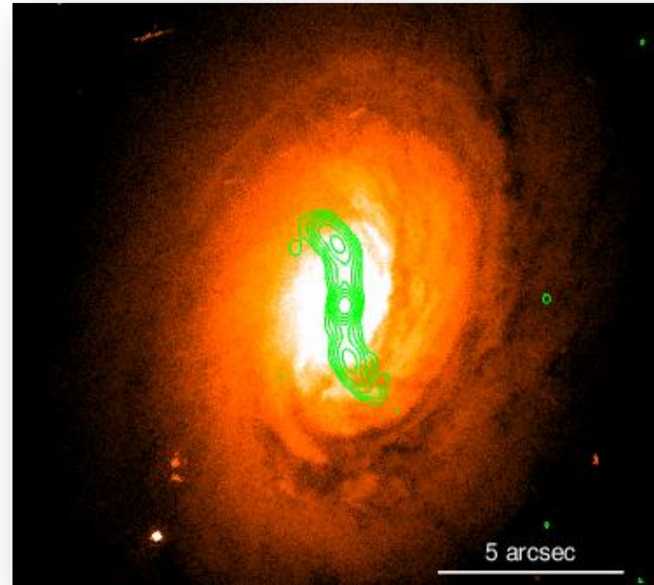
- Historical subclass of Seyferts with narrow (<600 km/s) optical lines (Seyfert 2-like) but much stronger hard X-ray emission (Seyfert 1-like)
- Flat X-ray spectra may imply they dominate XRB at low energies (e.g. Iwasawa et al. 1997)
- Transitional between Seyfert 1 and Seyfert 2? (Lawrence & Elvis 1982)

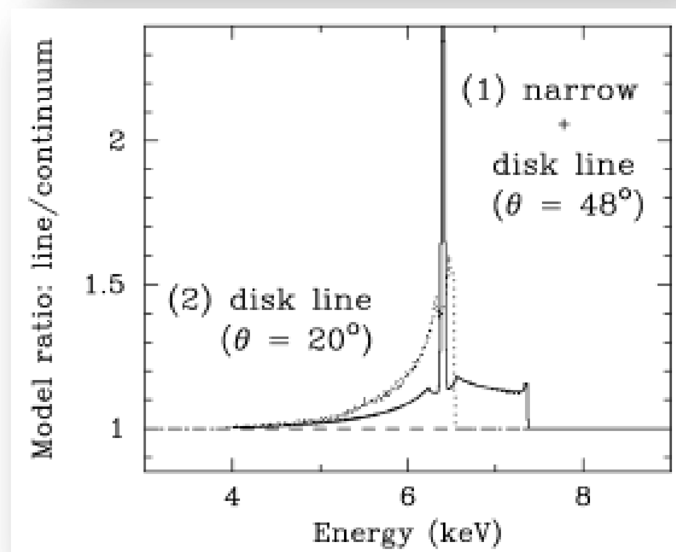
ASCA, BeppoSAX, etc. $\Rightarrow$ 2-10 keV X-ray spectrum is very flat (Γ=1.4)

- Accompanied by moderate absorption (N_H=3x10^{22} cm^{-2})

ASCA Fe K complex hard to interpret

- Diskline, either oriented at intermediate angles to l.o.s. (Weaver & Reynolds 1998) or nearly face-on (Turner et al. 1998)



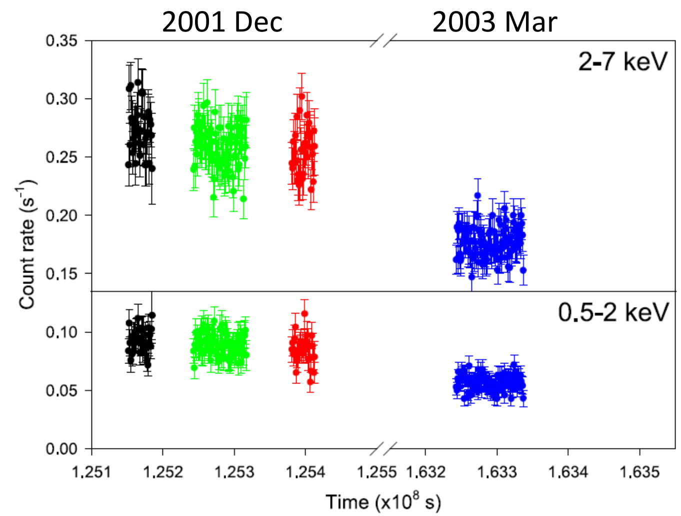


OBSERVATIONS AND RESULTS

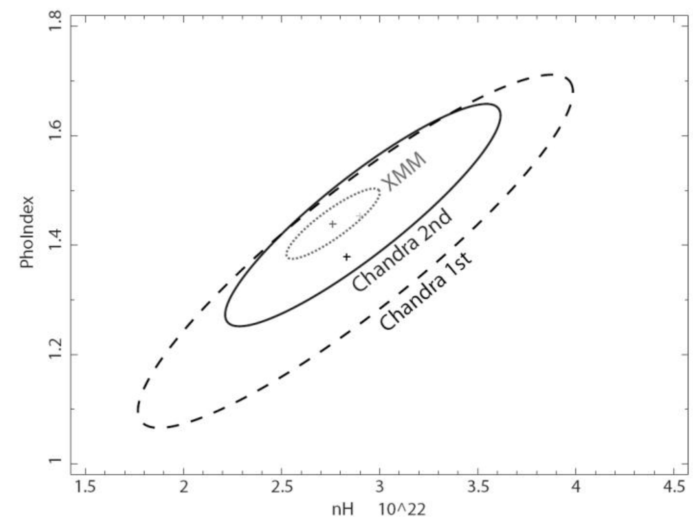
Chandra and XMM-Newton

NGC 2110 was observed with Chandra for a total of 250 ks and XMM-Newton for 60 ks. An initial analysis showed variability in flux only, and so the continuum spectra were analyzed jointly.

Instrument	Date	Exposure (ks)
HETGS	2001 Dec 19	35
HETGS	2001 Dec 20	80
HETGS	2001 Dec 22	35
HETGS	2003 Mar 05	100
EPIC/RGS	2003 Mar 05	60

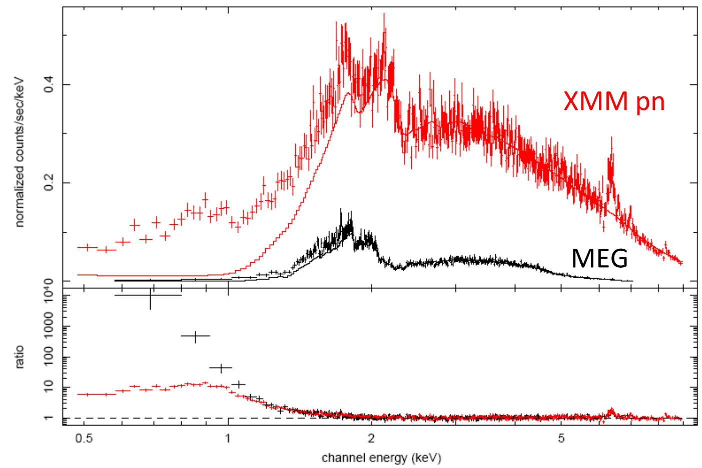


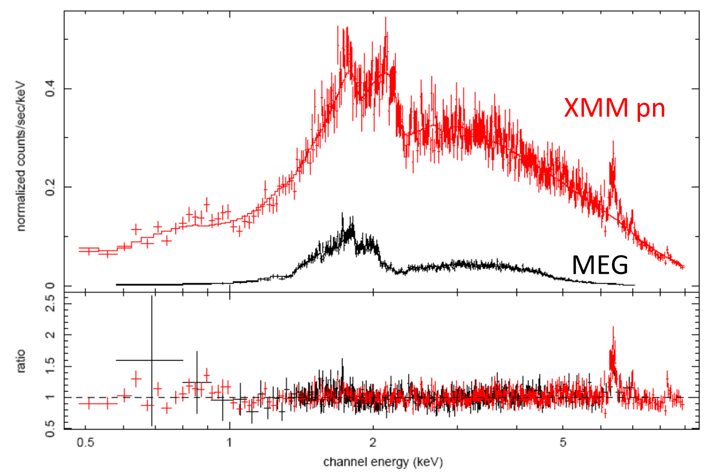
HETGS light curve



Continuum Fitting

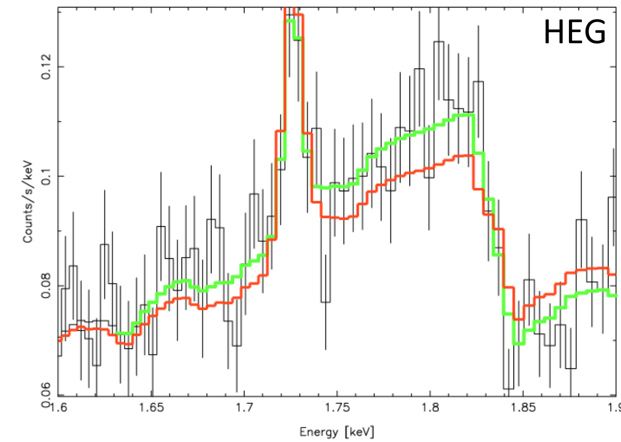
- Initial fit with single, moderately absorbed power law (N_H=3x10^{22} cm^{-2}, Γ=1.4)
- Soft excess seen below 2 keV
- Significant improvement in fit with the addition of a lightly absorbed (N_H=7x10^{20} cm^{-2}) power law (Γ_{soft}=Γ_{hard})
- Still very flat photon index (Γ=1.4), but…

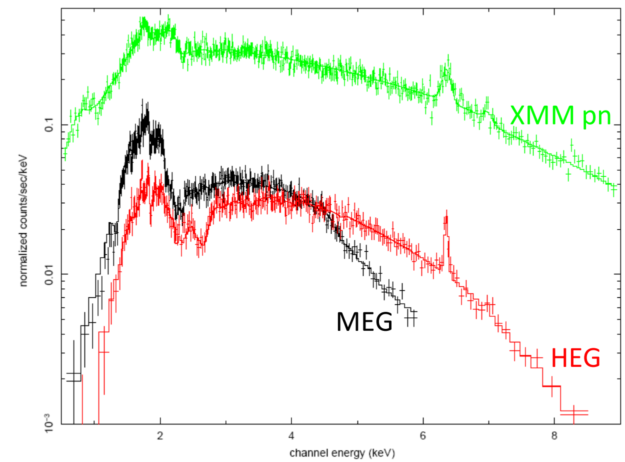




Continuum Fitting

- Insufficient opacity at Si K and Fe K edges
- Improvement in the fit with the additional edges
- Does this imply an extra absorber?
- Significant improvement with a 3x partially covered power law
- Photon index rises to $\Gamma=1.74\pm0.05 \Rightarrow$ consistent with canonical values in Seyferts
- No evidence for ionized absorption in HETGS data





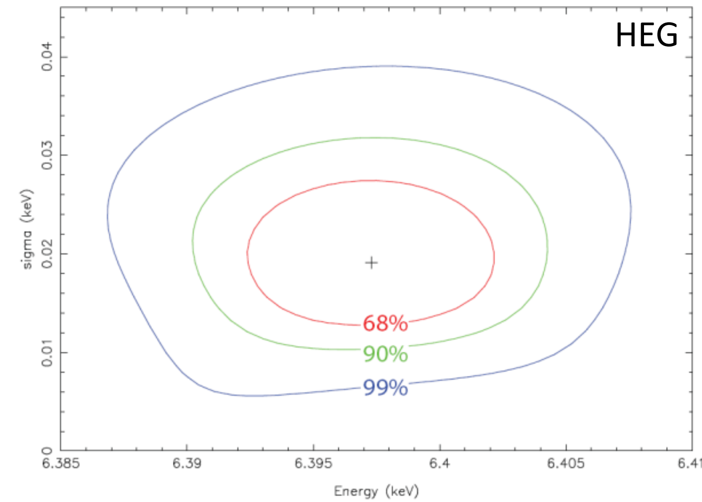
Component	Column density (cm^{-2})	Covering fraction
$N_{H,1}$	1.6×10^{23}	32%
$N_{H,2}$	2.8×10^{22}	65%
$N_{H,3}$	7.7×10^{20}	3%

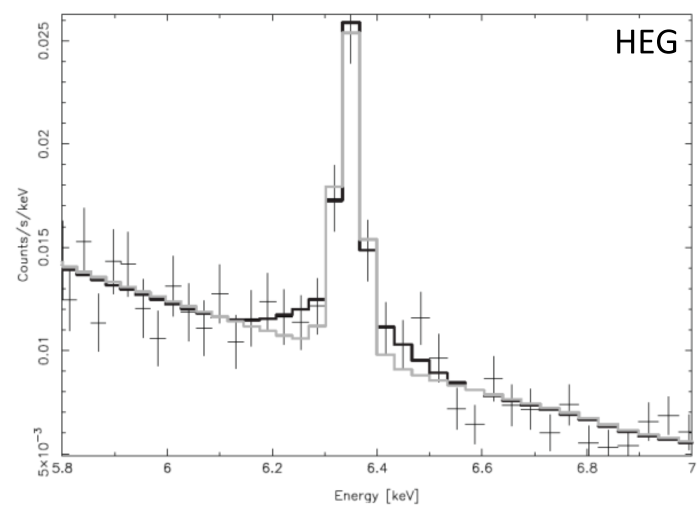
Fluorescent Line Diagnostics

- Chandra HETGS best suited to probe narrow lines
- Neutral fluorescent Kα lines detected from Si, S, Ar, Ca, Fe
- Narrow Fe Kα and Si Kα line cores just resolved with HETGS

Line	Energy (keV)	Width (km s^{-1})	Equivalent width (eV)
Fe Kα	6.397±0.007	900±500	80±30
Si Kα	1.740±0.002	600±400	6±2

- Distant, neutral fluorescing region
- No evidence for diskline
- Marginal (2.5σ) evidence for v. slight broadened base of Fe Kα

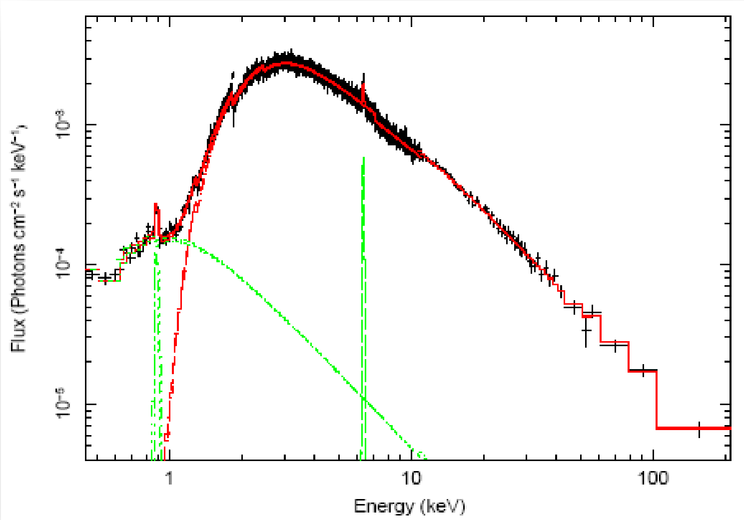




Reflection

- Self-consistent treatment of reflection (i.e., lines+pexrav continuum)
- No change in fit parameters
- Suzaku provides vital constraints on strength of reflection
- Stringent limit of *R*<0.1 (Reeves et al. 2006; Okajima et al. 2007)
- NGC 2110 is one of the few Seyferts with no evidence for disk reflection, nor complex absorption

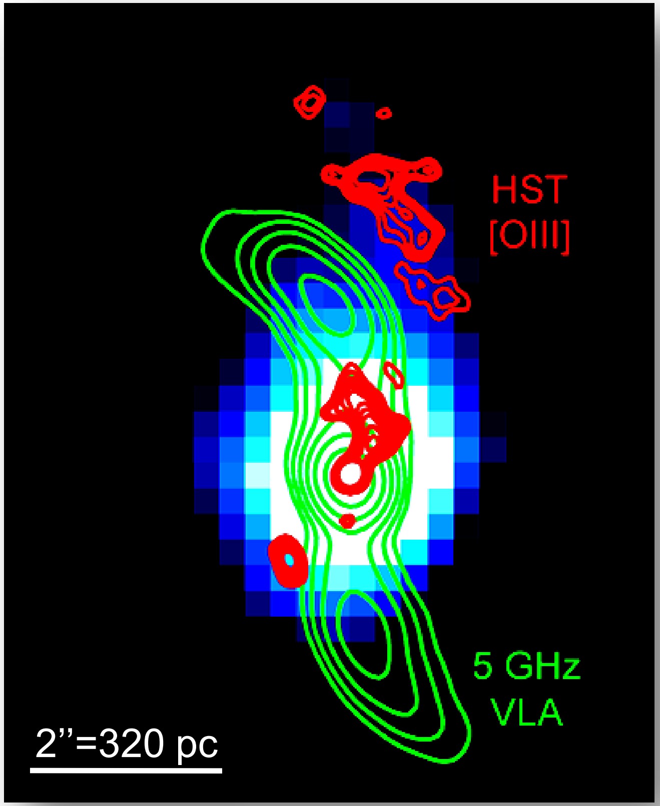
Suzaku – NGC 2110 (Reeves et al. 2006)



CIRCUMNUCLEAR ENVIRONMENT

Multiwavelength Imaging

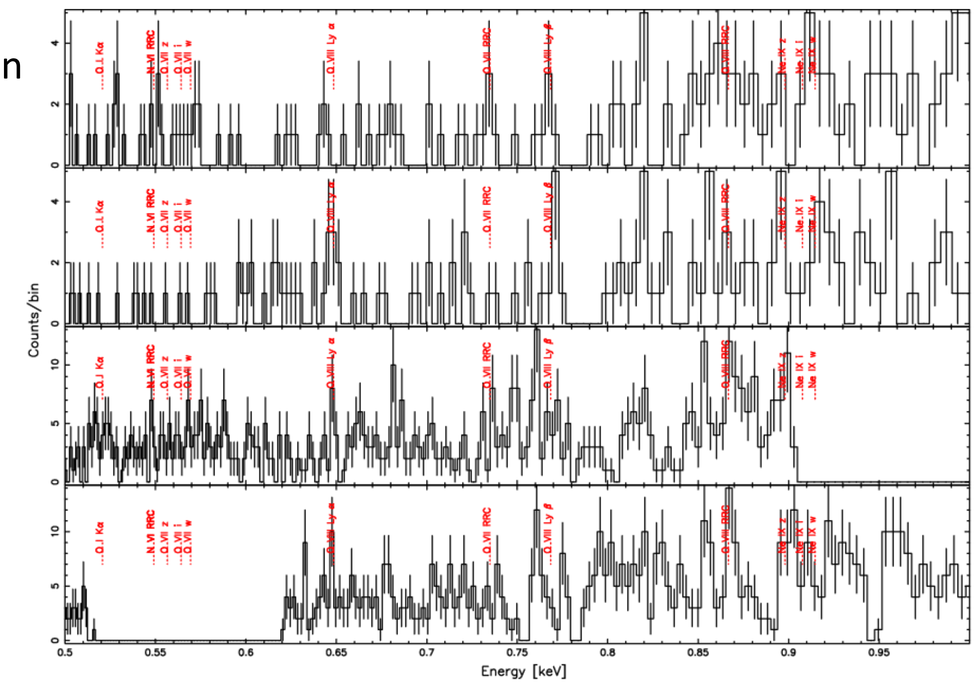
- Excellent spatial agreement between X-ray and [OIII] (Evans et al. 2006)
- Both clearly offset from radio, but extend along similar p.a.
- X-ray & [OIII] emission influenced by, but not directly associated with, radio jet?
- ACIS X-ray spectrum modeled by, e.g., two thermal plasma models (kT_1=0.3 keV; kT_2=5 keV)



Chandra (0.5-1.5 keV) / VLA / HST [OIII] overlay

Gratings Spectrum

- Evans et al. (2006) considered 3 mechanisms for producing the environment:
  - Shock-heating by the radio jet
  - Electron-scattered nuclear radiation
  - Photoionization by the AGN
- High-resolution grating spectroscopy can in principle distinguish between these models
- Tentative evidence for O VIII Ly α, as well as the O VIII RRC feature first reported by Guainazzi & Bianchi (2006)



- Photoionization and collisional ionization processes both important?

SUMMARY

Recap

ASCA, BeppoSAX, etc. found

- Flat (Γ=1.4) 2-10 keV spectrum
- Moderate absorption (N_H=3x10^{22} cm^{-2})
- Diskline emission, either face-on or at intermediate angles

Chandra, XMM-Newton (and Suzaku – Okajima et al. 2007)

- Compton-thin partial-coverer model
- Photon index 1.7-1.8
- No evidence for ionized absorption
- Marginally resolved (900±500 km s^{-1}) Fe Kα line core
- No evidence for disk reflection
- Multiwavelength imaging + HETGS evidence for (weak) ionized emission $\Rightarrow$ extended circumnuclear environment is photoionized or collisionally ionized?

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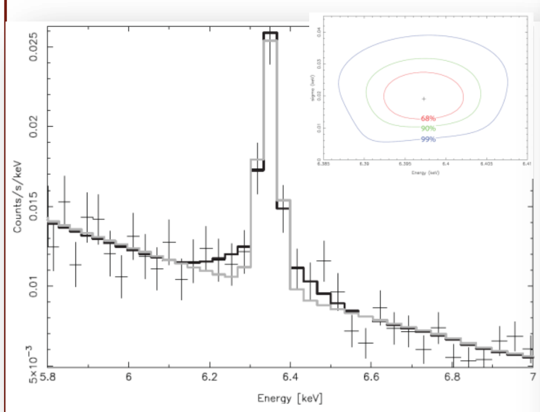

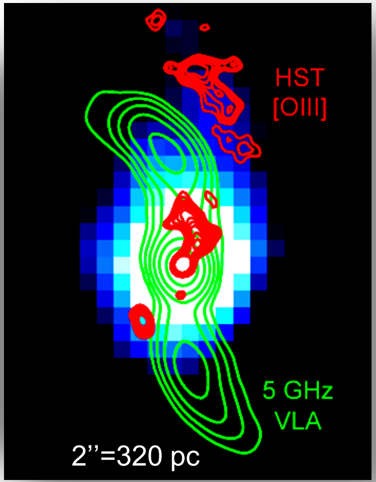

IMPLICATIONS

- Consistent with an origin in a Compton-thin, distant (> 1pc) neutral absorber
- Orientation consistent with edge-on view
- Steepening of photon index using multiple partial-coverer model $\Rightarrow$ NELGs do not have significantly flatter spectra w.r.t. Seyfert 1, 2?
- No disk reflection, unlike other Compton-thin Seyferts observed with Suzaku (Reeves et al. 2006)
- Vital to treat absorption and reflection effects in a self-consistent manner in order to evaluate AGN geometry
- High spatial and spectral resolution, together with high effective area, are key to determining the spatial distribution and energetics (collisional vs. photoionization) of circumnuclear environments in AGN