Chandra Imaging of the Nuclear Region in Nearby Seyferts: Disentangle AGN Feedback

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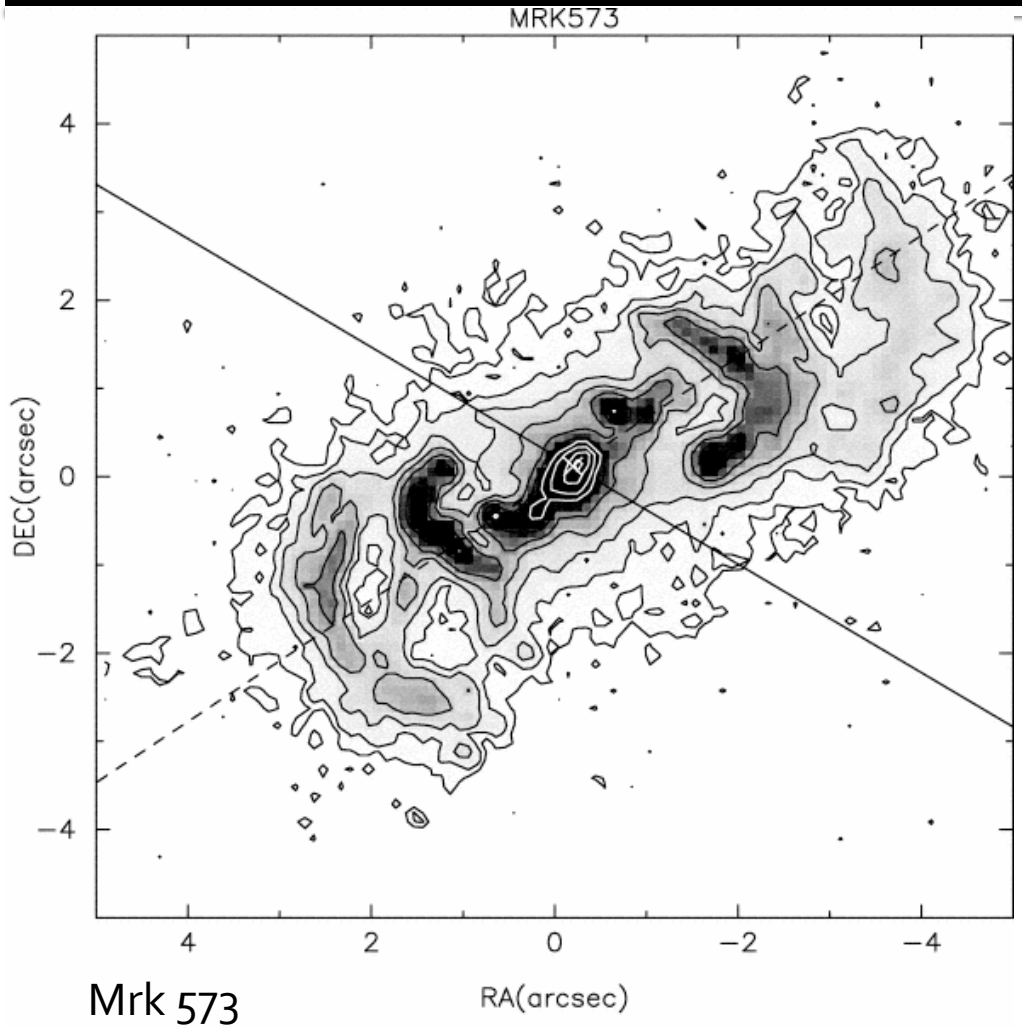
Accretion Processes in X-Rays: From White Dwarfs to Quasars

07/13/2010

Why Study the Complex Circum-nuclear Region



Mrk 573

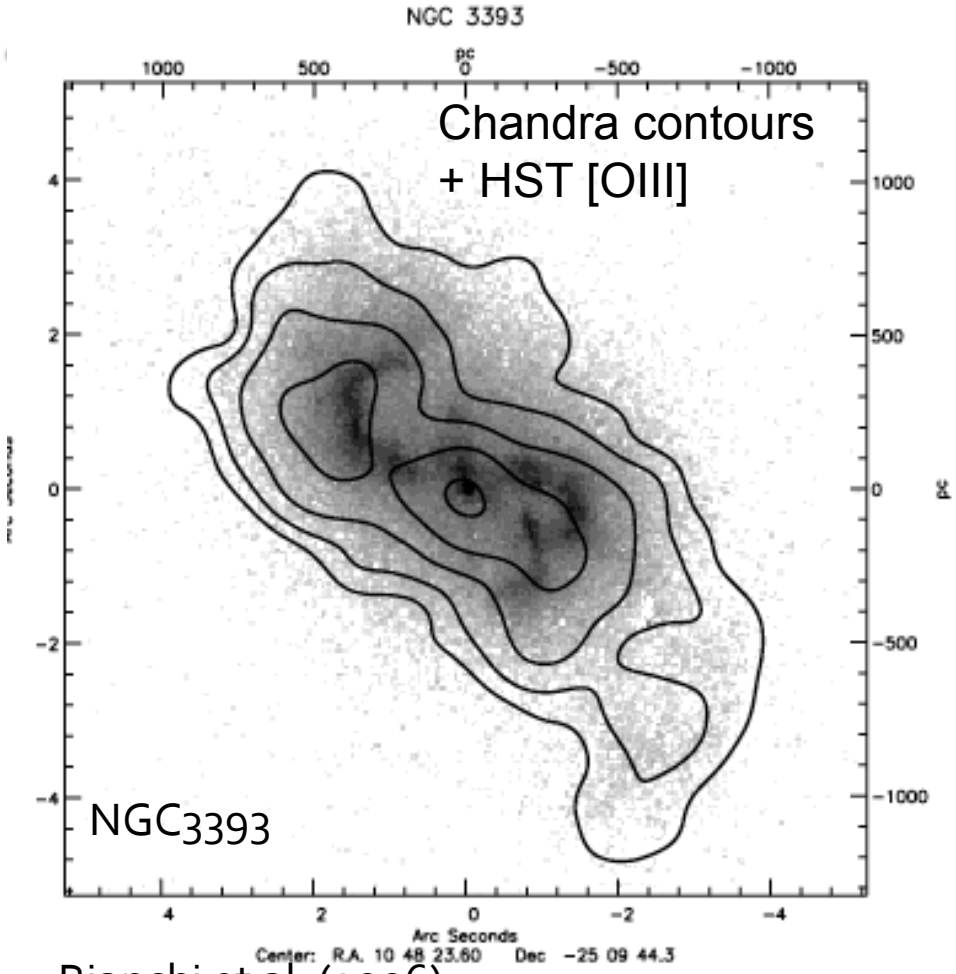
HST [OIII] survey by Schmitt et al. (2003); see also Bianchi et al. (2010)

AGN outflow is an important part of the accretion process
(cf. Proga, Chartas talks)

"AGN feedback" crucial to SMBH-galaxy co-evolution

Energy injection efficiency
often assumed
$L_{outflow}/L_{bol}$ ~ 5%-100%
(e.g., Scannapieco & Oh 2004; Silk 2005; see also Hopkins & Elvis 2010; Ciotti et al. 2010; Ostriker et al. 2010)

Soft X-ray/NLR Connection



Bianchi et al. (2006)

A single photoionized medium

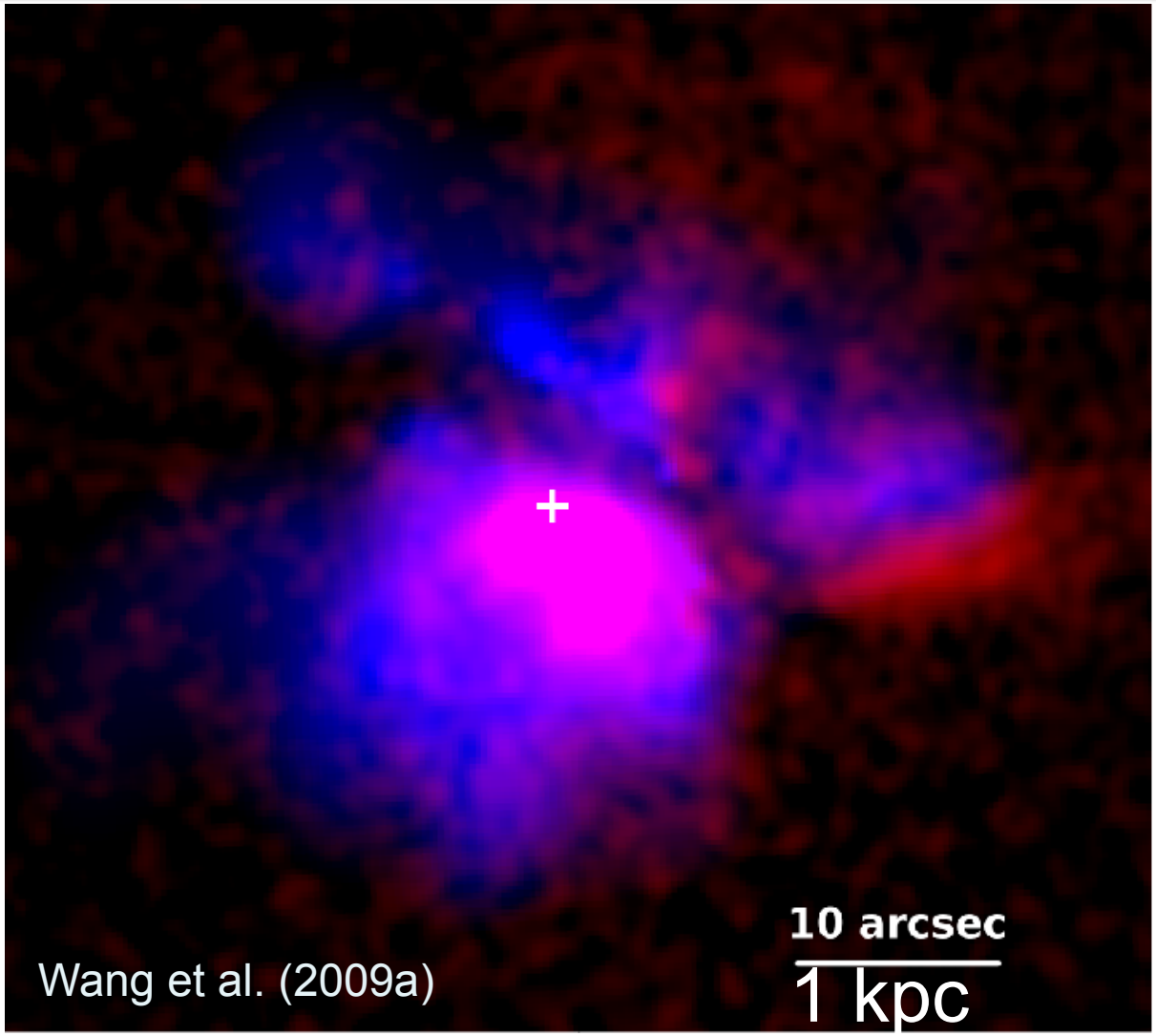
- Overall morphology coincident with the [OIII] emission
- Poor fit to the X-ray spectra with collisionally ionized thermal plasma

• Many Seyfert galaxies host vigorous star formation and/or eject relatively weak jets

• Competing processes of AGN photoionization and shock heating

See also Evans et al. (2006); Bianchi et al. (2010); Dadina et al. (2010)

Hot Gas Confining the Photoionized Clouds in NGC 1365 Blue: X-rays Red: [OIII]5007

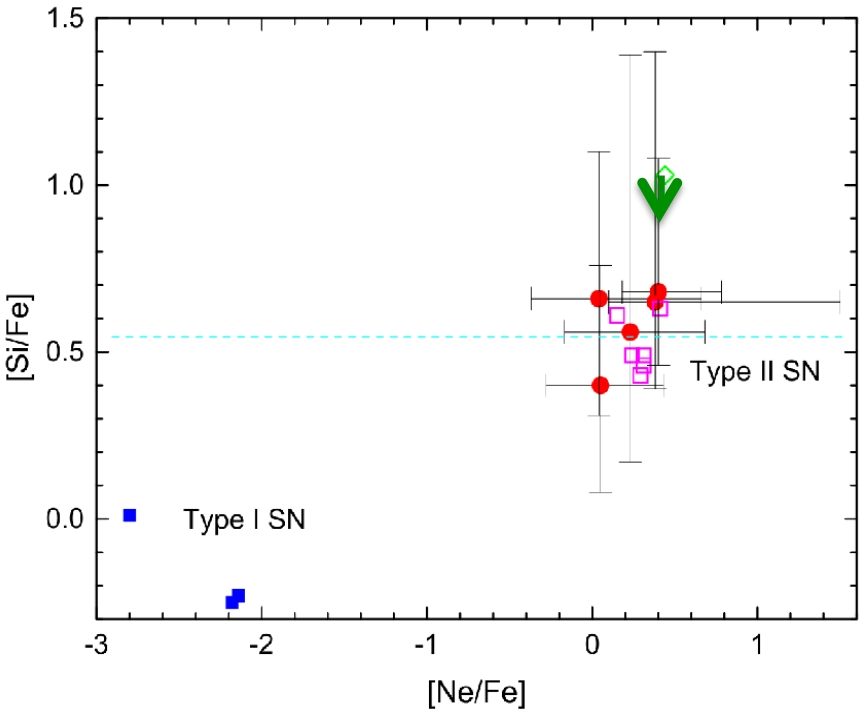


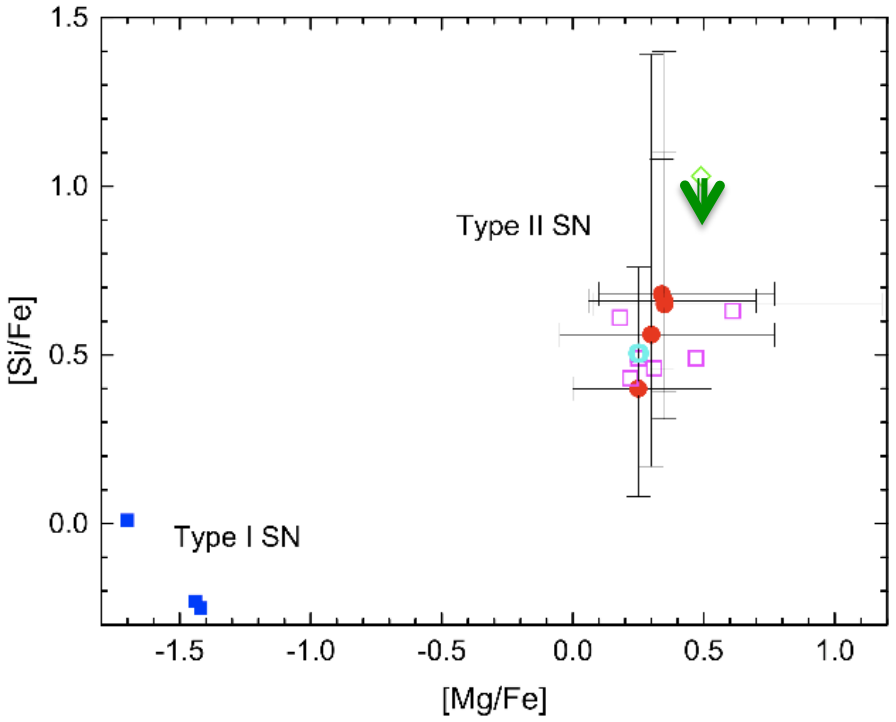
[OIII] clouds P~10^{-10} dyne cm^{-2} (Kristen et al. 1997)

Pressure equilibrium with cooler optical line-emitting gas

X-ray emitting hot gas may serve as the hot phase confining inter-cloud medium to the NLR cloud (Elvis et al. 1983, 1990)

Elemental Enrichment in the Hot ISM of NGC 1365

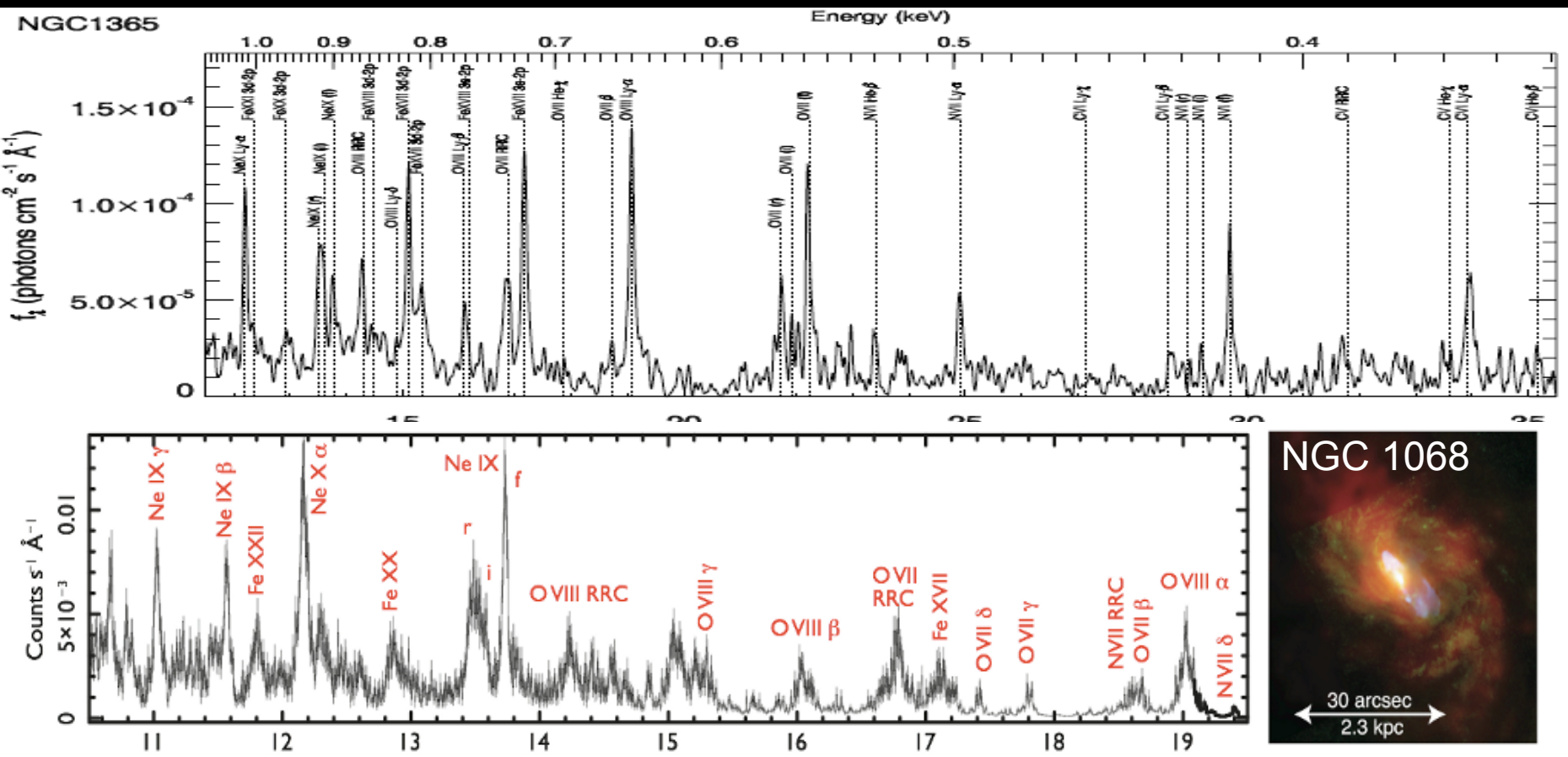




Filled circles: NGC 1365 regions
Diamond: Strickland (2004) starburst sample
Cyan circle and line: warm Galactic halo
Blue squares: stellar yields from SNe Type I
Magenta squares: SNe Type II (Nakataki & Sato 1998 and references)

Consistent with Type II SN enrichment

AGN Feedback Study: Spatial Resolution Needed



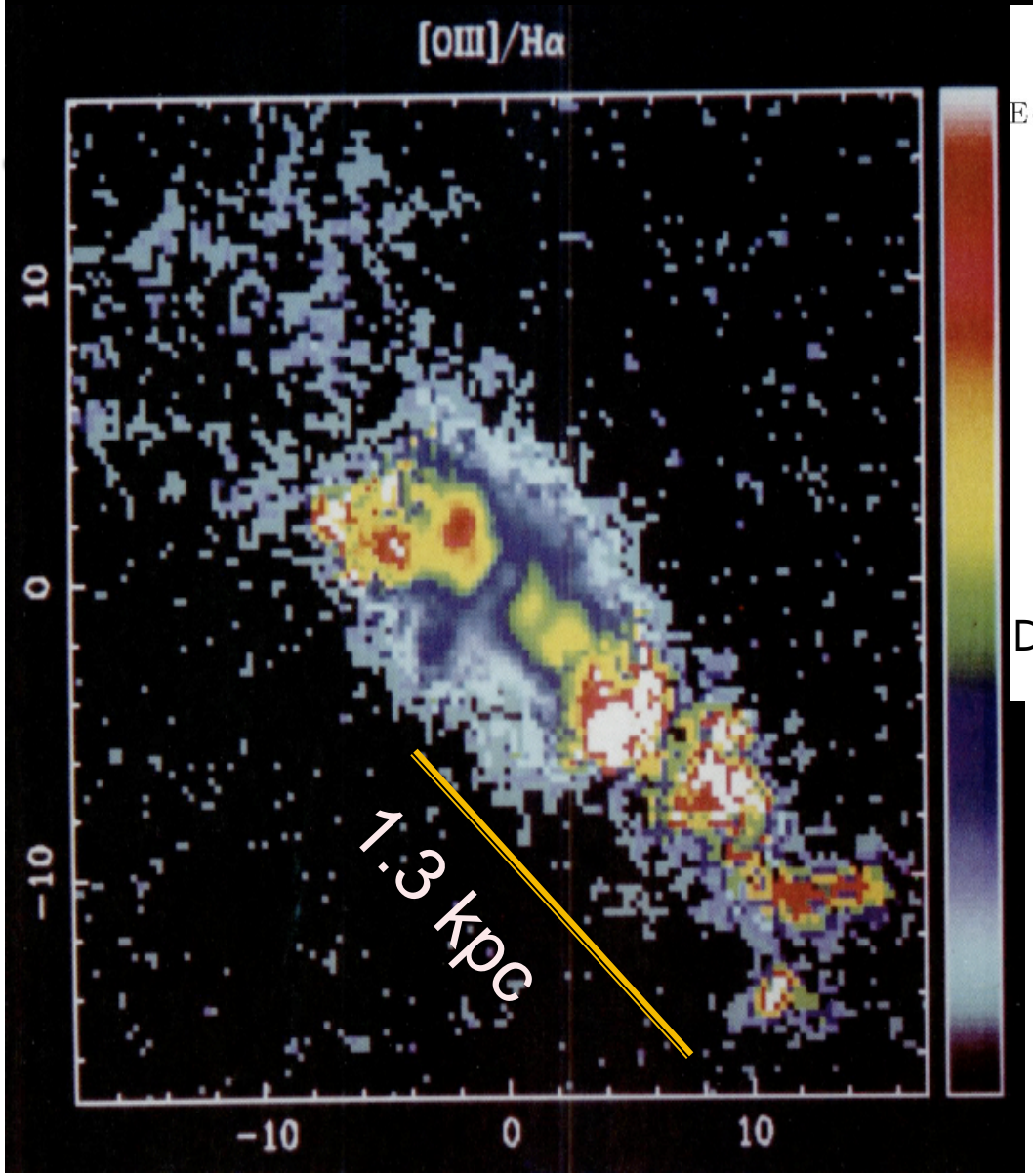
Soft X-ray emission in Seyfert 2s likely dominated by photoionized gas (Guainazzi & Bianchi 2007; Guainazzi et al. 2009) Line ratio diagnostics

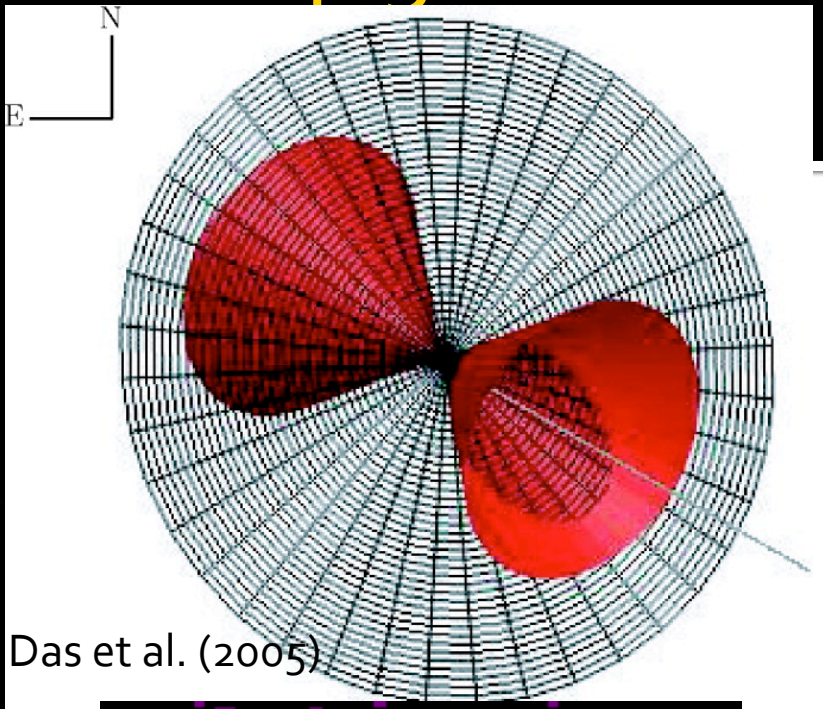
But … location of the X-ray photoionized gas

e.g., Mrk 355 <0.06 pc (**Longinotti+**08); NGC 1068 up to 1 kpc (**Evans**+10) → implications on the mass/momentum outflow

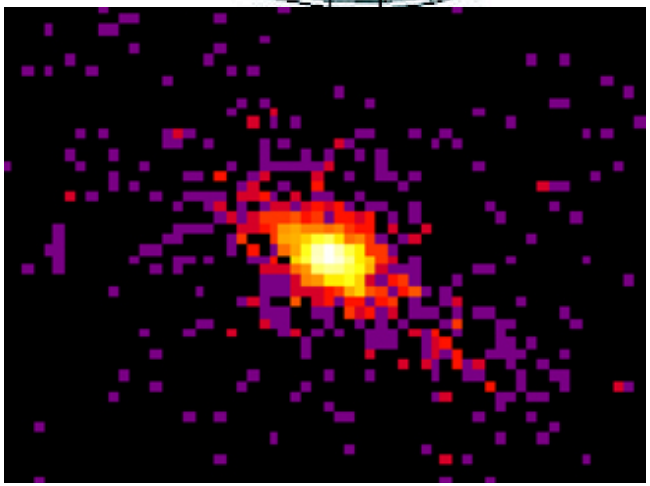
See Krongold+07; Arav+08; Steenbrugge+09; Ebrero+10

Biconical Outflow in NGC 4151 ENLR



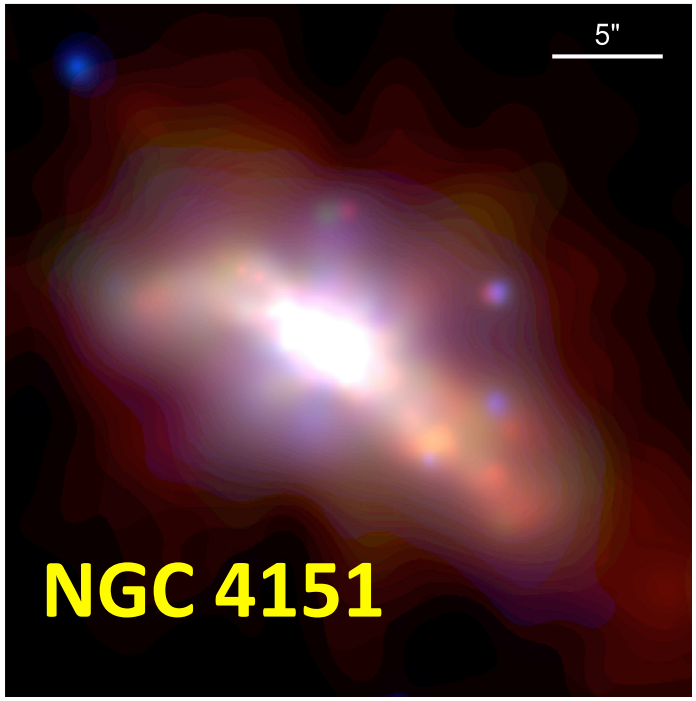


Das et al. (2005)



Ogle et al. (2000); Yang et al. (2001)

New Results from Our NGC 4151 Project (PI: G. Fabbiano)



~200 ks ACIS-S 1/8 sub-array (shorter frametime)

-X-ray spectral variability of the nucleus (Wang et al. 2010a)

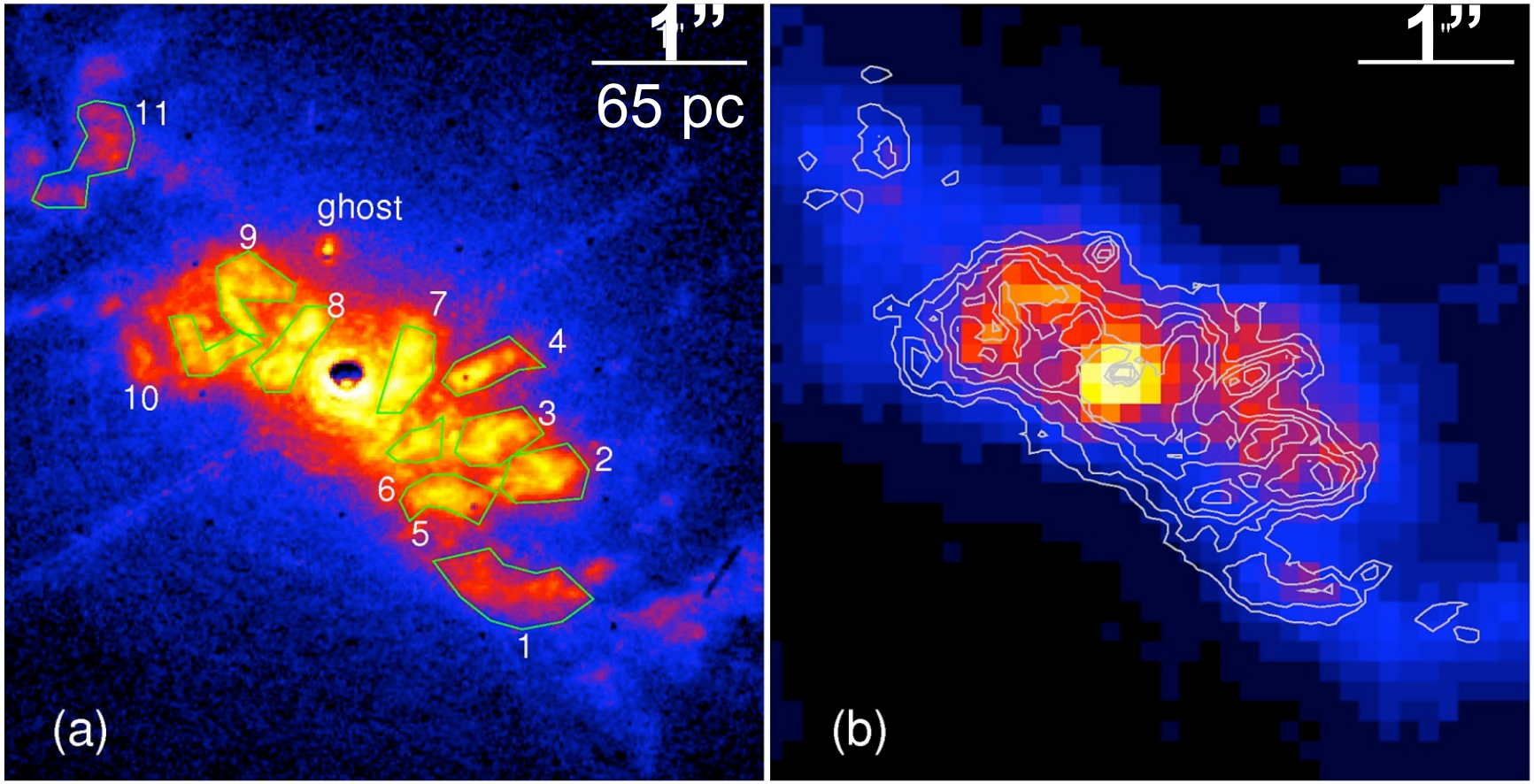
-Extended soft X-ray emission (Wang et al. 2010b)

50 ks HRC-I Imaging the inner-most region

(Wang et al. 2009)

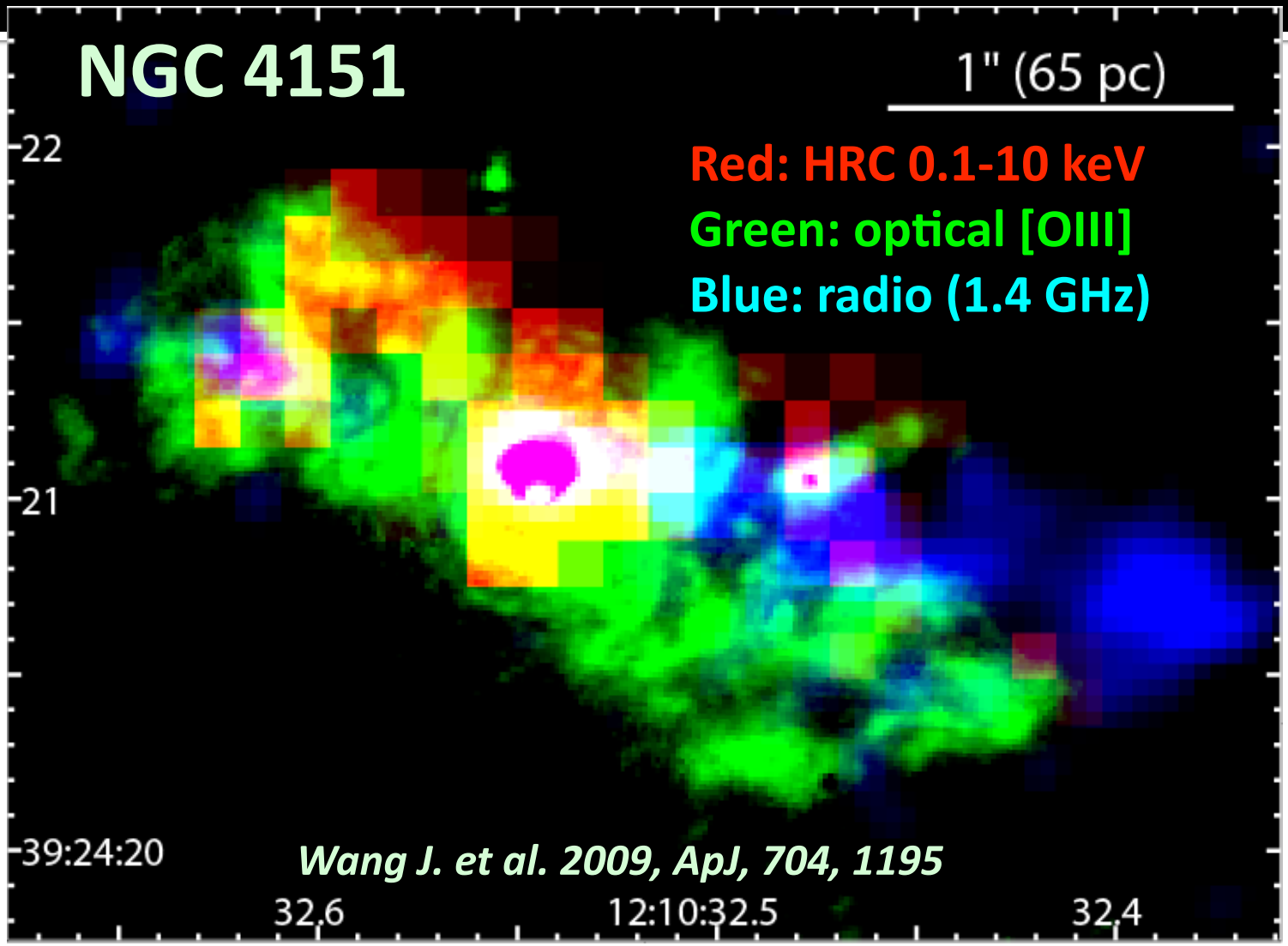
0.13 arcsec `pixel' but poor energy resolution (cf. 0.5"/pixel ACIS)

HST vs. Chandra (PSF deconvolved)



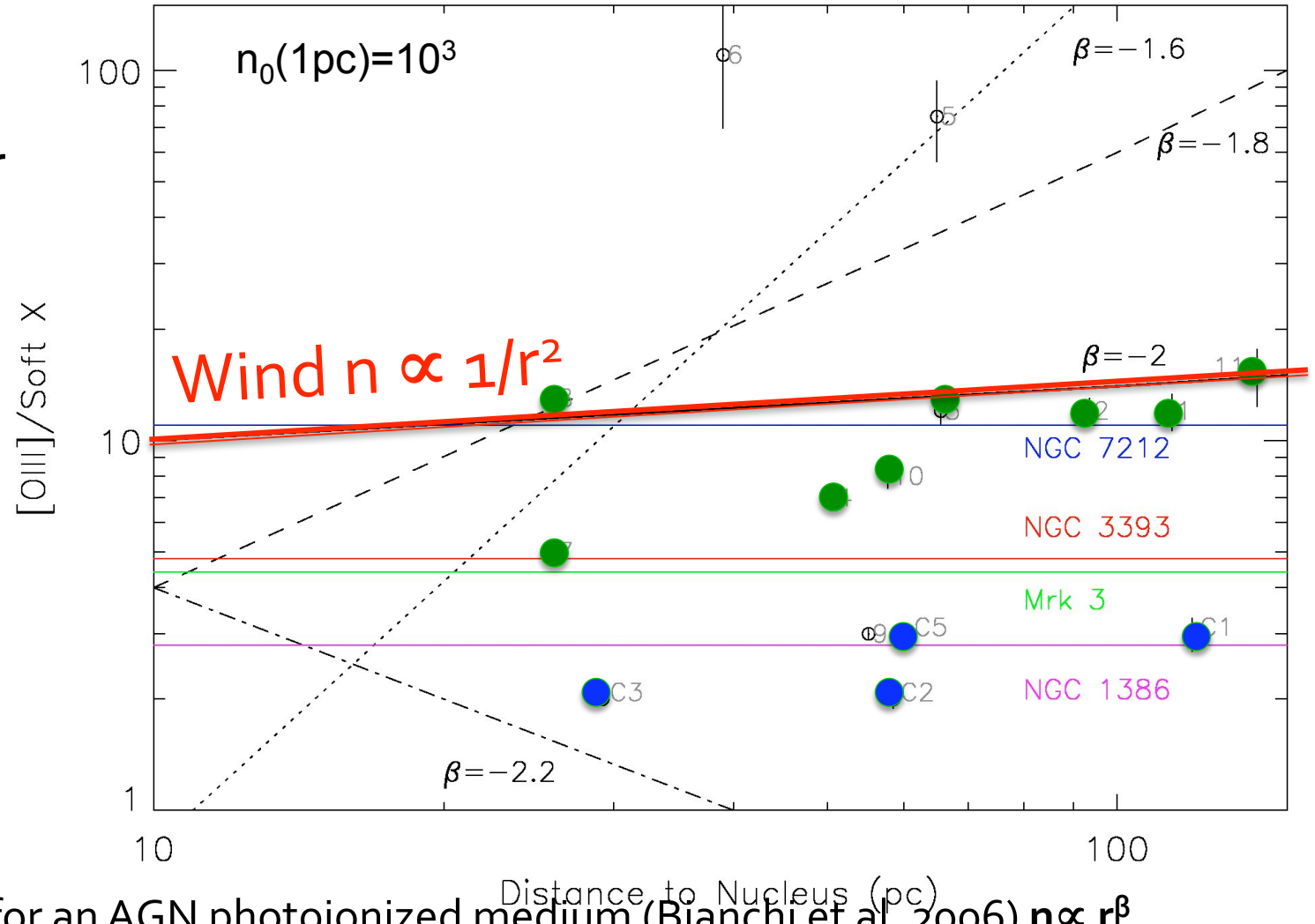
Wang et al. (2009); HST/FOC 502N data from Winge et al. (1997)

Enable multiwavelength view of the Jet-cloud interaction



Constraints on the X-ray Emission from the [OIII] Clouds

Ionization parameter
$\xi = L/(nr^2)$

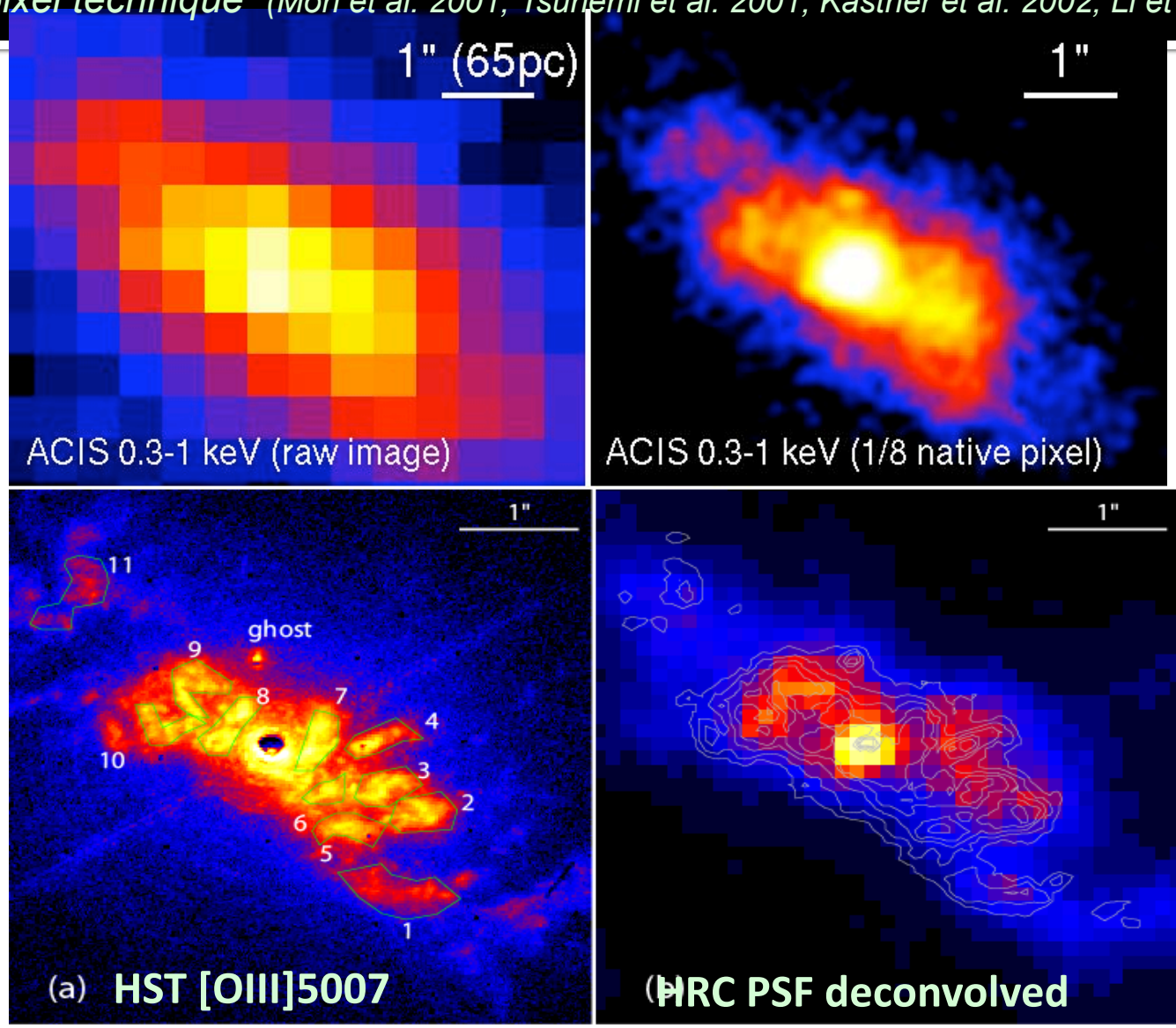


Enhanced X-ray emission in addition to photoionization

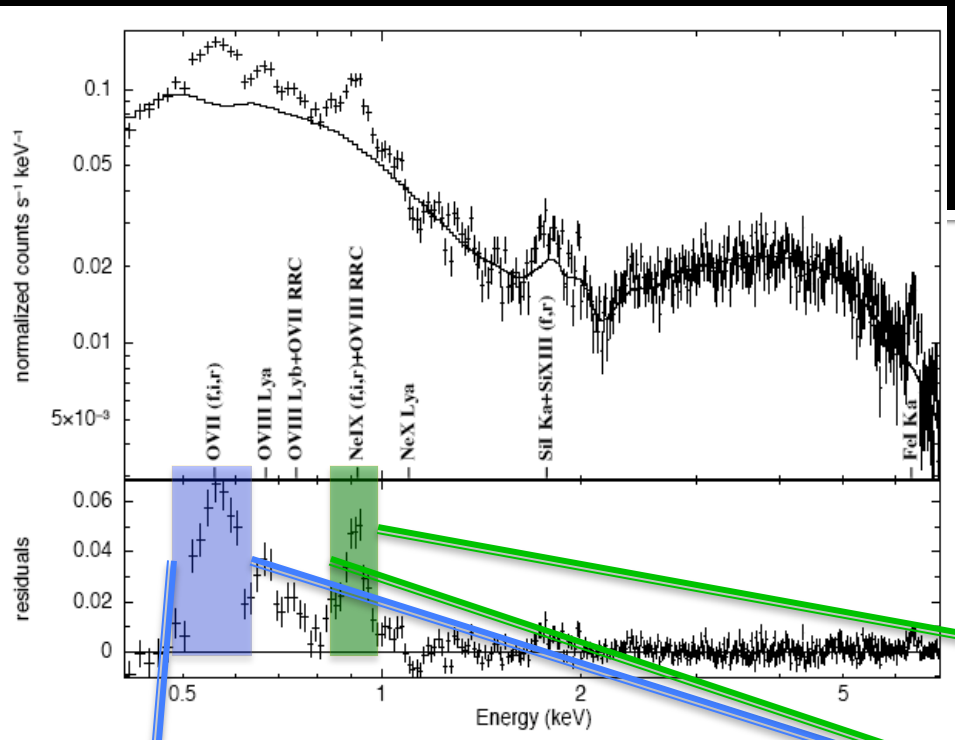
CLOUDY grid for an AGN photoionized medium (Bianchi et al. 2006) $n \propto r^{\beta}$

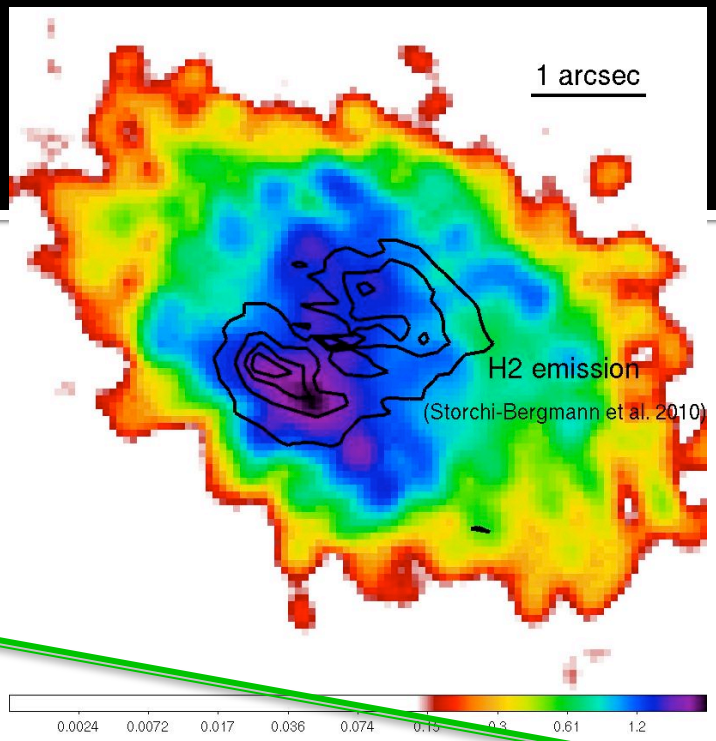
Study NGC 4151 NLR structure on physical scale of ~30 pc (0.5" @ 13 Mpc)

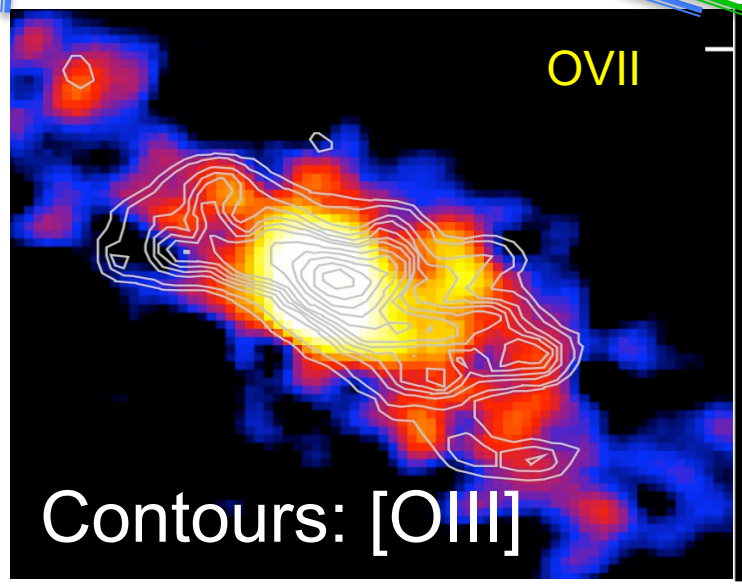
Subpixel technique *(Mori et al. 2001; Tsunemi et al. 2001; Kastner et al. 2002; Li et al. 2003)*

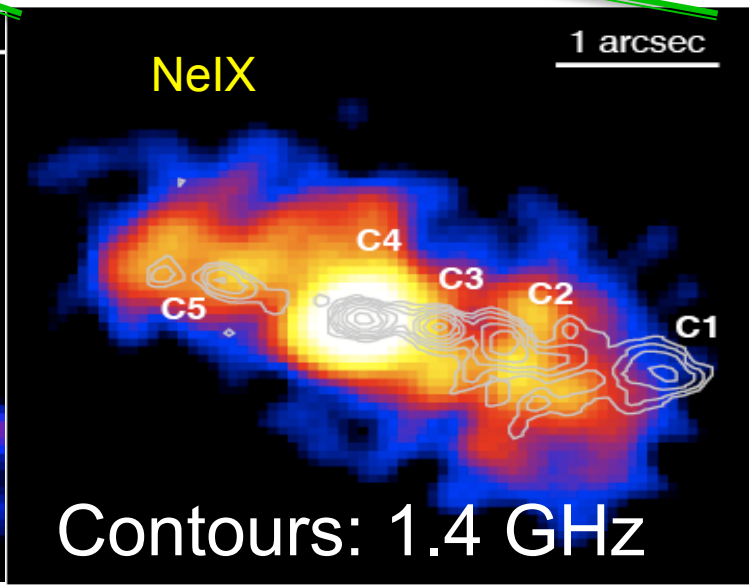


Disentangle the Emission with Spatially Resolved Spectroscopy





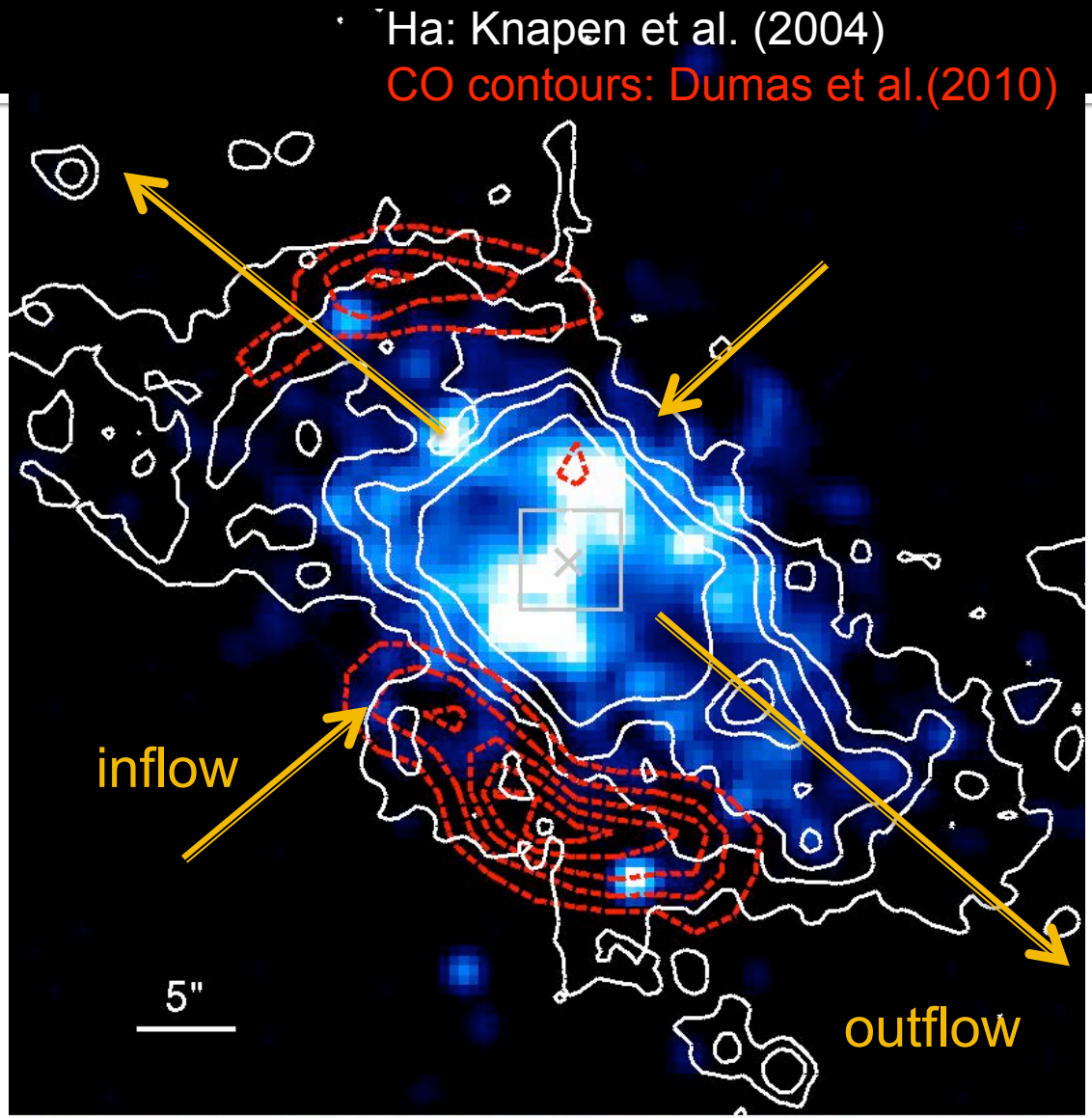




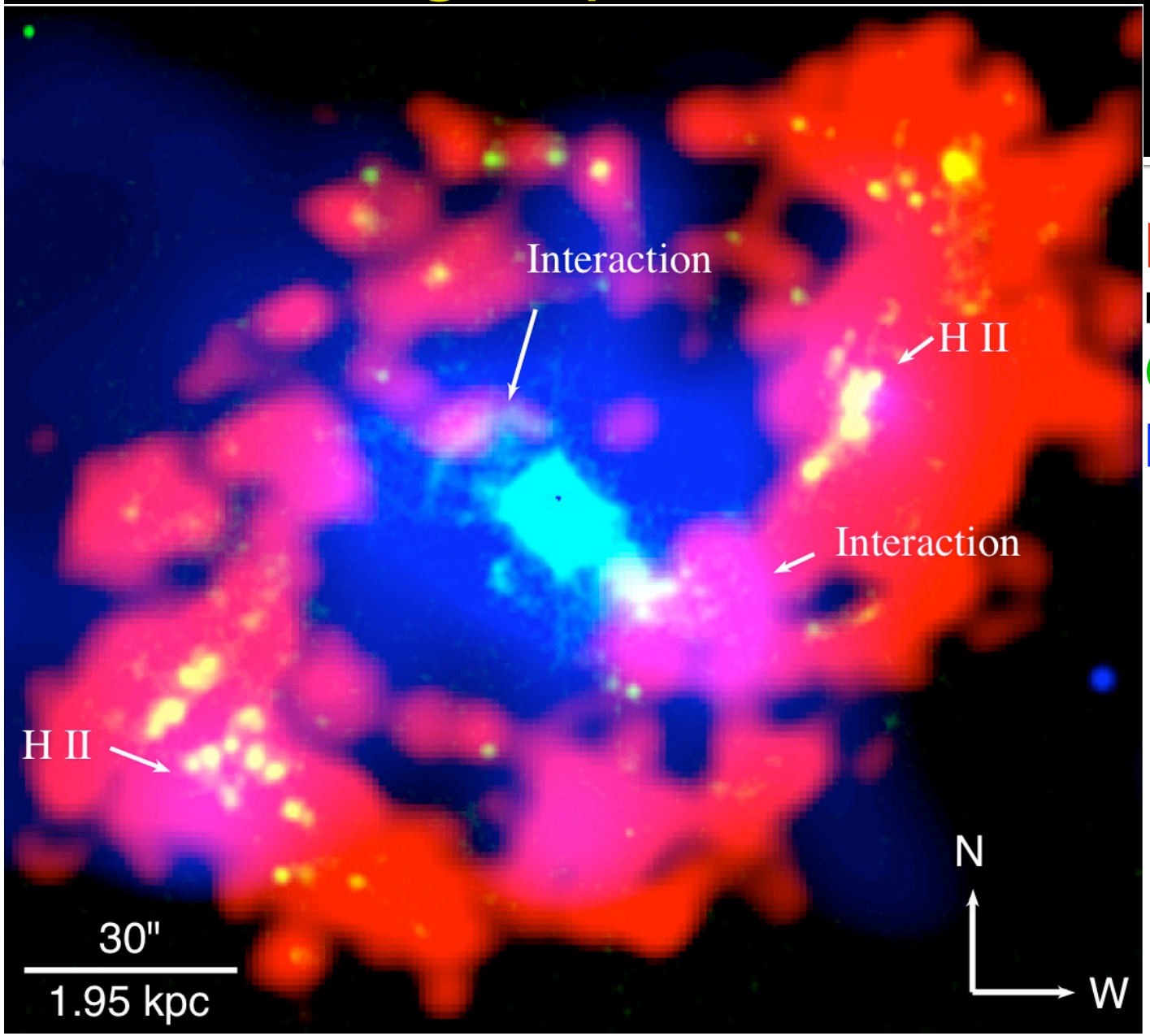
A Full View of AGN Feeding and Feedback

Hardness ratio map of the circum-nuclear region reveal hard spectral index or high obscuration region

Bianchi et al. (2008), Wang et al. (2010)



Evidence for galaxy-scale AGN feedback?



Red: HI

Mundell et al. (1999)

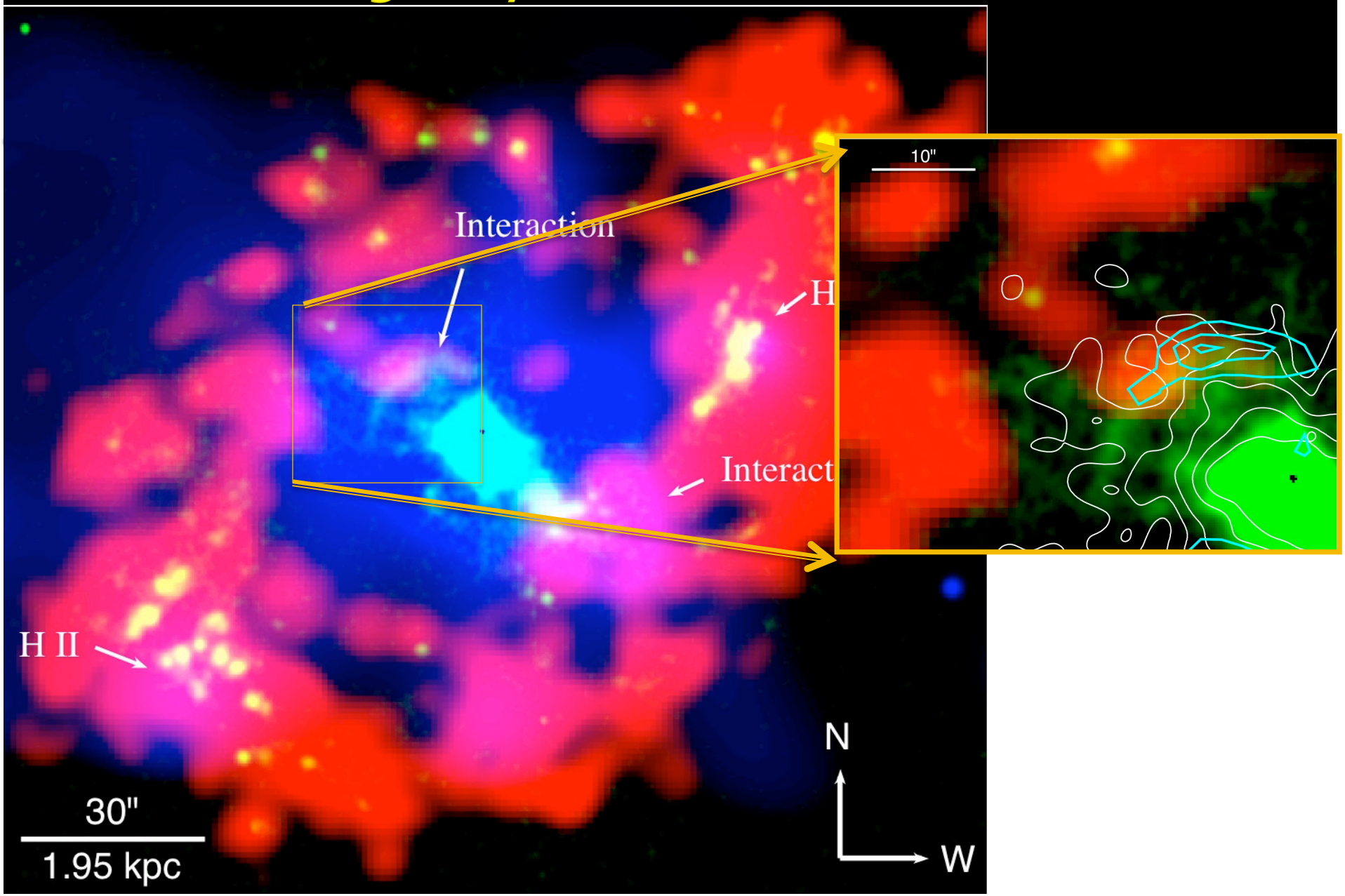
Green: Halpha

Blue: 0.3-1 keV

X PSF scattering
X Unresolved point sources
X Electron scattered nuclear emission

Wang et al. (2010) ApJL submitted

Evidence for galaxy-scale AGN feedback?



Origin of the large scale soft emission

? Relic photoionized gas from a past AGN outburst (L~ L_{edd} required)

light travel time + recombination time scale

$T < 2.5 \times 10^4$ yr

? Hot gas heated by AGN outflow

Pressure 10^{-11} dyne cm^{-2}

Additional confinement by HI gas inflow

$T \sim 10^4 - 10^5$ yr

Conclusions

- Chandra's high resolution images are powerful tools in studying the complex circum-nuclear regions of AGNs
- For the NGC 1365 X-ray emission cones, we find hot gas confining photoionized clouds, likely starburst driven "superwind"
- **In NGC 4151 Chandra resolves**
  - Photoionized emission. The radially constant ratio indicates a density dependence $n \propto r^{-2}$ as expected for a nuclear wind.
  - Thermal emission from interaction between radio outflow and the NLR clouds.
  - 'Fossil' large scale emission.

Given these diversities, we need to study individual objects in detail to learn AGN feedback physics

*CHandra survey of Extended Emission line Regions in nearby Seyferts: (**CHEERS**)*

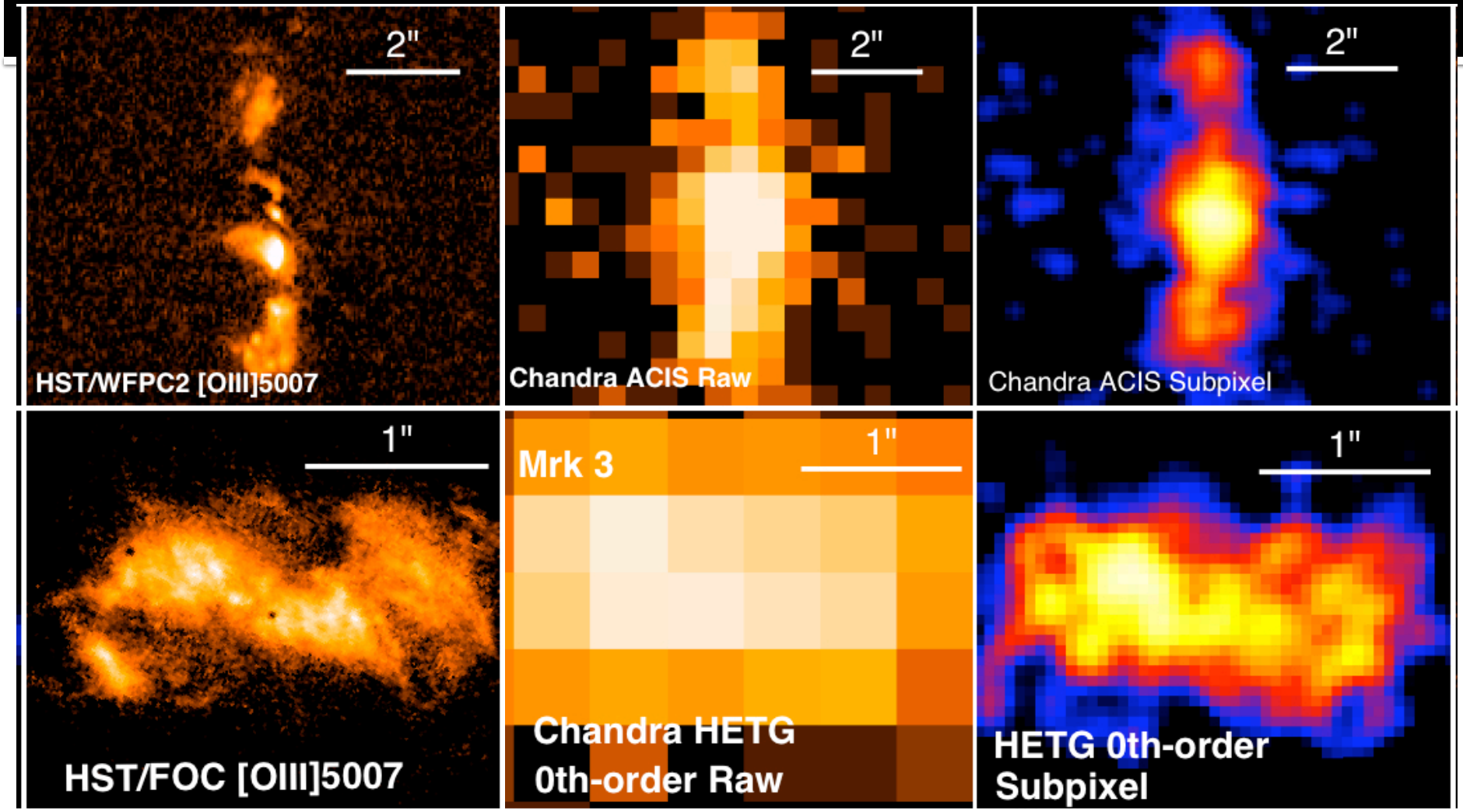
✧Full picture of the multiphase ISM

✧Mass-momentum outflow

Thank you!

Subpixel technique

(Mori et al. 2001; Tsunemi et al. 2001; Kastner et al. 2002; Li et al. 2003) ***applied***



Wang et al. in prep.