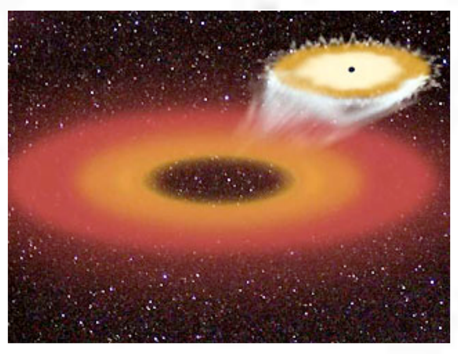
A recoiling BH: GW or slingshot?



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CID-42 (z=0.359, CXOC~J100043.1+020637)

- HST/ACS image: **Only double nucleus** host out of 2600 X-ray sources in COSMOS
- **Separation: 2.4±0.02 kpc** (0.495"±0.005")
- Hβ Broad and Narrow: **Δv~1000 km/s offset**
- X-ray: ***red*shifted Fe-K absorption line**
- Fe-K absorption line **changes energy by ΔE~500 eV** over 4 years.

$L_X = 10^{44}$ erg/s
$L_{bol} = 2.9\times10^{11} L_{sun}$
M_{BH}(SW)$=6.5\times10^7$ M_{sun}
L/L_{edd} (SW) = 0.04
SFR = 100 M_{sun}/yr

What is going on? Two possible explanations:

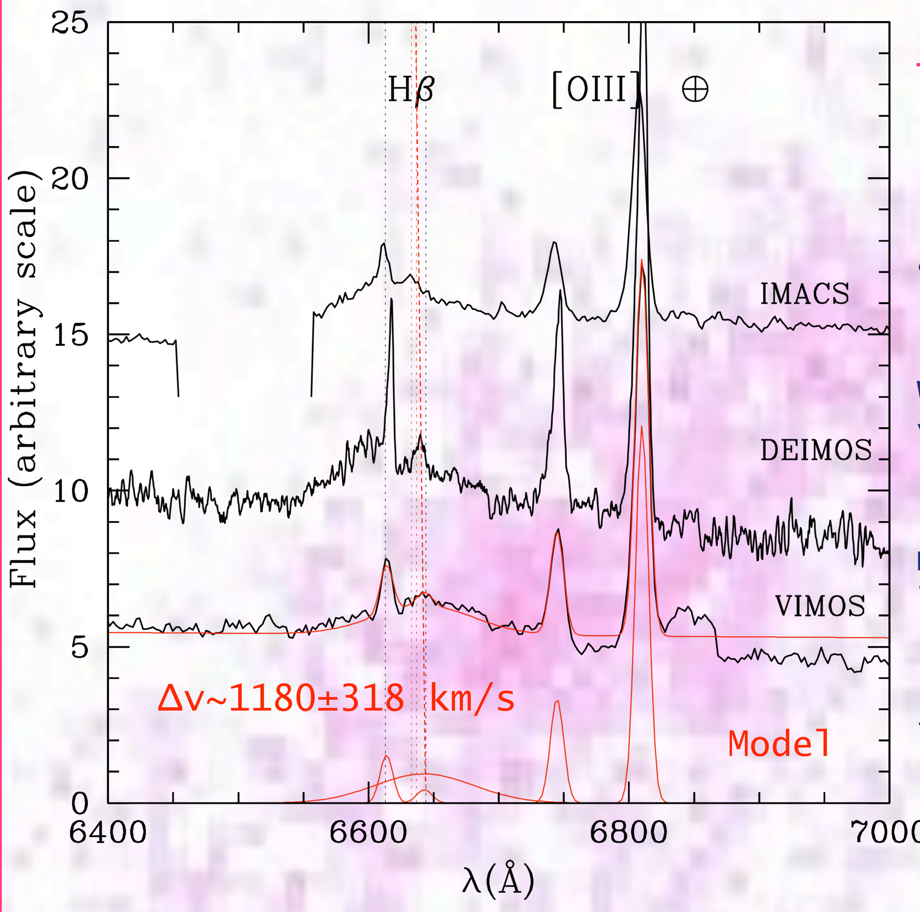
1. "Run-Away" BH: Gravitational wave recoil ejected the SMBH from the core of the galaxy just at merger, carrying with it the accretion disk and the BLR, but leaving behind the NLR. The high velocity shift requires the precursor BH to be rapidly spinning. *Weakness: why varying Fe-K absorption?*

2. BH ejcted by slingshot effect: in a triple BH system, 2 are merging (NE source) and the third has been ejected by slingshot effect; we look through a BAL-like highly ionized outflow from the nearer NE source at the recoiling BH. This scenario requires fast winds in obscured AGN. Not observable otherwise. BALs universal in AGNs?

Coming soon…**Chandra/HRC observations to resolve the X-ray**

HST imaging Analysis (Galfit)

- **SE nucleus: point-like** source → F814W=**20.5mag**
- **NW nucleus:** compact **scale length of ~0.5 kpc** → F814W=**19.67mag**
- Sersic component #2: large spheroid (r_{eff}~15 kpc)
- Sersic component #3: total light distribution plus the spiral arm
- Total magnitude: F814W=18.6mag

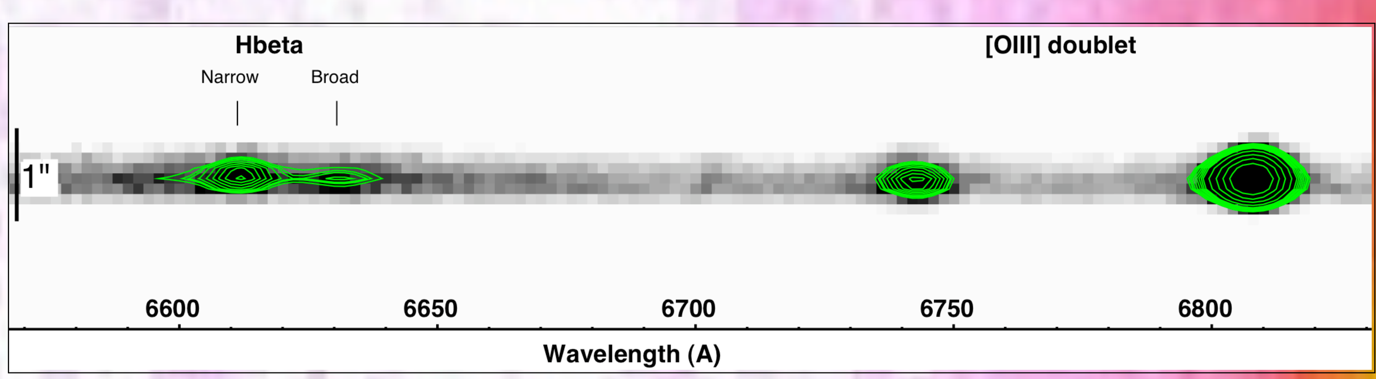


LINE VELOCITY OFFSET

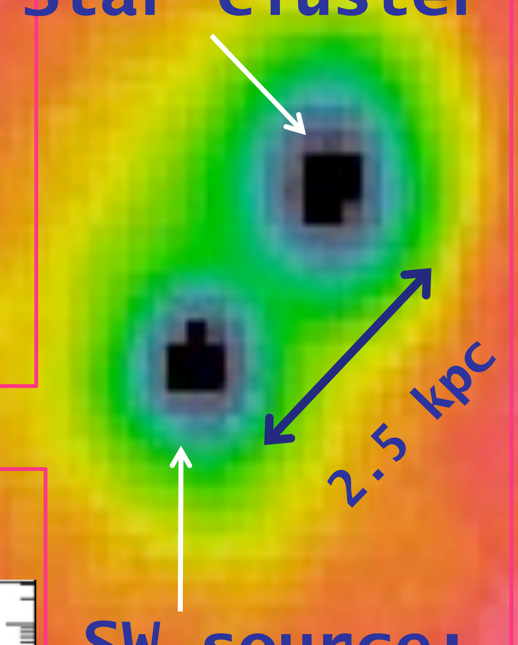
- Nuclei NOT spatially resolved.
- Narrow emission lines ([OIII] and Hβ) and stellar absorption lines → z=0.359.
- Broad and narrow Hβ components have widely offset peaks with a difference in velocity of Δv~1180±318 km/s.
- No [OIII] doublet with the same shift measured in the Hβ because of a Telluric line (~6825 A) at the expected λ.
- No redshifted broad Hα line because of fringing in the VIMOS spectrum

- NEW DEIMOS spectrum (R=2700, 45 mins, oriented): no presence of double peaks in OIII or Hα (as Comerford et al. 2009) but narrow Hβ ofsetted with respect to OIII and Hα plus second Hβ peak redshifted.

- 2D IMACS: the peak of the broad line is visible and shifted with respect to the narrow line



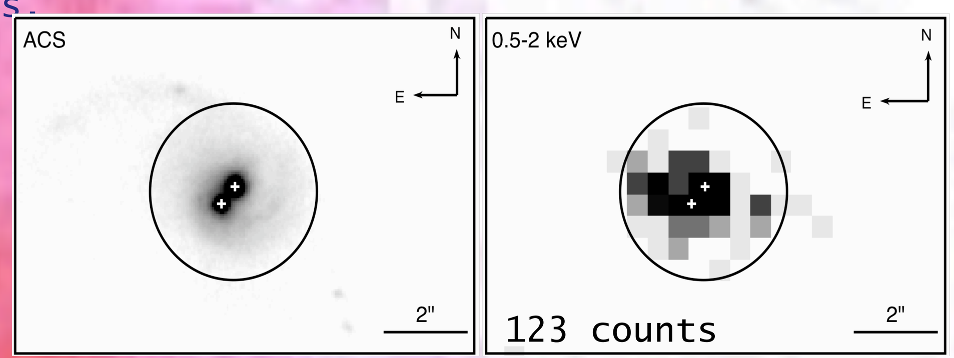
NE source: Obscured AGN or Star cluster



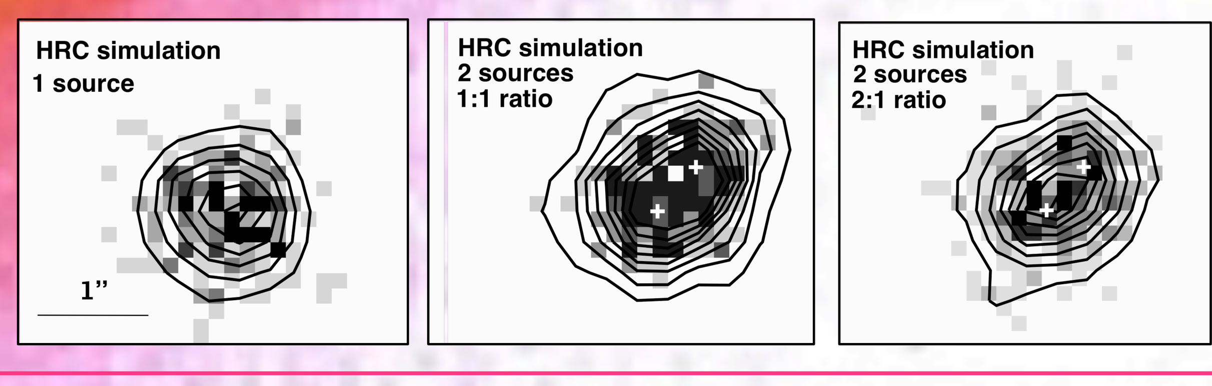
SW source: recoiling BH

Chandra/ACIS imaging Analysis

- 6 Chandra ACIS-I pointings (14-46 ks) with off-axis angles 3'-7.5', spread over 4 months.
- HST nuclei (left) not separated (right) in the best observation (3' off-axis angle and 46 ks)
- Analysis in energy bands: NO evidence for 2 point sources also in soft (0.5-2keV) and hard (2-7keV) band images.

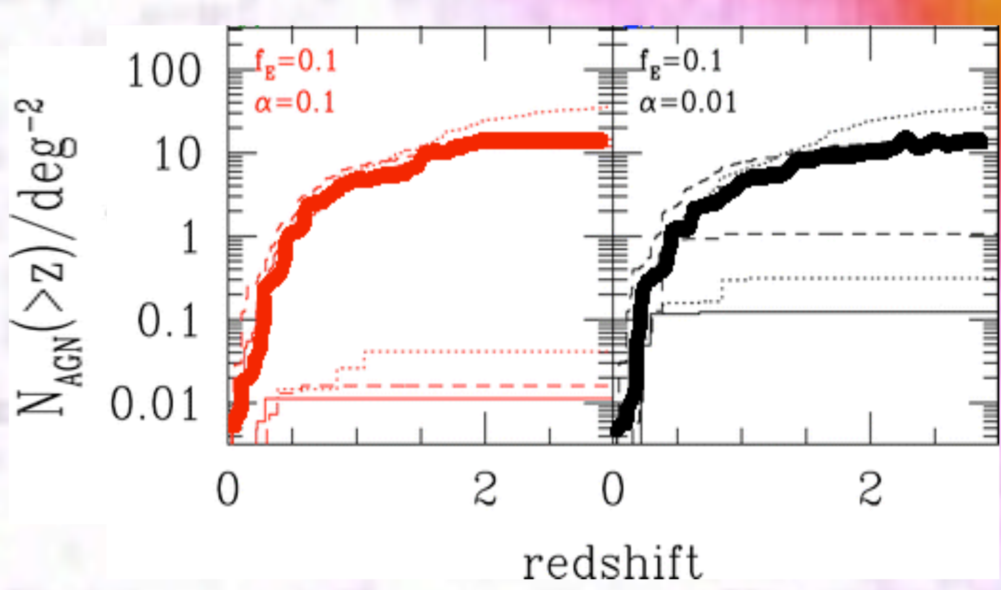


- HRC (0.15" PSF) could resolve the two nuclei in a 80 ksec observations up to a flux ratio between the two sources of 10:1. Marx simulations (below) show how the HRC PSF become distorted with two simulated sources at the observed distance.



Model Predictions for recoling BHs

Cumulative Number counts (Volonteri & Madau 2008 ApJL, 687, 58) of off-nuclear AGNs detectable in the HST-COSMOS survey (solid line), CDFN (dashed). In the HST-COSMOS fields (2 deg2), ~30 sources are expected for the best case of large kicks (spinning holes), long decay timescales (no bulge), and long active phase (f=0.1, α=0.01), but less than 1 in the unfavorable cases. In the Chandra COSMOS area, models predict to find up to a few sources.

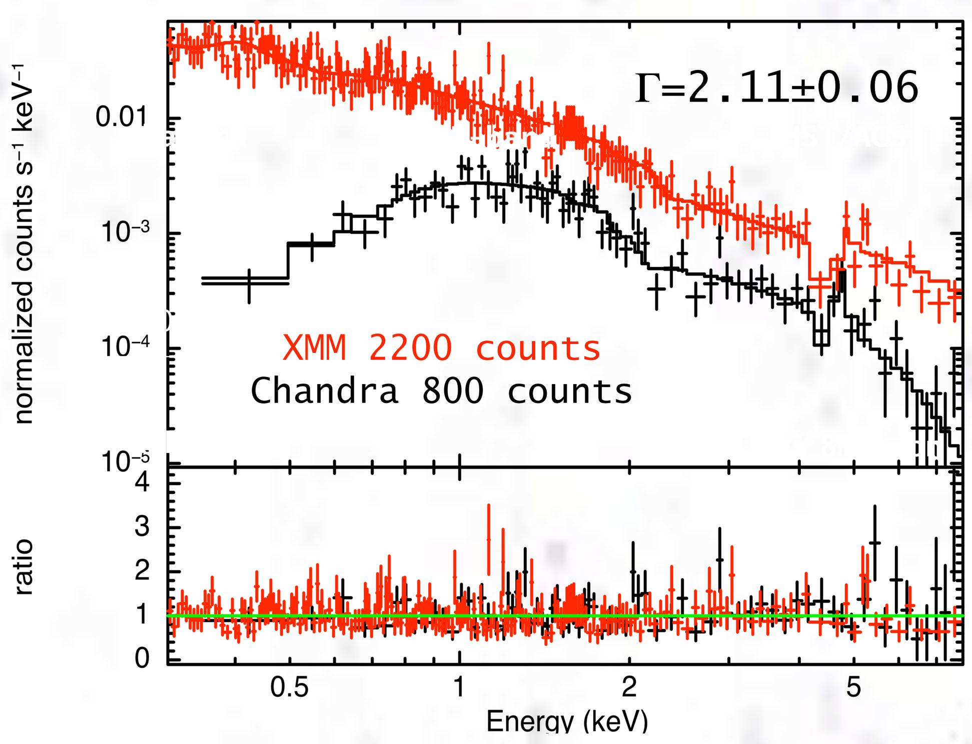


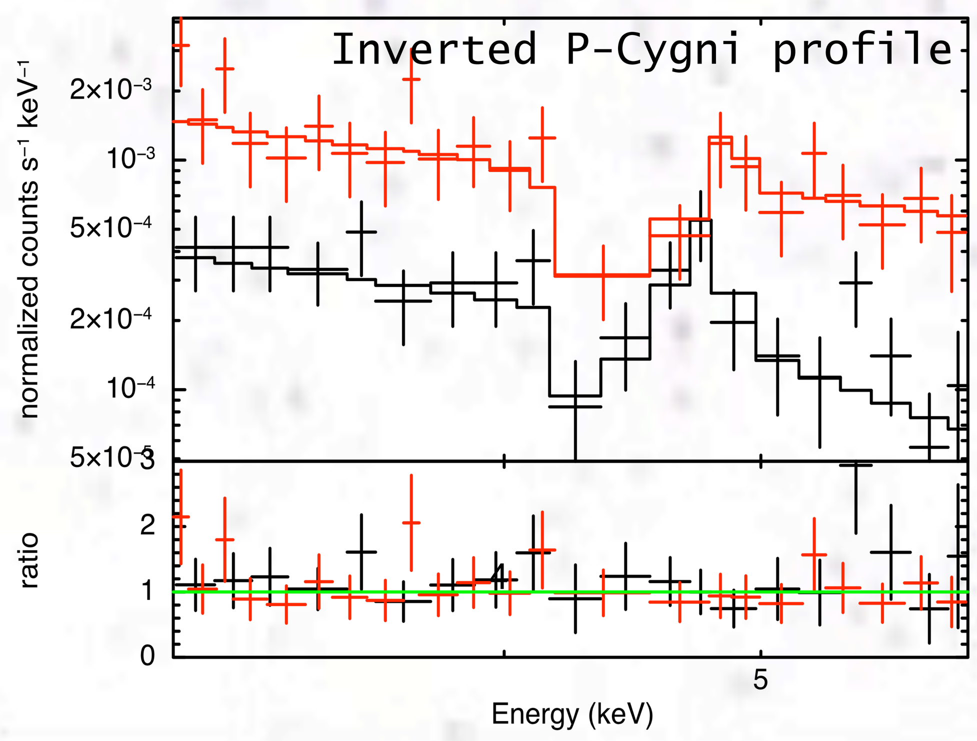
INVERTED P-CYGNI PROFILE

The most striking features in the X-ray spectra are around 5 keV (left): emission and absorption features are visible in both XMM and Chandra spectra, forming an **inverted P-Cygni profile**, the absorption component is *red*shifted with respect to the emission component.

❖Emission line: (1) neutral Fe line (2) constant flux (3) prominent in Chandra EW=570±260 eV (4) faint in XMM EW=142±80 eV.

❖**Absorption feature**: (1) strong variability both in flux and width (2) **broad** σ=0.22 Gaussian line in XMM (3) unresolved in the Chandra data (σ<0.5 keV) (4) the central rest-frame energy of the absorption line is ~6 keV therefore it is a ***red*shifted absorption iron line**.



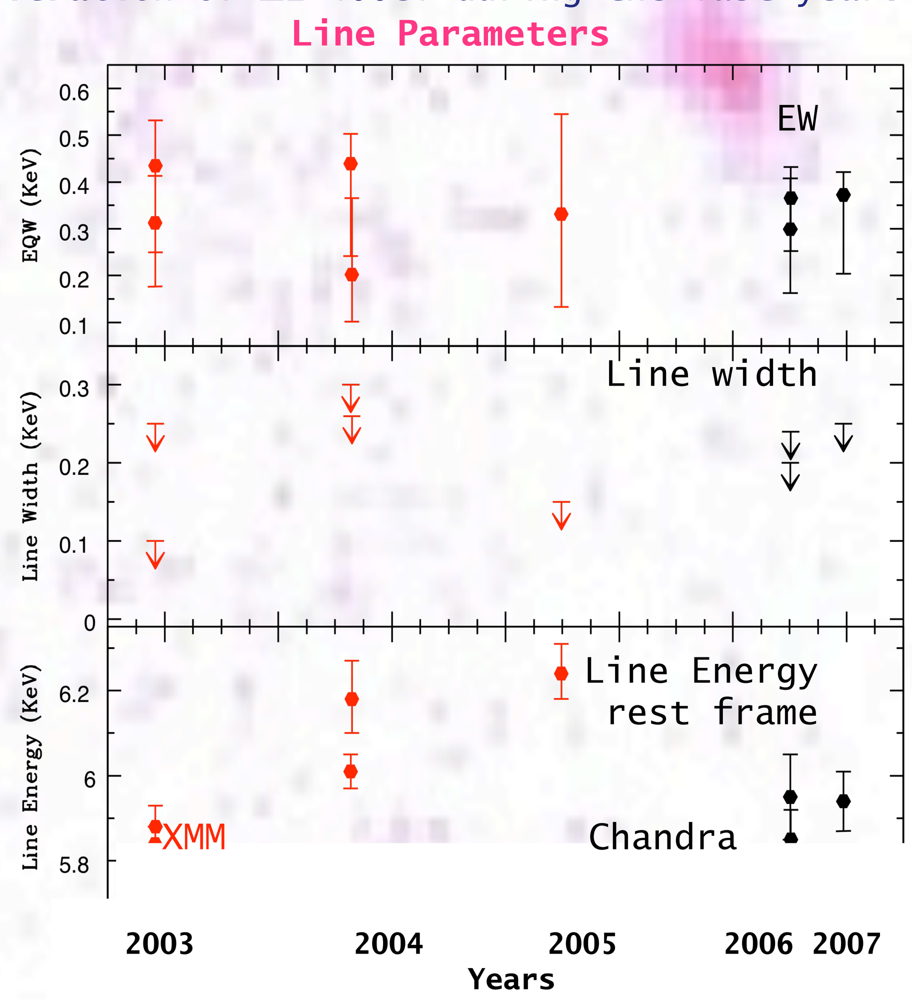


6"

Moving Fe-K Absorption Line

- Absorption feature detected at 2 to 3σ in 8 spectra (5 XMM and 3 Chandra, top).
- **Narrow** profile in all SPECTRA (middle).
- The line energy peak (bottom) in XMM changes in time over the range 5.9-6.3 keV, while in Chandra it is almost constant within the errors.
- **Broadening** explained as the superimposition of narrow absorption lines ***red*shifted** by 0.02-0.07c for neutral iron (Fe I) to 0.09-0.14c for completely ionized iron (Fe XXVI).
- Peak variability: **deceleration** of ΔE=500eV in the first 2 years of data (10,000 km/s/yr); **fast acceleration** of ΔE=400eV during the last year.

Line Parameters



Cosmic Evolution Survey
COSMOS

Civano et al. 2010, ApJ 717, 209
http://www.nasa.gov/mission_pages/chandra/multimedia/photo10-082.html

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