



Pepi Fabbiano
gfabbiano@cfa.harvard.edu

Three Types of AGN Feedback seen by Chandra

G. Fabbiano, Martin Elvis

CENTER FOR ASTROPHYSICS

HARVARD & SMITHSONIAN



Martin Elvis
melvis@cfa.harvard.edu

We Observe CT AGNs

- $N_H \sim 10^{24} \text{ H/cm}^2$
- The AGN is screened so that nuclear photons cannot get through to us
- We see instead the interaction of the AGN with the galaxy ISM
- Avoid 'contamination' by strong nuclear source
- Avoid instrumental effects in Chandra ACIS

ABSTRACT

Chandra high-resolution ACIS-S observations of nearby CT AGNs have provided clear evidence of three ways in which the AGNs interact with the ISM of the host galaxy:

- (1) **radiation**, affecting both the gaseous ISM and dense molecular clouds;
- (2) **jets**, causing localized shocks and lateral outflows;
- (3) **fast** (~200-2000 km/s) and **ultra-fast** (~0.1c) **nuclear outflows**.

These observations have led to a **revised AGN "standard model"**, where the interaction with the host galaxy has greater importance.

See review in **Handbook of X-ray and Gamma-ray Astrophysics eBook ISBN 978-981-19-6960-7**
DOI: [10.1007/978-981-16-4544-0_111-1](https://doi.org/10.1007/978-981-16-4544-0_111-1)
[Fabbiano & Elvis 2022 - 10.48550/arXiv.2022.13803](https://arxiv.org/abs/2022.10.48550)

Photoionization in the Narrow-Line Bicone

Soft: 0.3 – 2.5 keV

NGC 3393 (Maksym + 2017)
Red - Fe
Green - [OIII]
Blue - 0.3 – 2.5 keV Soft X-rays

Reflection and Fluorescence from Molecular Clouds

ESO 428-G014 – Fabbiano+2017

Typical Chandra CT AGN spectrum

Circum-Nuclear X-ray / molecular cloud interactions

NGC 5643
ALMA – Alonso-Herrero et al. 2018
26 pc rotating nuclear CO disk

Circum-nuclear X-ray emission filling CO 2-1 'cavities' (e.g., Feruglio+2020 in ESO 428-G014)

Embedded Jets

Shocks

NGC 1167, Fabbiano+2022

DATA - 210 ks ACIS-S - Chandra

Lateral Outflows

X-rays extended in the jet and cross-jet direction

NGC 4151, Wang+2011

Ne IX / O VII hot spots at jet terminations

- Thermal emission in addition to photoionization needed to fit hot spots
- $kT \sim 0.6 \text{ keV}$

The Revised AGN Model

SMBH-Host galaxy interaction out to several kiloparsecs shapes the AGN emission

Labels: Lateral hot outflows, Molecular clouds, Irradiated molecular clouds, Bicone/narrow line region, Jet/ISM shocks, Molecular clouds accretion, Galaxy disk, Jet, Circumnuclear molecular disk, LINER cocoon

Winds

Outflowing Bicones

Constant [OIII] / Soft X ratios in individual photoionized clouds in the bicone of NGC 4151 imply outflowing wind (Wang+2011)

Shocked/LINER cocoons: a common occurrence

Mkn 573, Serfati

NGC 5728 – Trindade Falcao+2024

BPT Mapping with narrow band HST observations (Ma + 2021)

Near-Relativistic Outflows?

Mrk 34 – Maksym+2023

- Spectral wings of the fluorescent 6.4 keV Fe Kα line
- If wings are due to FeKα outflows, $v = \pm 15,000 \text{ km s}^{-1} \sim 0.05 c$
- Red and blue components spatially displaced
- Consistent with inclined outflow

NGC 5728 – Trindade Falcao+2024

- Spectral wings of FeKα consistent with $v = \sim 0.1 c$
- Red and Blue components both spatially extended
- Kpc-size outflows