Recent Progress in Studying AGN Outflows

- Introduction to AGN Outflows
- Optical: Keck high resolution spectroscopy, surveys
- UV: HST and FUSE high resolution spectroscopy
- X-ray: Chandra and XMM “high resolution spectroscopy”
- Future Directions
Fundamental questions about AGN outflows:

- What is the relationship between the UV and X-ray warm absorbers?
- What are the ionization equilibrium and abundances?
- Where is the outflow, and what accelerates it?
- How important is the outflow in AGN and host galaxy evolution?
\[ I_2(v) = e^{-2\tau} \]

\[ I_1(v) = e^{-\tau} \]

\[ C(v) = \frac{I_1(v)^2 - 2I_1(v) + 1}{I_2(v) - 2I_1(v) + 1} \]

\[ \tau(v) = -\ln \left( \frac{I_1(v) - [1 - C(v)]}{C(v)} \right) = -\ln \left( \frac{I_1(v) - I_2(v)}{1 - I_1(v)} \right) \]
Paradigm Shift

- We cannot trust apparent optical depth, EW or Gaussian modeling when dealing with intrinsic AGN absorbers.
- Our conceptual picture of the absorbing medium has to shift from Gaussian clouds to dynamical outflows.
- We have to reexamine \( N_H \) and \( U \) in all the available data.
Fig. 4.— Best-fit dusty warm absorber model for MCG–6–30–15 (top) and Mrk 766 (bottom). Broad residuals are seen in both spectra, and cannot be explained by any absorption features.

Fig. 12.— Best-fit relativistic line models for MCG–6–30–15 (top) and Mrk 766 (bottom). No obvious residuals remain.
Fig. 11: The 16 – 20 Å region of the MCG–6–30–15 spectrum showing the higher series lines of O VII and the neutral Fe L UTA using the Lee et al. (2001) dusty warm absorber model, with a reduced neutral Fe L column density ($N_{\text{Fe}} = 7 \times 10^{20}$ cm$^{-2}$). The absorption line equivalent widths of O VII are severely overpredicted compared to the data. In addition, the model flux between the Heα and Heδ lines is overpredicted owing to the lack of O VII and Fe L opacity in this spectral region.

Figure 1. Combined MEG and HEG 900 ks spectrum binned to 0.01 Å. Each data point has an error bar representing its uncertainty. The He-like and He-like lines of the identified ions are marked in red and blue, respectively. For each ion the theoretically expected lines are plotted up to the ion’s edge (not all lines are identified in the data). The ions’ lines are marked at their expected wavelength in the rest frame of NGC5237, and the blueshift of the absorption lines is noticeable.


**Observational Ramifications**

- **HST: Two Doublets,**
  - $N\,v$ and $C\,iv$ doublets: $(1000\ \text{km}\ s^{-1}\ \text{and} \ 500\ \text{km}\ s^{-1})$
  - Ly$\alpha$: No hope on its own; Si$\,iv$ is seen in less than half of the objects.

- **FUSE: The Lyman Series,**
  - The Lyman series $Ly\beta \lambda1025.7$, Ly$\gamma \lambda972.5$, Ly$\delta \lambda949.7$
  - $C\,iii \lambda977.0$, $N\,iii \lambda990\ (540\ \text{km}\ s^{-1})$; O$\,vi$ heavily saturated.

- **Chandra and XMM: The Advantage of Line Series,**
  - Several hydrogen and helium like ions; EW can be used!

---

![Diagram with spectral coverage and spacecraft data](image)
Future Directions

- Instruments: +COS, -FUSE, Constellation X, Mega-X

- Crucial issues to address:
  - The relationship between the UV and X-ray warm absorbers
  - Distance and column density → \( \dot{m}, \dot{E}_k \)

- To extract the physics, a major UV/X-ray campaign is needed.

Summary

- High resolution spectroscopy is revolutionizing the study of AGN outflows

- Conceptual shift: Gaussian clouds → dynamical outflows.

- Crucial issue: The relationship between the UV and X-ray warm absorbers

- To extract the physics, a major UV/X-ray campaign is needed.