NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Research Opportunities in Space and Earth Sciences (ROSES)
Program Element: Astrophysics Data Analysis Program (ADAP)
Solicitation: NNH26ZDA001N-ADAP

Requested Budget: \$307,858
Proposed Duration: 3 Years
Submission Date: August 4, 2026

Probing Active Galactic Nuclei Feedback: A Multi-Wavelength Study of Outflowing Gas in Radio-Loud Quasars

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Proposal Category	Archival Data Analysis / Theoretical Modeling

1 Scientific/Technical Merit & Objectives

The interaction between supermassive black holes (SMBHs) and their host galaxies—commonly termed Active Galactic Nuclei (AGN) feedback—is a key component in modern galaxy formation theory. Feedback mechanisms are required to explain the tight correlations observed between SMBH mass and host galaxy properties (e.g., the M–σ relation) and to prevent the overproduction of overly massive galaxies. Despite its importance, the physical process of feedback, particularly how outflows transfer energy and momentum to the interstellar medium (ISM), remains poorly constrained.

This research program will utilize archival multi-wavelength observations from NASA space astrophysics missions to address these core questions. Our primary scientific objective is to determine the kinetic feedback efficiency of outflows in radio-loud quasars. Specifically, we will:

1. Measure mass-outflow rates ($\dot{M}_{\rm out}$) and kinetic luminosities ($\dot{E}_{\rm kin}$) in a sample of 124 radio-loud quasars at $z \sim 0.5$–2.0.
2. Map the ionization state and density structure of outflowing gas using photoionization modeling.
3. Determine whether radiation pressure on dust or mechanical jet-gas interaction is the dominant acceleration mechanism.

2 Background & Motivation

Theoretical models suggest that AGN feedback operates via two distinct modes: the "quasar mode" (wind-dominated) and the "radio mode" (jet-dominated). In the quasar mode, radiation pressure on gas and dust drives high-velocity outflows that evacuate the galaxy's core. In the radio mode, relativistic jets deposit kinetic energy into the circumgalactic and halo gas, suppressing cooling flows. However, the demarcation between these modes is not absolute; many radio-loud sources host powerful winds, suggesting a complex interplay between radiation and jets.

Ultraviolet spectroscopy provides an ideal tool to study these outflows. Absorption lines such as O VI λ1032, C IV λ1549, and N V λ1240 probe the highly ionized, high-velocity gas that carries the

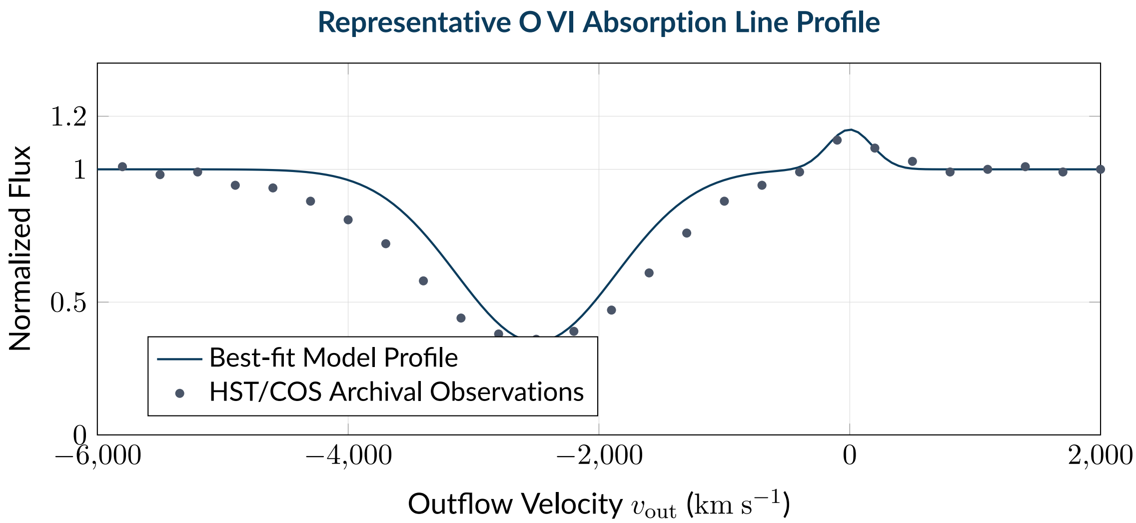

Figure 1: A representative self-contained profile showing a blue-shifted O VI absorption trough centered at -2500 km s^{-1}. The deep blue line shows our photoionization-driven kinematic wind model fitted to high-resolution HST/COS spectroscopy (gray data points).

bulk of the kinetic energy. Figure 1 shows a simulated absorption profile representing outflowing gas.

By characterizing the absorption depth, width, and velocity offset, we can calculate the column density and kinematics of the outflow. This allows us to quantify the feedback impact of the AGN on the surrounding host galaxy.

3 Methodology & Work Plan

We will execute this project in three structured phases over a 3-year timeline.

3.1 Phase 1: Sample Assembly and Data Reduction

We will construct a sample of 124 radio-loud quasars at $z \sim 0.5$–2.0 with high-quality spectra in the Mikulski Archive for Space Telescopes (MAST) and the Chandra Data Archive. The ultraviolet spectra will be acquired from the Hubble Cosmic Origins Spectrograph (COS) and Space Telescope Imaging Spectrograph (STIS). Complementary X-ray spectra from Chandra will provide constraints on the warm absorber column density.

3.2 Phase 2: Spectral Analysis and Photoionization Modeling

Using custom fitting pipelines, we will model the quasar continuum with a combination of power-law components and Fe II templates. Absorption lines will be modeled using Voigt profiles to determine column densities ($N_{\rm ion}$) and velocities ($v_{\rm out}$). We will run extensive grids of the photoionization code CLOUDY to determine the gas density, distance from the central engine, and total hydrogen column density.

3.3 Phase 3: Synthesis and Correlation Analysis

Finally, we will examine the scaling relations between the outflow properties (mass-outflow rate, kinetic luminosity) and key AGN metrics (bolometric luminosity, black hole mass, and radio power). The timeline is presented in Table 1.

Table 1: Project Timeline and Milestone Schedule by Year and Quarter.

	Year 1				Year 2				Year 3			
Task / Milestone	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Data Acquisition & Processing	•	•										
Voigt Profile Spectral Fitting		•	•	•								
CLOUDY Grid Simulations				•	•	•						
Jet/Wind Correlation Analysis						•	•	•				
Manuscript Drafting								•	•	•		•
Dissemination & Archiving										•	•	•

4 Relevance to NASA

This proposal is directly relevant to the Astrophysics Data Analysis Program (ADAP). Our project is entirely based on the analysis of archival data obtained by NASA space astrophysics missions, including the Hubble Space Telescope (HST) and the Chandra X-ray Observatory. By utilizing these public datasets, we maximize the scientific return on NASA's investments in these space platforms. The project directly supports NASA's strategic goal to "discover how the universe works, explore how it began and evolved, and search for life on planets around other stars," specifically by investigating the role of supermassive black holes in the structural evolution of galaxies.

5 Budget Summary

The requested budget supports one graduate student researcher, two months of PI summer salary per year, travel to scientific conferences, page charges for peer-reviewed publication, and institutional indirect costs. Table 2 outlines the budget summary.

Table 2: Budget Summary by Project Year (Direct and Indirect Costs).

Budget Category	**Year 1 ($)**	**Year 2 ($)**	**Year 3 ($)**	**Total ($)**
PI Salary (2 months/yr)	24,500	25,235	25,992	75,727
Graduate Student Researcher	32,000	33,280	34,611	99,891
Travel (Conferences & Collabs)	4,500	4,500	5,000	14,000
Computing & Publication Costs	3,000	2,500	3,500	9,000
Total Direct Costs	**64,000**	**65,515**	**69,103**	**198,618**
Indirect Costs (F&A, 55%)	35,200	36,033	38,007	109,240
Total Requested Funding	**99,200**	**101,548**	**107,110**	**307,858**

References

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