From Young Stars to Active Galaxies: Development of Foundational Lessons for Authentic Astronomy Research

Olivia Kuper[1,2], Thomas Rutherford[3,4], David Forester[5], Luisa Rebull[6], Varoujan Gorjian[7] John Blackwell[8], Debbie French[9], Donna Kaiser[10], James Newland[11], Laura Orr[12], Elizabeth Ramseyer[13], Ace Schwarz[14], Vin Urbanowski[10]

[1]North Greene High School (Greeneville, TN), [2]Texas Tech University (Lubbock, TX), [3]King University (Bristol, TN), [4]East Tennessee State University (Johnson City, TN), [5]Mission Vista High School (Oceanside, CA), [6]Caltech (Pasadena, CA), [7]Caltech/Jet Propulsion Laboratory (Pasadena, CA), [8]Phillips Exeter Academy (Exeter, NH), [9]Wake Forest University (Winston-Salem, NC), [10]Academy of Information, Technology & Engineering (Stamford, CT), [11]Texas Advanced Computing Center, UT Austin (Austin, TX), [12]Ukiah School District (Ukiah, OR), [13]Niles West High School (Skokie, IL), [14]The Shipley School (Bryn Mawr, PA).

Abstract

The NASA/IPAC Teacher Archive Research Program (NITARP) provides teachers and their students with a year-long, authentic research experience guided by a mentor astronomer. Each NITARP team consists of three or four teachers and a mentor teacher who had previously completed the program. Teachers may also bring up to four students. The research project culminates in a poster presentation at the winter meeting of the American Astronomical Society (AAS). The NITARP team's results are presented alongside other astronomy research to the professional astronomy community.

The **Big NITARP Alumni Project (BINAP)** enables former NITARP participants to provide rigorous astronomy education resources that utilize authentic data from IPAC by creating publicly available standalone lessons, which serve as resources for teachers who have not formally participated in the NITARP program. Now in its third year, BINAP has developed a series of modular instructional materials designed for middle school, high school, and introductory college astronomy courses. These resources were initially developed as step-by-step activities that scaffolded the skills necessary to enable the research of young stellar objects. This year, 2025, BINAP members developed foundational lessons on extragalactic astronomy that incorporated authentic data. Future work will focus on developing guided student research projects that build on these lessons.

Resource Location

Extragalactic resources will be located on the NITARP Cool Wiki page in the near future. Young stellar object resources are currently available at this location: https://coolwiki.ipac.Caltech.edu/index.php/Main_Page

Acknowledgements

This work was conducted as part of the NASA/IPAC Teacher Archive Research Program (NITARP), which receives funding from the NASA ADAP Program.

Instructional Story Arc

The extragalactic lessons are classroom-ready materials that enable educators to guide students through the reasoning process astronomers use to determine:

- What constitutes a galaxy;
- Earth's location within the Milky Way;
- which nebulae are extragalactic; and
- how galactic nuclei are identified in distant galaxies

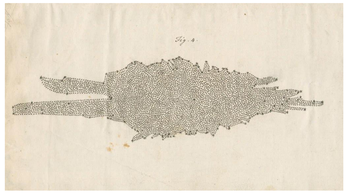


Figure 1: Source: On the Construction of the Heavens. By William Herschel, Esq. F. R. S. Philosophical Transactions of the Royal Society of London, Vol. 75. (1785), pp. 213

Anchoring the Story Arc: The Campus Galaxy Map

The Campus Galaxy Map activity serves as the foundational lesson in the extragalactic sequence. Students are asked to map their campus using only what is visible from a fixed location, without movement or reliance on prior knowledge. The resulting maps are incomplete, biased by perspective, and vary widely between observers.

By comparing these maps to aerial views of multiple campuses, students confront the limits of observation, the role of inference, and the difficulty of reconstructing global structure from within a system, such as in Figure 1, Herschel's attempt to reconstruct the Milky Way in 1785. above. This activity directly parallels the historical and contemporary challenges of mapping the Milky Way and motivates the need for indirect evidence in astronomy.

Selected student-generated campus maps of the same campus, are shown below (Figure 2, Figure 3). highlighting how perspective and limited sightlines shape observational models of the same space.

Figure 2: Student sample 1

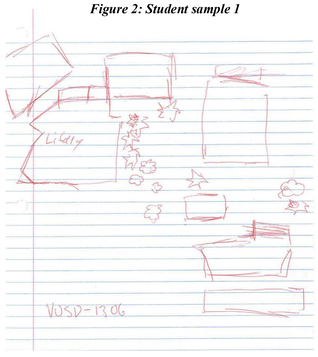
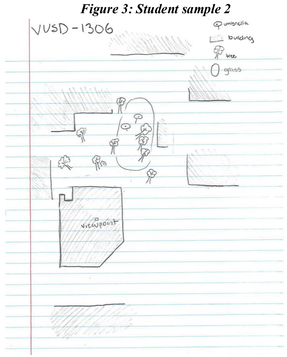


Figure 3: Student sample 2



From Human-Scale Models to Galactic Classification

Following the Campus Galaxy Map activity, students examine resolved galaxies with visible structural features which support shape-based classification. Students develop their own classification systems and then compare them to canonical morphological schemes (e.g., Hubble sequence), reinforcing classification as a scientific practice.

Figure 4: Selection of cards from the Galaxy Sort activity

Students then examine galaxies across multiple wavelengths to explore how different physical components such as dust, star-forming regions, and older stellar population, etc., appear or are obscured depending upon the wavelength used. This step transitions students from shape-based reasoning to the use of quantitative photometric data.

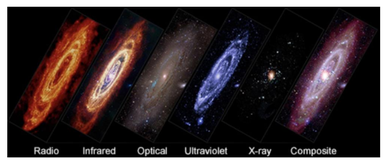


Figure 5: M31 in different wavelengths
Credit: X-Ray: NASA/CXO/Umass/Z.Li & Q.D. Wang, ESA/XMM-Newton; Infrared: NASA/JPL-Caltech Wise, Spitzer, NASA/JPL-Caltech/K.Gordon (U.Az), ESA/Herschel, ESA/Planck, NASA/IRAS, NASA COBE; Radio: NSF/GBT/WSRT/IRAM/C.Clark (STSci); Ultraviolet: NASA/JPL-Caltech/Galex; Optical: Andromeda, Unexpected, Marcel Dreschsler, Xavier Strotter, Yann Sainty & J. Sahner, T. Kottary. Composite image processing: L: Frattare, K. Arcand, J. Major

Using IPAC Data and IRSA Tools

Most galaxies accessible through modern surveys are not spatially resolved. At this stage in the story arc, imagery alone becomes insufficient, and photometric catalogs become the primary source of evidence.

BINAP lessons explicitly introduce educators and students to NASA/IPAC archives and IRSA tools, where they:

- access curated, multiwavelength catalogs;
- generate color–color and color–magnitude diagrams; and
- use photometric properties to classify galaxies and identify active galactic nuclei (AGN).

Authentic Data Practices & Research Readiness

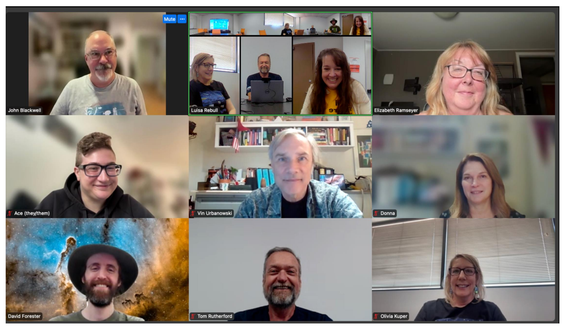
Across the sequence, students engage in authentic astronomical practices:

- classification and re-classification;
- evidence-based argumentation;
- interpretation of outliers; and
- comparison of models to data.

By the end of the extragalactic sequence, students and teachers are prepared to initiate investigations of AGN, using archival photometric data to examine galaxy properties, redshifts, and large-scale structures.

Future Work

Future work includes expanding the BINAP extragalactic sequence to include lessons focused on the identification AGN using photometric data from NASA/IPAC archives. These lessons will support progressively scaffolded investigations in which students analyze AGN properties, compare populations, and develop evidence-based claims. The sequence will ultimately culminate in a full, NITARP-like research experience that allows students and educators to carry out extended AGN investigations using archival astronomical data.



BINAP collaborators during the summer meeting, 2025