# Assignment for Week 1

**Writing Prompt**:

As a postgraduate student preparing for PhD admission in astrophysics, my goal for this course is to deepen my understanding of key topics in modern astronomy—particularly in areas related to black holes and time-domain phenomena. I believe that the skills and knowledge gained through this workshop will better equip me to engage with current research questions and methodologies, especially those involving the analysis of dynamic, rapidly evolving astronomical events. Participating in this course will also help me build a strong academic foundation and exposure to tools that are essential for success in a research-intensive PhD program.

Topic of interest

I am especially interested in **black holes**—from stellar-mass black holes in X-ray binaries to supermassive black holes in active galactic nuclei. Their role in shaping their environments through feedback processes, accretion physics, and relativistic effects fascinates me. In addition, I am drawn to **time-domain astronomy**, which involves studying transient and variable events such as tidal disruption events, microlensing, and fast X-ray variability. The combination of black hole physics and time-resolved data offers powerful insights into the most energetic and extreme environments in the universe, and I hope to explore these topics further through research during my PhD.

**Question: "Which paper proposes a novel method that could be utilized to attract the attention of, and ultimately communicate with, extraterrestrial intelligence?"**

Answer: Transit Light-Curve Signatures of Artificial Objects” by Luc F. A. Arnold

Arnold suggests that advanced civilizations could build large, artificial structures (such as triangles or multi-panel screens) designed to transit their host stars. These artificial objects would produce non-natural, distinctive transit light curves that could be detected by other civilizations (like ours) using exoplanet survey missions.

This concept is proposed as a new SETI (Search for Extraterrestrial Intelligence) method—based on passive detection of techno signatures in transit photometry, rather than traditional approaches like radio or laser signals.

**Summary of Each Paper:**

1. **“Transit Light‑Curve Signatures of Artificial Objects”** by Luc F. A. Arnold (Astrophysical Journal, volume 627, pages 534–539; DOI: 10.1086/430437):

In this paper, Luc Arnold explores the possibility of detecting artificial objects—like large spacecraft or megastructures—built by advanced extraterrestrial civilizations through their transit signatures. Unlike natural planets, these artificial structures could have unique shapes (e.g., triangles or multi-panel designs) and orientations that create distinctive features in a star’s light curve when they pass in front of it. Arnold simulates how different shapes and configurations—especially rotating or sequentially aligned objects—would produce transit light curves that differ from those of spherical planets. While some artificial shapes may resemble natural phenomena like ringed planets, others generate complex, non-symmetric dips that are unlikely to be produced by nature. He suggests that future exoplanet surveys (such as Kepler, though it hadn’t launched yet) could detect such anomalies and proposes this as a novel SETI strategy: searching for technosignatures through photometric transit data rather than relying solely on radio signals.

1. **“Searching for GEMS: Confirmation of TOI‑5573 b, a Cool, Saturn‑like Planet Orbiting an M‑dwarf”** (arXiv:2505.08947, submitted May 13 2025) by Fernandes et al.

This paper confirms the existence of TOI-5573 b, a cool, Saturn-like exoplanet orbiting an early M-dwarf star. It was originally detected by the TESS space telescope through transit observations, and its planetary nature was confirmed using radial velocity measurements from HPF and NEID spectrographs. The planet has a mass of about 0.35 Jupiter masses, a radius close to 0.87 Jupiter radii, and a low density similar to Saturn. What makes TOI-5573 b especially interesting is its low equilibrium temperature (~528 K), making it one of the coolest giant planets known around M-dwarfs. The host star has super-solar metallicity, which supports the core accretion model of planet formation. This aligns with the trend that metal-rich M-dwarfs are more likely to host giant planets. The system belongs to the GEMS (Giant Exoplanets around M-dwarf Stars) category and stands out as a promising candidate for future atmospheric characterization, helping us better understand how giant planets form and evolve around low-mass stars.

1. **“Parallax Effect in Microlensing Events due to Free‑Floating Planets”** (arXiv:2403.16089, submitted March 24, 2024) by Parisa Sangtarash & Sedighe Sajadian:

This paper investigates how the annual parallax effect—caused by Earth’s motion around the Sun—can influence the analysis of microlensing events produced by free-floating planets (FFPs). Although these events are typically short (under 10 days), and the parallax might not be directly observable, the authors show that it can still introduce significant distortions in the light curve. Using simulations of FFP events as would be seen by the Roman Space Telescope, the authors found that in nearly half the cases, fitting the light curves with a standard model that ignores parallax leads to biased estimates of key parameters like the Einstein timescale and source size. These biases can affect how we interpret the mass and distance of the lensing object. The study highlights that even if parallax isn’t detected, neglecting it can still mislead us, especially in population studies of FFPs. To avoid this, the paper recommends coordinated multi-observatory campaigns to better constrain microlensing parameters.

1. **“Earth as an Exoplanet: Investigating the effects of cloud variability on the direct-imaging of atmospheres”** (arXiv:2503.09136, submitted March 12, 2025), by Soumil Kelkar, Prabal Saxena, Ravi Kopparapu & Joy Monteiro

This paper explores how cloud variability on Earth would affect the direct imaging and atmospheric characterization of an Earth-like exoplanet. The authors use real cloud data from NASA's MERRA-2 dataset to model how clouds influence the observed spectra, especially for key biosignature gases like O₂, O₃, and H₂O. They find that cloud coverage, altitude, and variability can significantly distort or hide spectral features, reducing the signal-to-noise ratio and making it harder to detect biosignatures. Since cloud conditions can change rapidly, single-time observations may give misleading results about the planet’s atmosphere. The study emphasizes that future telescopes like NASA’s Habitable Worlds Observatory (HWO) must consider multi-epoch observations or cloud-aware models to reliably interpret exoplanet atmospheres and assess their habitability.