Scientific Justification *Be sure to include overall significance to astronomy. For standard proposals limit text to one page with figures, captions and references on no more than two additional pages.*

As galaxies merge, the supermassive black holes (SMBH) ($M_{BH} > 1 \times 10^5 M_\odot$) at their cores are destined to similar fates [Burke-Spolaor et al., 2019]. Once the SMBHs reach an orbital separation of milliparsecs, their binary evolution is governed by nanohertz gravitational wave (GW) emission [Kelley et al., 2019]. Recently evidence for a stochastic background made up of these nHz gravitational waves emitted by SMBH binaries (SMBHBs) was reported by several Pulsar Timing Array (PTA) experiments around the world, hinting at a population we have yet to directly confirm [Agazie et al., 2023]. While these SMBHBs emit GWs through their inspiral, they are expected to emit electromagnetic (EM) radiation through interactions with their circumbinary disk [Kelley et al., 2019]. The chase is on to confirm one such SMBHB due to the treasure trove of astrophysics potential within each. While the mechanism that dictates the binary's late time or milliparsec-separation evolution is known, there is still ongoing debate about those that bring the binary through parsec separations [Kelley et al., 2019]. These are theorized to be three-body interactions with stars, known as loss-cone dynamics, and or the SMBHB having angular momentum extracted from it by a gaseous disk [Merritt, 2013, Colpi, 2014]. The efficiency of these two methods is not currently known, nor if one plays a dominant role or a combined effect is the mechanism to shrink the binary. A confirmed SMBHB would provide an excellent opportunity to study the environment surrounding it, informing theories of binary evolution. Additionally, the information gained from EM data could support targeted searches of PTA datasets for continuous GWs from the confirmed binary [Kelley et al., 2019]. As such, it is critically important to follow up extragalactic sources that display EM emission similar to that predicted from a SMBHB. One such EM tracer of a binary is through relativistic Doppler boost. This is a result of the fact that the photon phase-space density, I_ν/ν where I_ν is a specific intensity at a given frequency ν, is the same in all inertial frames, or Lorentz invariant. Intuitively, this can be understood as the fact that all observers will count the same number of photons from a source. Since SMBHB's at milliparsec separations are moving relativistically, the Doppler effect will shift frequencies, resulting in an increase in brightness when the secondary, or less massive, SMBH is approaching the observer's line of sight [Charisi et al., 2022]. This effect would introduce a periodic variability in the brightness of the system, as the secondary SMBH processes through its orbit [Charisi et al., 2018]. Such a variability was found by Graham et al. [2015] within the Catalina Real-time Transient Survey. D'Orazio et al. [2015] determined a model for this source, PG1302-102, as a SMBHB with evidence of a relativistic Doppler boost. Their model found the candidate to have a sinusoidal variability profile, with a period of 4.04 years and an amplitude of ± 0.14 mag in the V band. Within this model, they found the mass ratio q of the binary to be $q \leq 0.3$ and a total binary mass of $M_{Tot} \gtrsim 10^{9.1} M_\odot$. The velocity determined from this level of Doppler boosting is $.07c$ and the emission was attributed to the gas surrounding the secondary SMBH. Adding to the significance of this target, theoretically calculated amplitudes for UV variability are consistent with archival UV data from the Hubble Space Telescope (HST) and Galaxy Evolution Explorer. This UV variability is also sourced from the gaseous disk surrounding the secondary SMBH, so it shares a period with the optical variability. This presents itself as an immediately ready test of this Doppler boosting model of PG1302-102's multi-wavelength variability. We plan to test this model via a concurrent HST UV and Las Cumbres Observatory (LCO) optical observing campaign which is described in the Experimental Design section. Confirming this SMBHB candidate would be the first discovery of a sub-parsec separation binary. The observations as part of this campaign would also further constrain the Doppler boosting model, providing more information about a binary that cannot be directly observed due to small orbital separation. Multi-wavelength follow up to study the galactic environment would illuminate the nature of dynamics that harden the binary, as described previously. Additionally, further studies could investigate how the SMBHB co-evolved with the galaxy and provide a stepping stone for nHz GW searches. If the observations refute the Doppler boosting model, they will elucidate details about the system that masqueraded as a Doppler boost phenomenon, adding to studies of quasar variability.

Experimental Design *Describe your overall observational program. How will these observations contribute toward the accomplishment of the goals outlined in the science justification?*

To test the predictions from D'Orazio et al. [2015], we propose a simultaneous campaign of optical and UV observations of PG1302-102 over a three 6 month semesters, examining whether the UV emission matches the behavior in the optical. The UV observations will be taken by the HST due to the opacity of Earth's atmosphere in this wavelength range. The 1-meter telescopes of the Las Cumbres Observatory (LCO) will be the ground-based, optical counterpart to the HST UV observations, using the Sinistro imager. The LCO is the optimal observatory for this campaign as its thirteen 1-meter telescopes around the world with remote observing capabilities will provide a great deal of flexibility to respond to changes in the HST observing schedule. The spread of these telescopes will give many opportunities for observation of PG1302-102 once the HST schedule has been set, resulting in nearly or completely simultaneous observation. Since the period of variability is 4.04 years, observations should be taken throughout a half period ($\sim$2 years), however, due to the long-term status we are requesting being limited to three 6-month semesters[1] and the visibility of the target (January$\sim$July), the total campaign duration of 1.5 years will not be consecutive semesters. The cadence for the 10 observations will be roughly every 55 days or about 3 to 4 nights per semester for three semesters. While there exists time-series data of PG1302-102 in the G band from the Zwicky Transient Facility (ZTF) Data Release 19 [Masci et al., 2018], they are not concurrent with UV observations to assess the veracity of D'Orazio et al.'s model. This data does show recent (June 2023) photometric variability relatively consistent with the observations reported in Graham et al. [2015], teasing the potential that this campaign could unleash. This time-series data can be seen in Fig 1. The amplitude of this variability is reported to be around $\pm$0.14 mag with a median V magnitude of 15.0 in Graham et al. [2015]. The reader may notice that the ZTF data shows a peak at 14.80 mag, implying an sinusoidal amplitude of 0.2 mag, but this is in the G band. The spectral energy distribution from the NASA/IPAC Extragalactic Database[2] for the target can be seen in Fig 2, explaining the increase in brightness in the G band observations.

Technical Justification: To sample the 0.14 mag variability of PG1302-102 will require observations that have uncertainties one-fifth to one-tenth of this amplitude. This means that a fractional uncertainty of 0.014 to 0.028 will translate to a desired signal-to-noise (S/N) ratio of 71 to 35 respectively. Utilizing the LCO exposure time calculator with an input flux of 15.2 mag in the V band, we found that 2-6 second exposures would give the necessary S/N for a new or full moon respectively. We chose a slightly dimmer flux than predicted for these calculations to provide some buffer in case any observation epochs fall in the trough of emission. Since these observations will not be limited to dark time, we are requesting on each night of observation 10 frames on the Sinistro imager. Utilizing the longest exposure time of 6 seconds with an overhead of 28 seconds per frame sums to 34 seconds of observing time per frame. This amounts to just under an hour (3400 seconds) of observing time across the 100 frames (10 frames per night for 10 nights over 1.5 years). While this is not a lot of time to request, LCO's flexibility in observing locations and ability to react to unpredictable HST schedules is unparalleled in ground-based optical observatories. Most of the LCO 1-meter telescopes are located at latitudes around 30ºN and 30ºS which result in minimum airmasses of 1.3 and 1.06 respectively, as the target is at -10º Declination. Due to its location at 13 hours at Right Ascension, PG1302-102 will be visible roughly from January to July, meaning that the three observing semesters will not be consecutive. This actually will allow for a sampling of the quasar's variability over 2.5 years, just over half a period.

[1] See CfP24A: https://noirlab.edu/science/observing-noirlab/proposals/call-for-proposals

[2] The NASA/IPAC Extragalactic Database (NED) is funded by the National Aeronautics and Space Administration and operated by the California Institute of Technology.

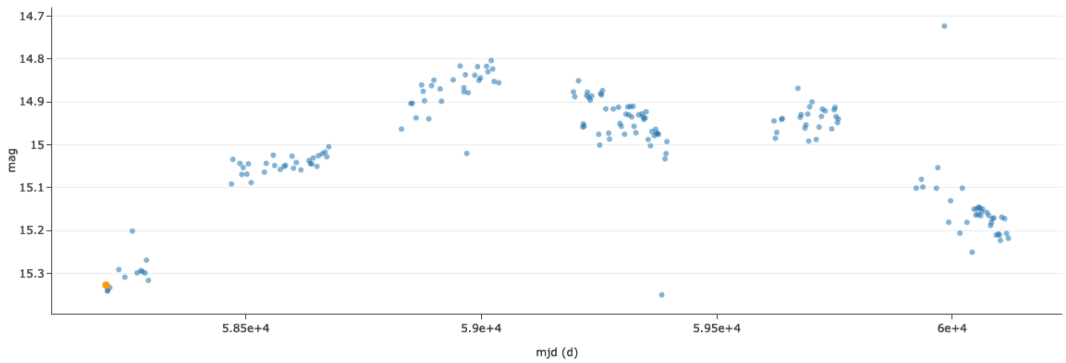

Figure 1: Zwicky Transient Facility observations of PG1302-102 from Data Release 19. A peak in photometric variability occurs around 14.8 mag in the G band.

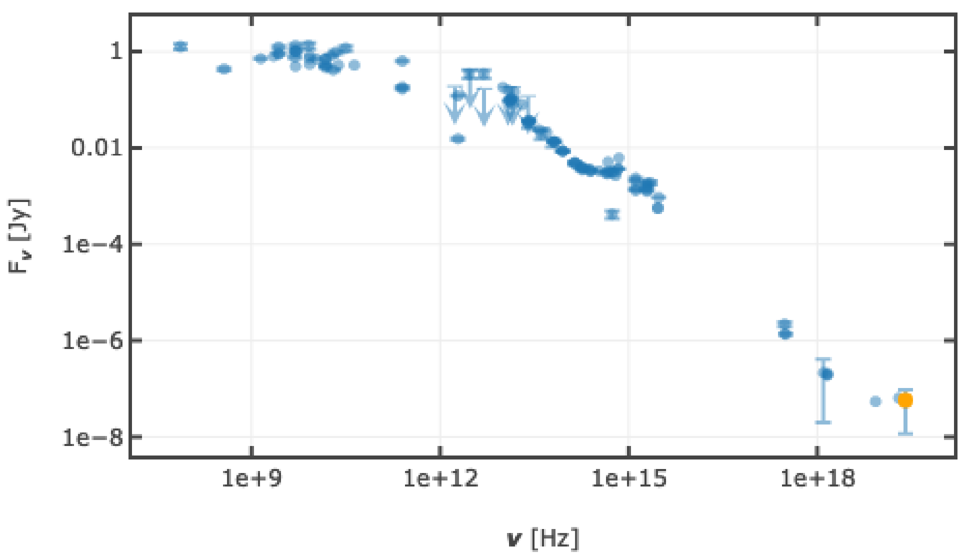

Figure 2: Spectral Energy Distribution for the target, PG1302-102, from the NASA/IPAC Extragalactic Database.

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