OIRMA : Optical-Infrared Reverberation Mapping of AGN

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Abstract

Continuum reverberation mapping (CRM) can be used to infer the physical dimensions of accretion disks of active galactic nuclei (AGN). UV and x-rays originating from the center of the AGN varies in intensity, and those variations are echoed when absorbed and re-emitted by the progressively cooler and more distant material of the accretion disk and torus. The time delay between a short-wavelength variation and the corresponding change in flux at a longer wavelength may be attributed to the transmission time, allowing determination of the distance from central structures to peripheral ones.

Limited number of studies have been conducted to measure the continuum reverberation of Type 1 Seyfert galaxies due to the paucity of continuous observations in both the optical and infrared (IR). This project mines data from the Near Earth Objects Wide-field Infrared Survey Explorer (NEOWISE), the Transiting Exoplanet Survey Satellite (TESS), and the Zwicky Transient Facility Survey (ZTF) where they have spatial and temporal overlap. We used the CatWISE Catalog to identify potential AGN by infrared color selection, and examined their light curves at multiple wavelengths for variability. We identified 11 AGN candidates in or near the NEOWISE continuous viewing zone which may be suitable for CRM between the optical and the IR.

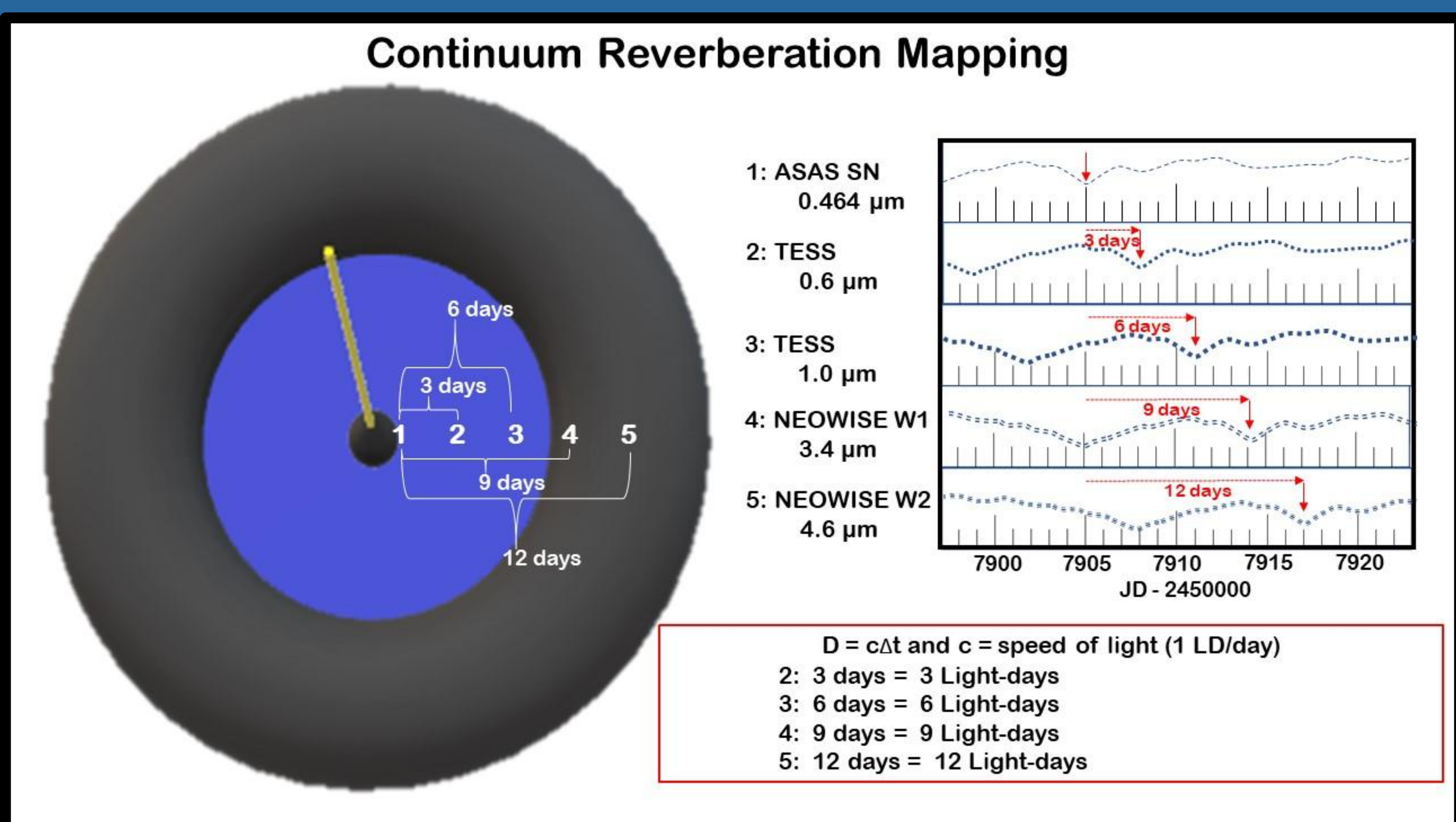


Figure 1: Continuum Reverberation Mapping with hypothetical light curves (N. Boys, NITARP)

Background

In the unified model of AGN, a central black hole is surrounded by a rotating accretion disc. The accretion disc is surrounded by a dust torus, see Figure 1. (Peterson, 1997)

One approach to determining the scale of the disc and torus is Reverberation Mapping (RM), the process of examining time-domain data from the AGN at multiple wavelengths. The technique hinges on the following process: for reasons that are poorly understood, there is significant energy generated from a position directly above the black hole. This energy propagates outward and irradiates the accretion disc and the torus. As the energy is absorbed by the accretion disc and re-radiated outward, the re-emissions map out the temperature profile of the accretion disc. The closer/hotter emission occurs at shorter wavelengths and the further/cooler emissions occurs at longer wavelengths. (Figure 3)

Because of the physical separation between the central source and absorbing regions, there is a transmission-time delay between the primary signal from the central source and the secondary signal from the site of absorption and re-emission. The physical separation from the accretion disc to the torus structure may be determined from the time delay (Δt) between the UV or optical re-emission from the accretion disc and the infrared re-emission from the torus. The delay is reminiscent of acoustic reverberation, hence the term RM.

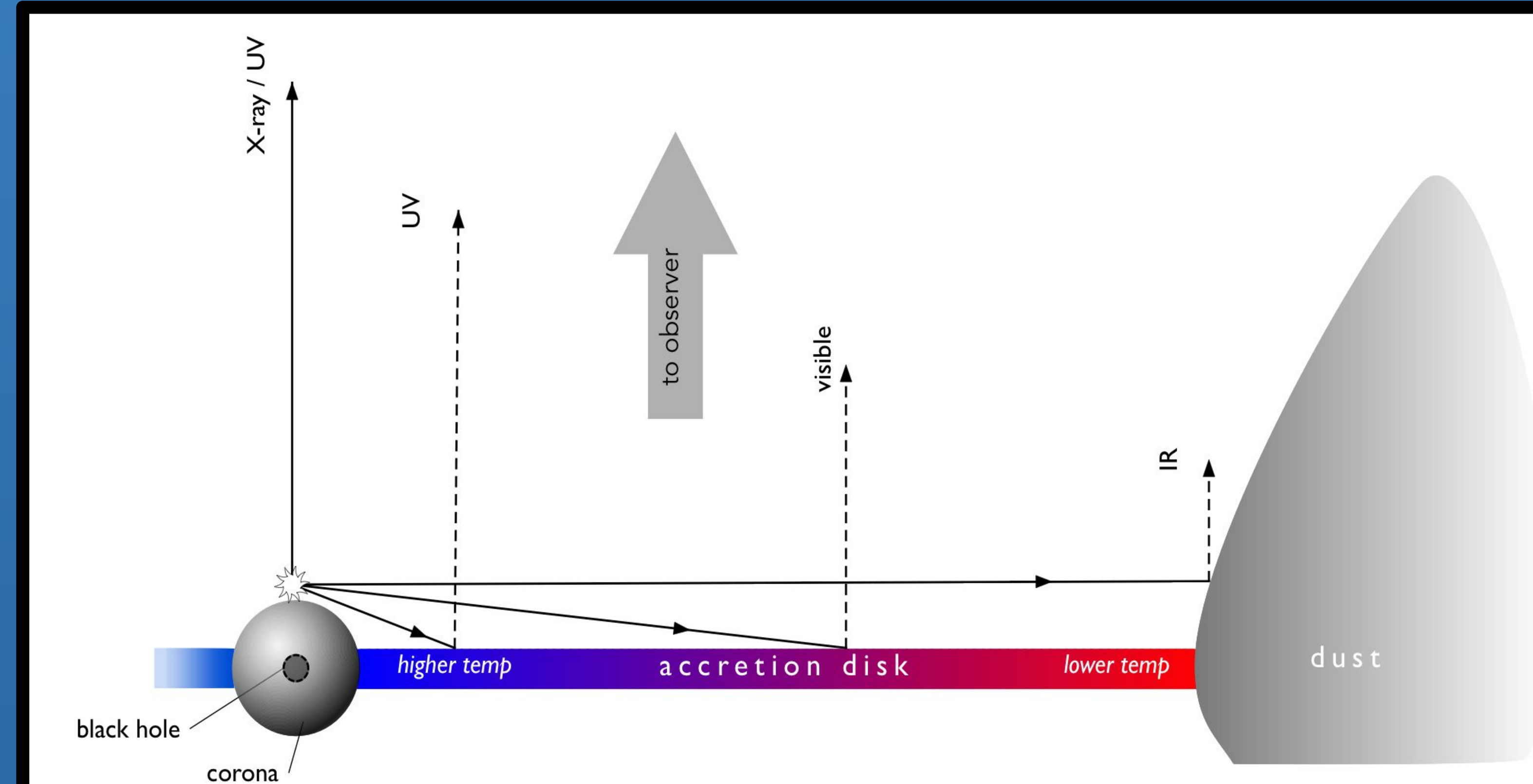


Figure 2: Continuum Reverberation Mapping (edge on view) (D. Strasburger NITARP).

Method of Selection

Sources within 30 arcminutes of the ecliptic poles have essentially continuous coverage by NEOWISE. Sources between 30 and 60 arcminutes of the poles have gaps in their light curves, but the data is sufficient for us to identify variability.

Criterion 1-- Spatial Selection:

Objects in the CatWISE2020 catalog within 60 arcminutes of the north and south ecliptic pole

Criterion 2 -- Color:

We used mid-IR color to identify candidate AGN within the spatially selected population. We noted that on the Stern et al plot, the great majority of AGN may be identified on the diagram by a single color cut: [I1] - [I2] ≥ 0.4, the purple dotted line.

[W1] - [W2] ≥ 0.4

The first two WISE bands (3.4µm and 4.6µm) are nearly identical to the IRAC bands I1 and I2 (3.6µm and 4.5µm), so we use [W1] - [W2] as a proxy for [3.6] - [4.5].

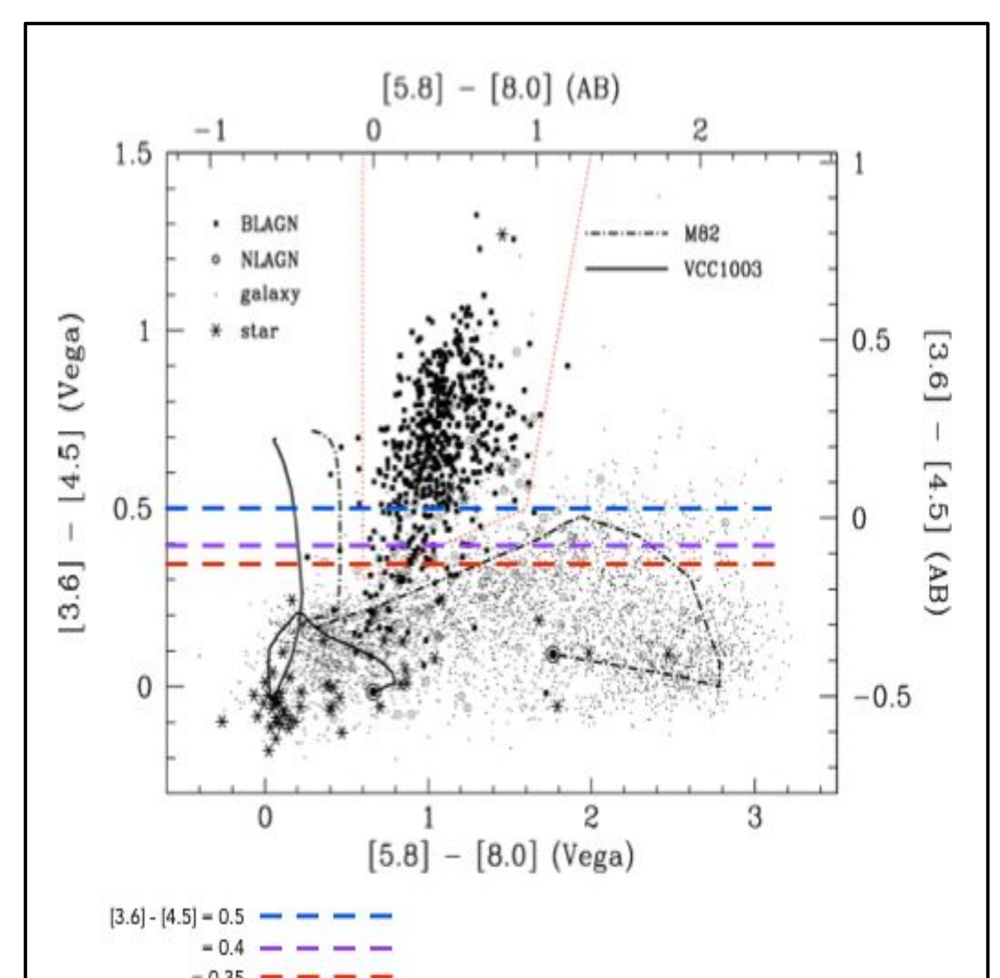


Figure 3: Identification of AGN from mid-IR colors (Stern et al 2005)

Criterion 3 -- Reliable Light Curve:

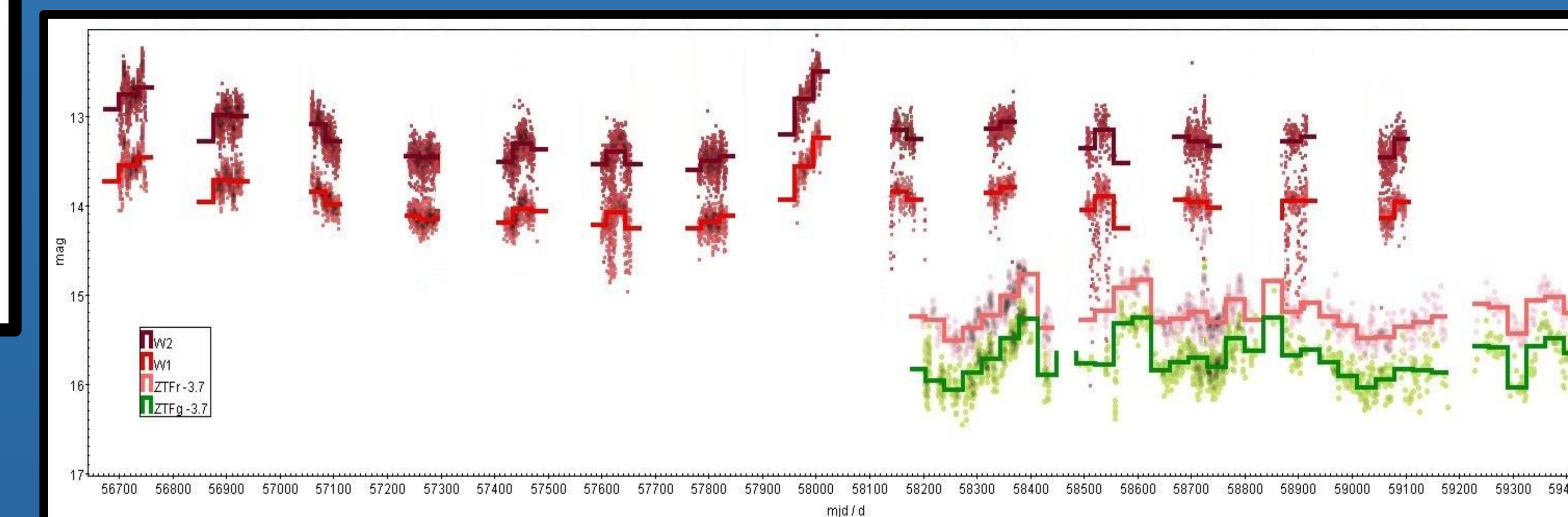
W1 and W2 SNR > 10

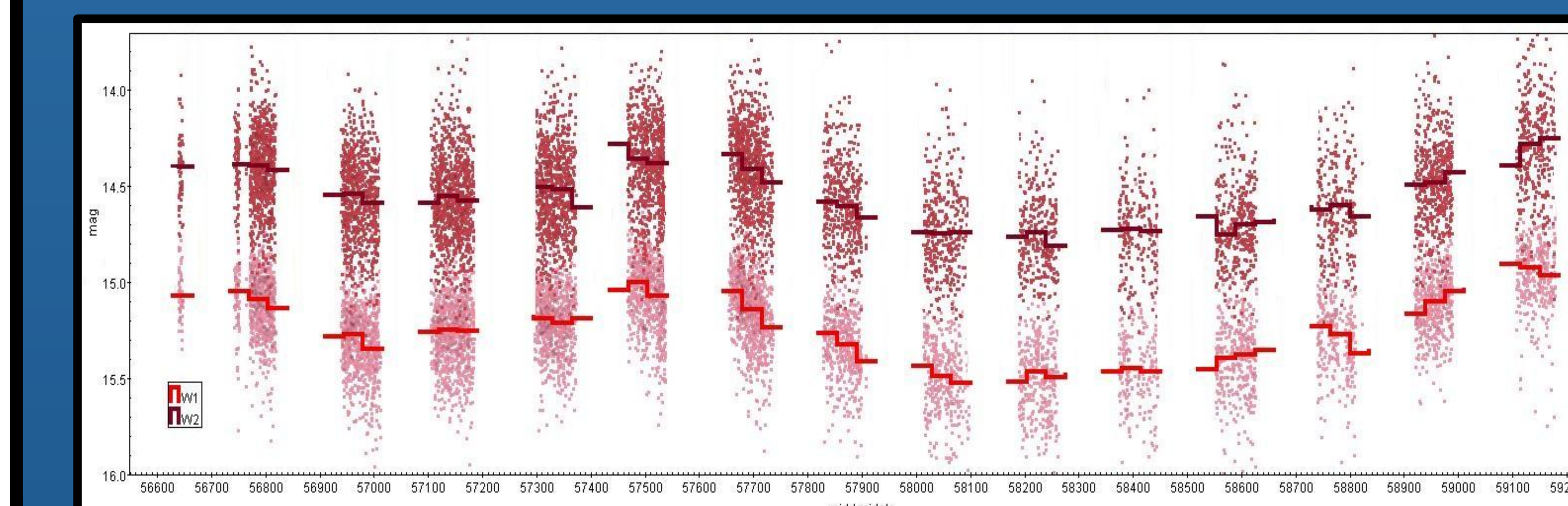
[W1] < 15.5

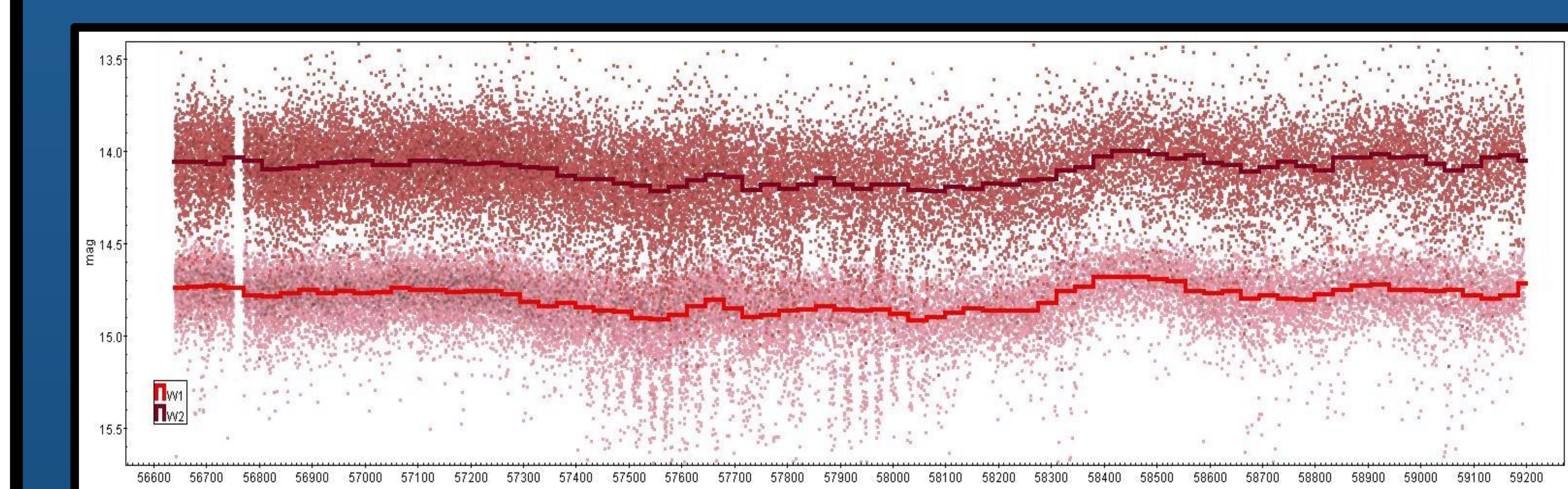
Results

Our selection criteria yield roughly 500 sources, of which eleven showed variability greater than 0.20 magnitudes and are good candidates for continuum reverberation mapping. Of the sources that showed variability, none showed obvious reverberation between the optical and the IR.

Below are light curves of three of our candidates.







Future Work

- Check possible sources to other optical databases (such as the Catalina Sky Survey)
- Perform continuum reverberation mapping on the sources based on the optical and infrared data collected
- Add new NEOWISE data
- Search for more optical data in order to cross-correlate between the IR and optical

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