SunPhot: Progress on a Photometric Data Pipeline for Extracting Quasar Light Curves from ILMT Images

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Abstract

Recent research suggests a correlation between the variability and intrinsic brightness of quasars. This could lead to the use of quasars on the cosmic distance ladder, but this work is currently limited by lack of quasar light curve data. The new 4-metre International Liquid Mirror Telescope (ILMT)'s nightly imaging could produce high quality light curves for thousands of faint quasars in its field. The Python photometric data pipeline SunPhot is under development at UBC to directly extract light curves from calibrated ILMT images using aperture photometry.

Introduction

Quasars are the most luminous objects in the known universe and emit extreme amounts of energy comparable to that of entire galaxy clusters. Recent research suggests a link between the absolute brightness of quasars and the characteristic rate of variation in their light curves [1-2]. Establishing and calibrating such a link could contribute to cosmological measurements such as H0 and extend the cosmic distance ladder to as far as quasars can be observed.

The International Liquid-Mirror Telescope (ILMT) is a 4-m zenith-pointing optical telescope located at the Devasthal Observatory in India (79°41′ E′, 29°21′ N, 2450m). The ILMT views a 115 square degree strip of sky and is the only liquid mirror telescope currently in operation. The telescope saw first light in April 2022 and began a period of commissioning in October 2022.

4939 confirmed quasars from SDSS DR16Q are in the ILMT field. These can be imaged nightly in SDSS g', r', or i', with no competition for time with other science campaigns. Such a well sampled light curve is in high demand for variability studies but is currently only available for less than a thousand quasars[1,3], primarily quasars caught in microlensing surveys.

SunPhot* is a Python photometric data pipeline is being developed at UBC to extract these light curves directly from ILMT images and make them available for study.

*SunPhot by Ethen Sun, pronounced like "sunspot".

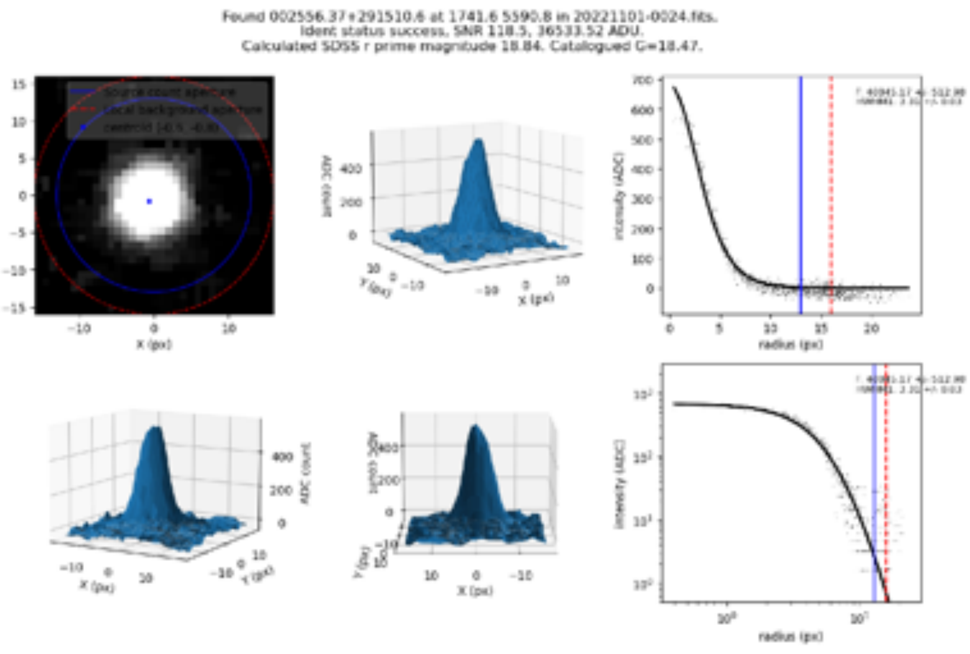

Fig. 1. Sample of SunPhot output panel. Top left: Inset of image containing catalogued quasar with, aperture and background aperture, and apparent centroid represented. The image scale is 0.3278″ per pixel. Top right, bottom right: PSF plotted as a function of radius with basic Kolmogorov fit. Other subplots: 3D representation of pixel values showing distribution shape from different angles.

SunPhot capabilities

Given a catalogue of objects of interest, SunPhot performs aperture photometry on the location of each object. The source flux is counted within an aperture and the background is estimated as the median value in an annulus around the aperture. Astrometric errors comparable to the aperture size are mitigated by re-centering the aperture on the centroid of the area of interest. Sources that are contaminated, not found, or have low SNR are flagged.

The light curve of each successfully measured source is output in CSV table format and PNG image format (Fig. 2). A photometry panel (Fig. 1) can be returned for each measurement if human review is necessary. SunPhot accepts images that have been preprocessed with biases and flats and have an astrometric calibration and photometric zero point from earlier stages in ILMT's data pipeline.

Processing one night of ILMT data takes a few minutes on a modern laptop.

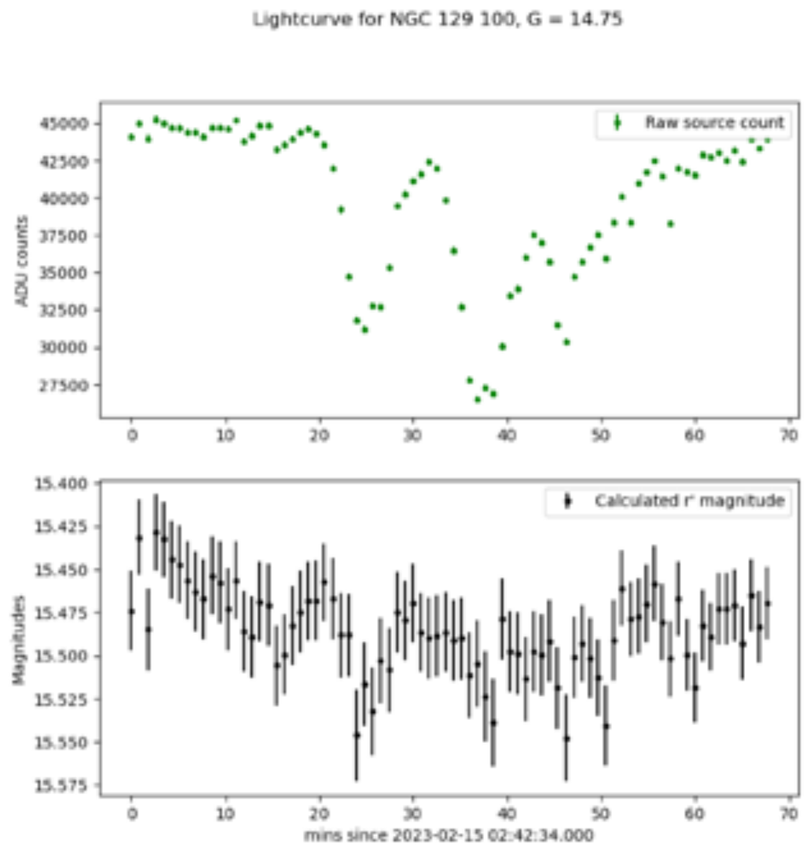

Fig. 2. Test of Sunphot light curve extraction using low quality images from Plaskett Telescope. Data from this night contained elongated PSFs due to tracking issues and large (30-40%) transparency changes due to cloud cover. The star is not thought to be variable.

Ongoing work

As the ILMT is still in the commissioning stage, its PSF may change with further adjustments to the telescope. We are working on software to characterize the PSF in each image using the methods in [4] which would allow the flux to be calculated from smaller apertures. This reduces the effects of crowding and noise.

The ILMT uses time-delay integration (TDI) imaging where electrons are shifted along the CCD at the sidereal rate as the sky moves over the fixed telescope. As a result, stars in the same image were not imaged at the same time and do not necessarily have the same zero point. We are working on a way to calibrate parts of the image separately to reduce flux uncertainties in the event of changes in clouds or suspended dust during imaging.

When more ILMT science data is available, quasar variability will be measured from the light curves using the methods in [1].

References

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Acknowledgements

The 4m International Liquid Mirror Telescope (ILMT) project results from a collaboration between Aryabhatta Research Institute of Observational Sciences (ARIES, India), the Institute of Astrophysics and Geophysics (University of Liège, Belgium), the Universities of British Columbia, Laval, Montreal, Toronto, Victoria and York University. The authors also thank Hitesh Kumar, Himanshu Rawat and Khushal Singh for their assistance at the ILMT. PH acknowledges financial support from the Natural Sciences and Engineering Research Council of Canada, RGPIN-2019-04369, and thanks ARIES for hospitality during his visits to Devasthal.