THE GRANGE OBSERVATORY PHOTO-SPECTROGRAPH

Paolo Pognant B.Sc. - MPC 476 Director

ABSTRACT

The MPC 476 Grange Observatory Photo-Spectrograph (GOPS) instrument began its activity in February 2018 at the 0.14-m Petzval f/5.7 astrograph.
The system is based on a SXL8-P peltier-cooled camera with a filter wheel, having photometric Johnson BVR channels plus an interference 35 nm wide H-alpha filter, all used for pointing the star field, and an 100 grates per mm reticle with a final dispersion of 23 A/pixel at 5500 A.
The CCD camera in the imaging mode gives a field scale of 3.87 as per pixel, well suited for the observatory seeing mean conditions at night.
The star sources low-resolution spectrum, ranging from 3950 to 7000 A wavelengths, has a 12 bit sampling (2048 gray levels), which is obtained in the brighter order 1 (slit-less mode) by GOPS.

TYPICAL GOPS OPERATIONS OVERVIEW

The GOPS operations have two main purposes, the first is to classify targets, as early as possible after discovery in case of bright transient sources, and the second is the photometric follow-up of targets, typically bright (<17 Vegamag) SNs.
The observed sources light curve is usually taken with the photometric filters, which provide the target star field reference astrometry and photometry.
The Johnson V filter is mostly used for deep field pointing purposes, since the SXL8-P camera Quantum Efficiency (QE) peaks actually at 5400 A.
The reference stars and targets spectra are normally imaged together in the observing sessions.
The star source spectrum integrated time is normally set on the basis of the CCD 12 bits native sampling, depending on the target relative magnitude and on camera QE spectral response.

DATA REDUCTION, CALIBRATION AND QUALITY

Bias Calibration: A set of 10 bias frames are typically taken and are used to create a master bias with the SXL8-P camera with peltier on (the CCD current temperature monitoring is possible).
This nightly master bias frame (bias.fit) is applied to the spectral dark calibration.

Dark calibration: Photo-spectrometric dark frames are taken after the spectrum acquisition (dark.fit) using the same CCD exposition time (EXPTIME).

Flat Field calibration: A set of 10 photo-spectrometric Flat Fields frames are normally taken in the late afternoon, and are used to create a master flat field (flat.fit).
The master flat field is repeated depending on the amount of time passed from one observing session to another. Normally the same master is used for subsequent nights data take (up to 3).

Cosmic Rays Removal: The GOPS pipeline includes spectral images manual checks prior to raw data save, and spectra in the reticle blazing brighter order 1 are usually mediated.

Wavelength Calibration: Arc frames are taken during the day using a tri-phosphor lamp with a 30 μm pinhole in front of the astrograph, and known distant street lights might be also imaged at night.

Photo-spectrometric standards and flux calibration: a set of photo-spectrometric standard stars is used for GOPS flux calibration before and after the spectral data take subset.
That is valid for photometry and spectrometry jobs performed at Grange Observatory.

Telluric absorption and fringes correction: GOPS uses a reference model of the atmospheric absorption, related to H2O and O2 lines. An applicability model check is also performed on the standard stars data on night.
No detectable fringing effect has been found in the GOPS spectrum in its short UV part and before 7000 A.

Sky subtraction: Due to the 33% maximum QE of Philips FT12 CCD and pixel size (15 μm) of the SXL8-P "vintage" camera, the GOPS targets spectra are mostly in a relatively uncrowded star field. The sky background is mediated and is easily removed, picking reference points above and below the horizontal spectrum using valuable IRIS and VisualSpec shareware programs.

Astrometric Calibration: The GOPS imaging mode astrometric calibration is derived using the ASTROMETRICA program and a local UCAC-4 DVD reference catalogue, having a positional error of 20 mas for all-sky stars from 10 to 14 Vegamag. The GOPS field is about 30x30 arcmin.
A distortion model described by a third order polynomial is written on FITS header on a WCS export format for science frames.
A typical scatter of 30-40 mas per coordinate has been found for science frames with around 40 stars usually recognized by the catalogue in each image processing session.
This typically improves to an rms of 200 mas with >20 stars in the science frames.
The information of the rms of RA - DEC is provided in the output star list obtained from the ASTROMETRICA program, limiting the aperture photometry fit to 0.2 as.

Photometric Calibration: A manual astrometric calibration is firstly done by cross-correlating the sources detected by ASTROMETRICA program with the positions of UCAC-4 catalogue, incorporating the APASS photometric catalogue (B, V, g, r and i bands) as well.
In the GOPS photometric mode, the instrumental aperture magnitudes of the sources in the field as measured by ASTROMETRICA are then calculated, using an Excel spreadsheet, and compared to their catalogued APASS relevant band magnitudes to determine the applicable photometric zero point during the EXPTIME by manually minimizing the average input and instrumental data errors.
The zero point ZP is employed for relevant magnitude (MAG) derivation simply as:

$$\mathbf{MAG = ZP - 2.5 * \log_{10}(COUNTS_{ADU}/EXPTIME)}$$

where $COUNTS_{ADU}$ is the measured star signal in ADU, and EXPTIME is expressed in seconds.
Using this spreadsheet for APASS Johnson (or Sloan bands in the Grange Observatory 0.3-m main telescope), the typical photometric standard deviation is as good as 3 mmag for the stellar sources in front of the reference APASS catalogue error of about 1% on Landolt/SDSS standard stars.

Time correlation: The SXL8-P camera native FITS headers are very complete, including MJD and a correct time formulation (DATE-OBS with compact time format T) derived from an ASUS laptop clock, which is aligned with the INRIM NTP servers (193.204.114.232 or .233).
The Windows XP Time Client can easily handle the timing issue, and the computer clock must be updated in GOPS prior to any science image acquisition.

CONCLUSIONS

The GOPS instrument is ready to be proficient for bright star objects characterization job, including a potential transients follow-up.
In 2018 a test data campaign will be granted by the Grange Observatory's budget, using local human resources. The spectral data pipeline shall be developed, while the photometric follow-up data processing is a current data operation at MPC 476.
In the following years, considering the photometric and spectral data quality provided, we assume to apply for institutional grants as well.