Design concepts of the "Fly's Eye" all-sky camera system

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Abstract

This poster briefly summarizes the design concepts of the **"Fly's Eye" camera system**, a proposed high resolution all-sky monitoring device intended to perform high cadence time domain astronomy ([1]) in multiple optical passbands while still accomplish a high étendue. **Fundings have already been accepted by the Hungarian Academy of Sciences** in order to design and build a "Fly's Eye" device unit. Beyond the technical details and the actual scientific goals, here we also demonstrate the possibilities and yields of a possible network operation involving approximately a dozen of sites distributed geographically in a nearly homogeneous manner. Currently (summer of 2012), we expect to finalize the **hexapod** mount assembly – that performs the sidereal tracking during the exposures – until the end of 2012 and to have a working prototype with a reduced number of individual cameras in the spring or summer of 2013.

In this project, we intend to follow **an "open design, open source and open data" model**. In other words, both the mechanical or electronic schematics and the data acquisition control and data processing program codes will be publicly available as well as the pre-processed imaging, calibration and photometric data would also go into the public domain after a relatively short period of time. In addition, the design would be more feasible for **operation in harsh environment**, due to the involvement of an enclosure with optical windows and regulated temperature and humidity **inside** the enclosure. The robust mechanical design that exploits a hexapod for local sidereal tracking will **lack unique moving parts** and be fault tolerant due to its redundancy. Moreover, exactly the **same instrument** can be built **independently from the** actual **geographical location** and the installation procedure is simple since there is **no need for polar alignment**.

Optical imaging instruments

Basic parameters and properties:

- Aperture size; field of view; detector resolution; imaging resolution; physical detector size; focal ratio; étendue (FOV area multiplied by effective light collecting area, $\deg^2 m^2$).
- Exposure time, readout time, sampling cadence, duty cycle.

These are not independent quantities, and all of them determine the usability and the types of practical applications of a certain optical and/or imaging system (e.g. a telescope).

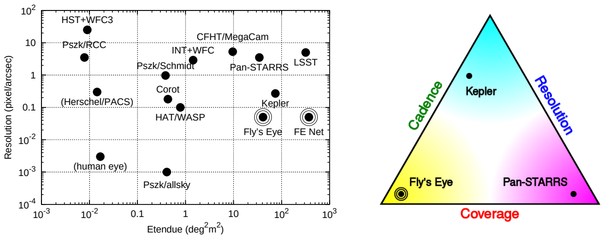


Fig. 1. *Left: the optical light-collecting phase volume, or étendue and effective resolution for various known, mostly optical telescope systems. Right: the sampling cadence, solid angle coverage and resolution for some optical systems having an étendue of $30-70\,\deg^2\,m^2$.*

The "Fly's Eye" device

- Combination of an all-sky camera and a sidereal tracking mechanism.
- Enclosure with optical windows: suitable in harsh weather.
- Redundancy: no unique moving component. Tolerance: the device is operational if one of the moving parts fail. Sidereal tracking has a fault tolerance ratio of "3 out of 6".
- Project model: "open design, open source and open data".

The "Fly's Eye" camera mount and instrument design

- 19 wide-field cameras, equipped with Sloan g/r/i filters, covering the sky above the $30^\circ \leq h$ horizontal altitude.
- Lenses: $f = 85\,\mathrm{mm}$, $f/1.2 \rightarrow$ photometric precision is $4-5\,\mathrm{mmag}$ for $r = 10^m$ stars, expecting a sampling cadence of 3 min. Limitations: confusion noise. Practical limit: $r \leq 15-16^m$ (close to the saturation limit of LSST, see [2]).
- Effective resolution: 22"/pixel, by employing KAF16803 detectors (0.32 Gpixels in total per unit). Étendue: $\approx 40\,\deg^2 m^2$ (instruments with nearly similar values: Kepler spacecraft, a single Pan-STARRS telescope ([3], see also Fig. 1, left panel).
- Minimization of moving parts: sidereal tracking is done by a *hexapod* mount; onboard computing using single-board computers with no moving parts; off-the-shelf, commercially available parts.
- Camera platforms: $\approx 50\,\mathrm{kg}$ of instruments (cameras, lenses, filters), with a base diameter of $\approx 60\,\mathrm{cm}$ and an effective diameter of $\approx 1\,\mathrm{m}$.
- Data reduction: efficient software solutions are available (FITSH, [4]), it is possible to perform on-the-fly with the proposed cadence. Data flow: few hundreds of gigabytes on a clear night.

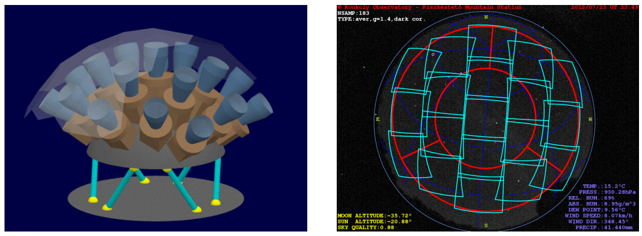


Fig. 2. *Left: a simple visualization of the camera mount shown to scale. The effective diameter of the setup is nearly 1 m. Right: the field-of-view of the 19 cameras shown on an all-sky image.*

Data acquisition principles

In order to achieve both a scientifically rational and an easily manageable data acquisition scheme, in a single "Fly's Eye" device we employ the following:

- Currently expected exposure cadence: exactly 03:00 sidereal minutes, i.e. roughly 179.51 seconds. Assuming a detector readout time of 16 seconds, this cadence implies a duty cycle larger than 90%.
- Image expositions are scheduled by Greenwich sidereal time.
- Filter sequences: periodic in all filters, every second is Sloan r' (highest quantum efficiency, central both in *ugriz* and *gri*).

Data flow rates (assuming 3 minutes of cadence):

- continuous: 200 MB/min ≈ 110 TB/yr; yearly mean on temperate latitudes (assuming clear weather): 80 MB/min ≈ 45 TB/yr;
- slightly smaller to the poles and slightly larger to the equator;
- daily peak rate: strongly depends on the season and the location.

Scientific key projects

- Atmospheric phenomena (e.g. meteors);
- Solar System: unbiased photometric sample of 10k main belt asteroids and flybys of near-Earth objects;
- Astrophysics of young stellar objects;
- Stellar activity and pulsating variables;
- Eclipsing stellar systems and transiting extrasolar planets (uninterrupted monitoring, discovery, color information, etc);
- Extragalactic astrophysics: nearby supernovae;
- Complementary to both LSST and "Mascara" (`http://lsst.org/`, `http://mascara.strw.leidenuniv.nl/`).

Additional projects or application ideas:

- photometric and imaging data will also be publicly available (search and analysis of moving targets, extended sources, etc.);
- a small workshop sometimes in 2013: further projects and involvements.

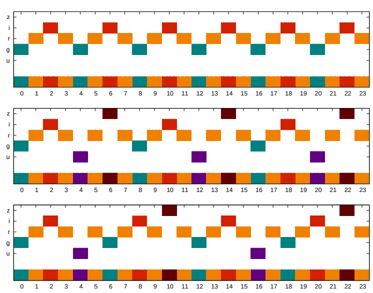
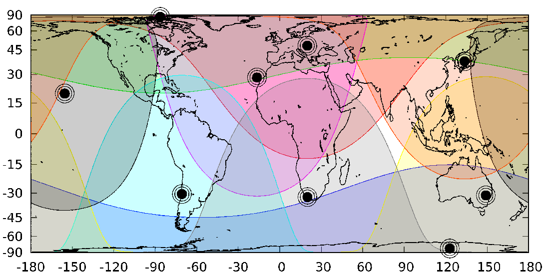


Fig. 3. *Some considered image acquisition sequences. All of the images for a given filter are periodic. The top panel shows a 12-min (4 image) period pattern using only g, r and i filters. The lower two panels show a pattern involving all of the five ugriz filters.*

A possible network and spherical coverage of "Fly's Eye" devices



References

[1] Blandford, R. D. et al. (Committee for a Decadal Survey of Astronomy and Astrophysics): *New Worlds, New Horizons in Astronomy and Astrophysics* The National Academic Press, Washington DC, USA (available from `http://www.nap.edu/catalog.php?record_id=12951`)

[2] Ivezić, Ž. et al: *LSST: from Science Drivers to Reference Design and Anticipated Data Products*, available from `http://lsst.org/lsst/overview/`

[3] Kaiser, N. et al, 2002, in the proceedings of "Survey and Other Telescope Technologies and Discoveries"; Proceedings of the SPIE, Volume 4836, pp. 154-164

[4] Pál, A. 2012, MNRAS, 421, 1825

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