The Fly's Eye camera system

a proposed instrument for large étendue time-domain survey

IAU XXVIII. General Assembly, Beijing, China

Krisztián Vida (kvida@flyseye.net),
András Pál, Zsolt Regály, Katalin Oláh,
Csaba Kiss, László Döbrentei, György Mező

20 – 31 August, 2012

http://flyseye.net/

Optical imaging instruments

What are the basic parameters of an instrument?

- aperture size;
- field of view;
- detector resolution;
- imaging resolution;
- physical detector size;
- focal ratio;
- étendue (FOV area multiplied by effective light collecting area, $\mathrm{deg}^2\mathrm{m}^2$);
- sampling cadence.

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).

Étendue and resolution

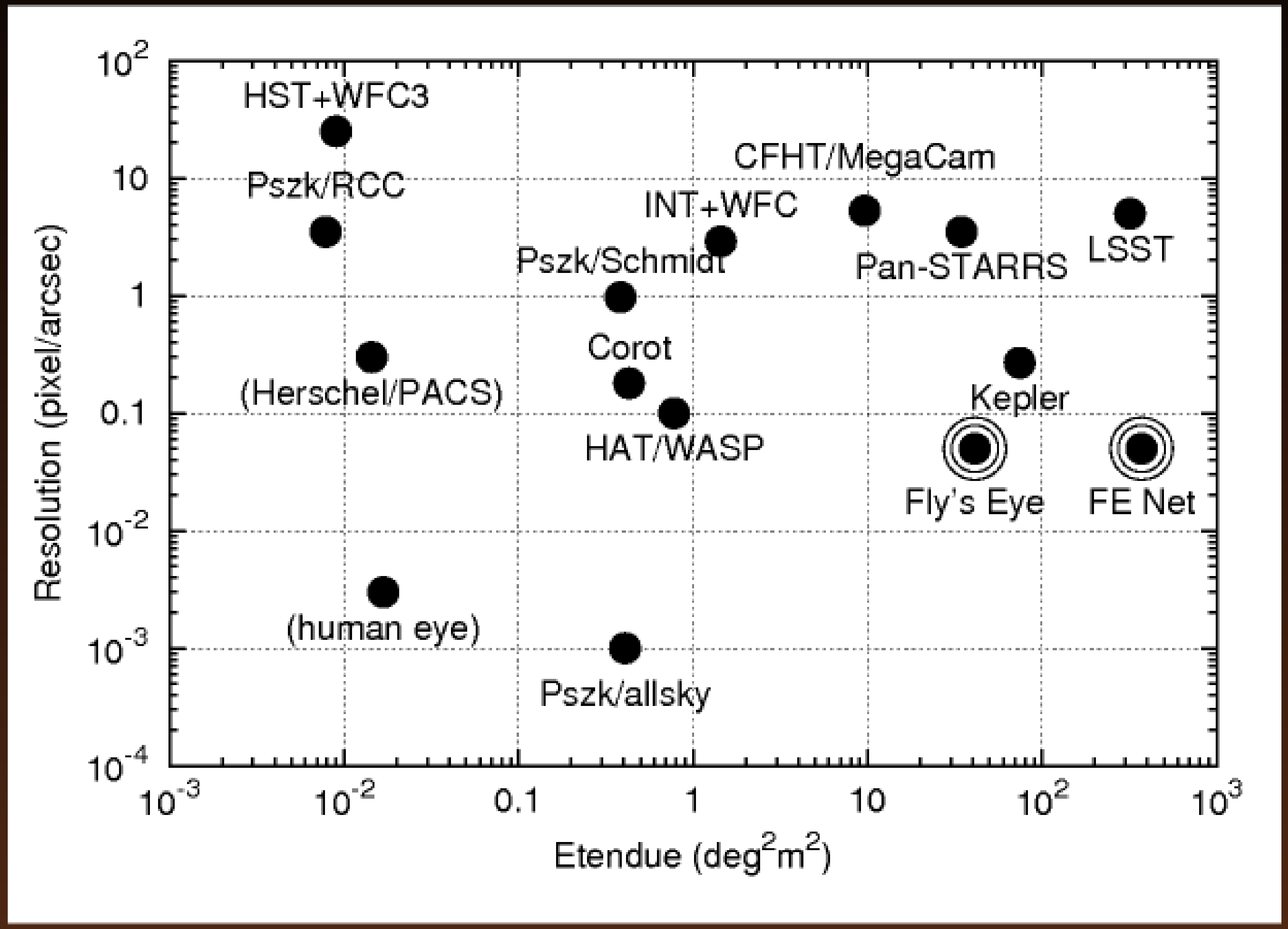

Fig. 1: *Effective resolution and optical étendue of some currently operating and proposed telescopes. LSST is expected to have the largest étendue among both the available and proposed telescope designs.*

Resolution, cadence and sky coverage

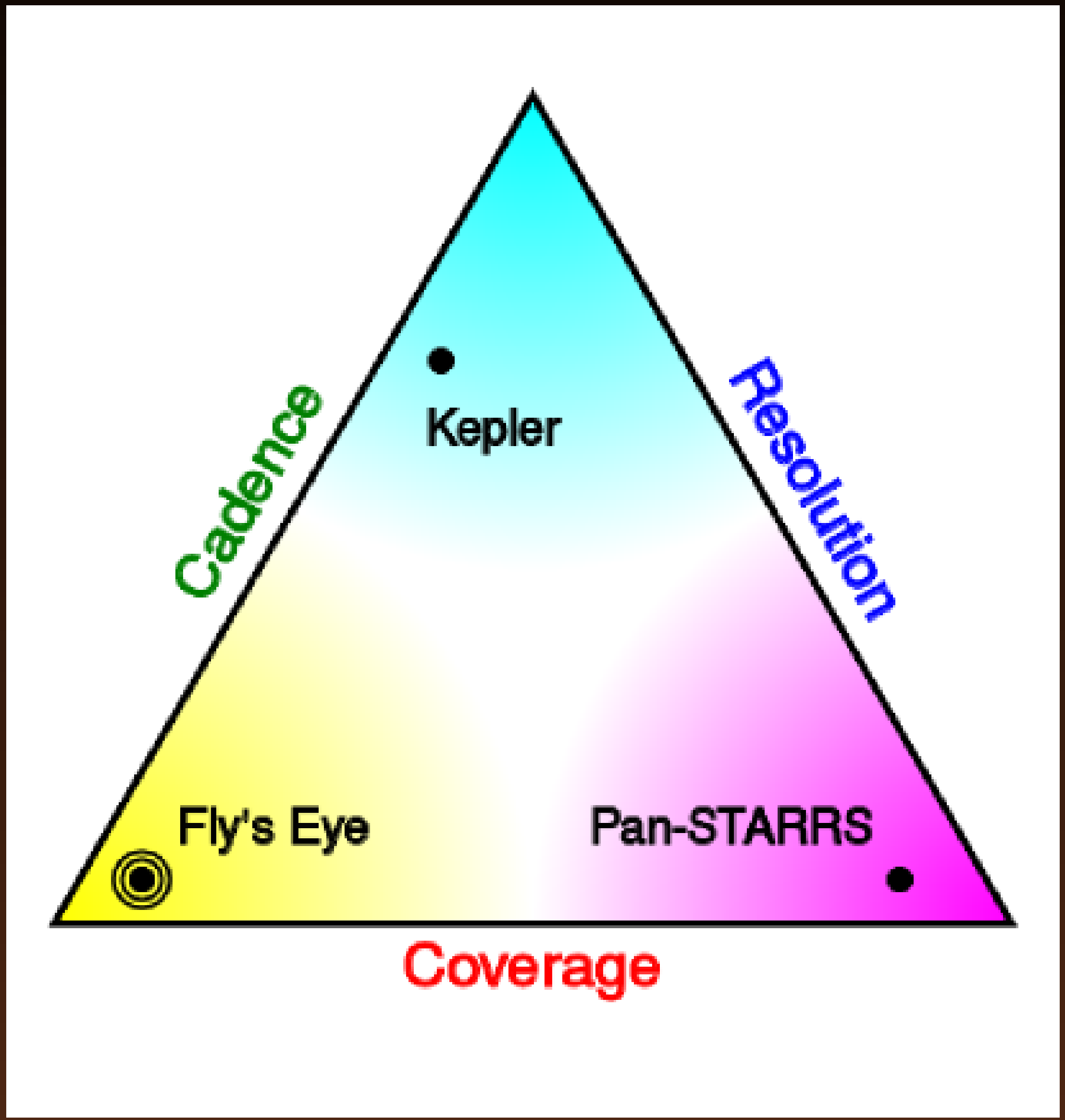

Fig. 2: *The imaging resolution, data sampling cadence and cumulative sky coverage of various optical telescope systems having an étendue in the regime* $30 - 50\,\mathrm{deg}^2\mathrm{m}^2$. *Now the "high cadence – high coverage – low resolution" (bottom left) corner is empty.*

The Fly's Eye camera mount

The current design concepts are the following:

- 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 $r = 10^{\mathrm{m}}$ stars, expecting a sampling cadence of $3\,\mathrm{min}$. Limitations: confusion noise. Practical limit: $r \leq 15 - 16^{\mathrm{m}}$ (close to the saturation limit of LSST).
- Effective resolution: $22''$/pixel, by employing 4k×4k KAF16803 detectors (0.32 Gpixels in total per unit). Étendue: $\approx 40\,\mathrm{deg}^2\mathrm{m}^2$ (instruments with similar values: Kepler spacecraft, a single Pan-STARRS telescope).
- Minimization of moving parts: local sidereal tracking involving a hexapod mount; onboard computing using SBCs (single-board computers) with no moving components; off-the-shelf, commercially available components.
- 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), it is possible to perform on-the-fly with the proposed sampling cadences. Data flow: few hundreds of gigabytes on a clear night.

The camera mount

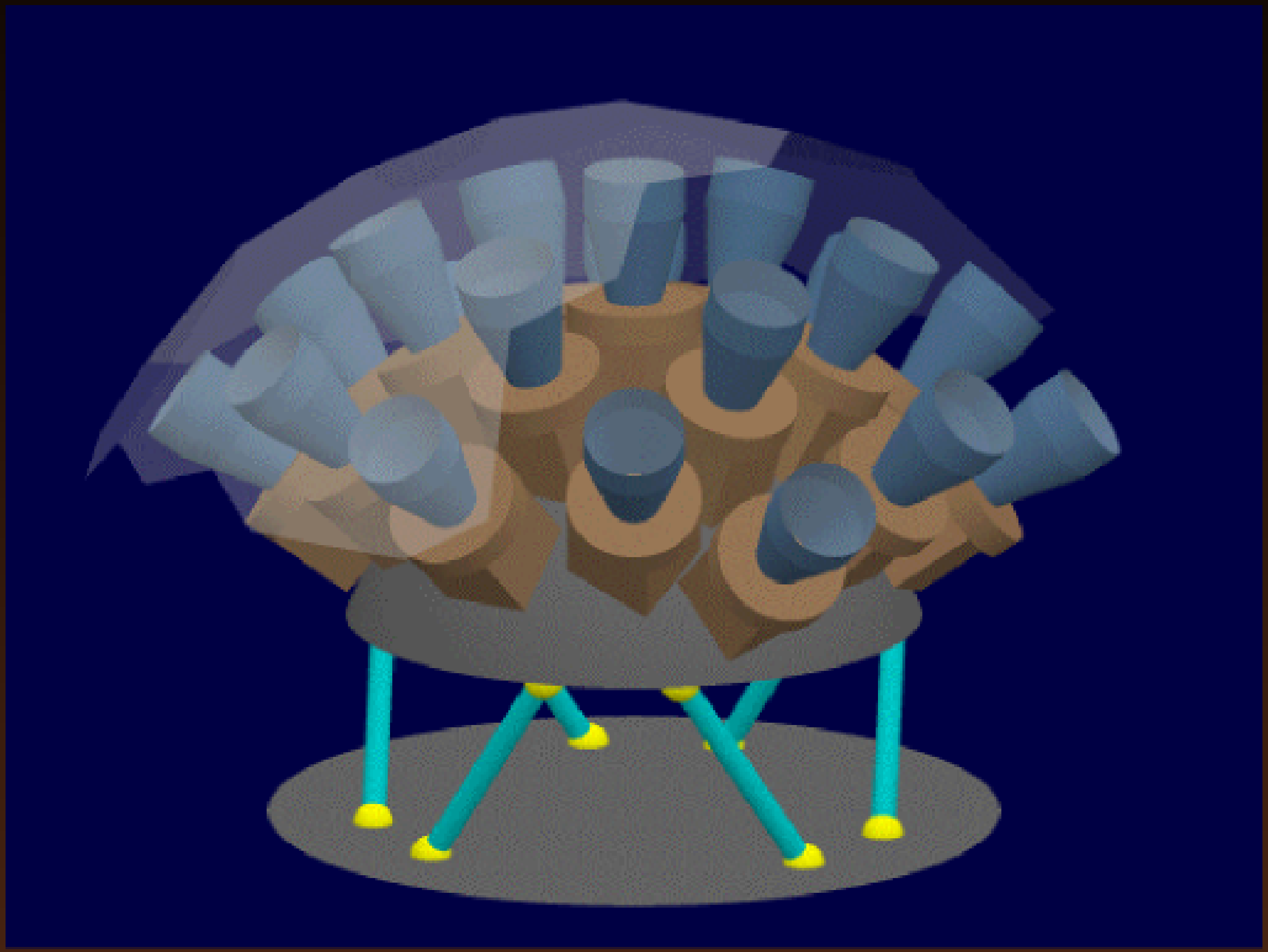

Fig. 3: *A visualization of the camera mount. The payload platform – on which the 19 cameras are mounted – is shown to scale. The hexapod legs are merely figurative, however, the retracted length of these is the same as implied by the scale. The characterisic size of the instrument is ≈1m.*

The total field-of-view

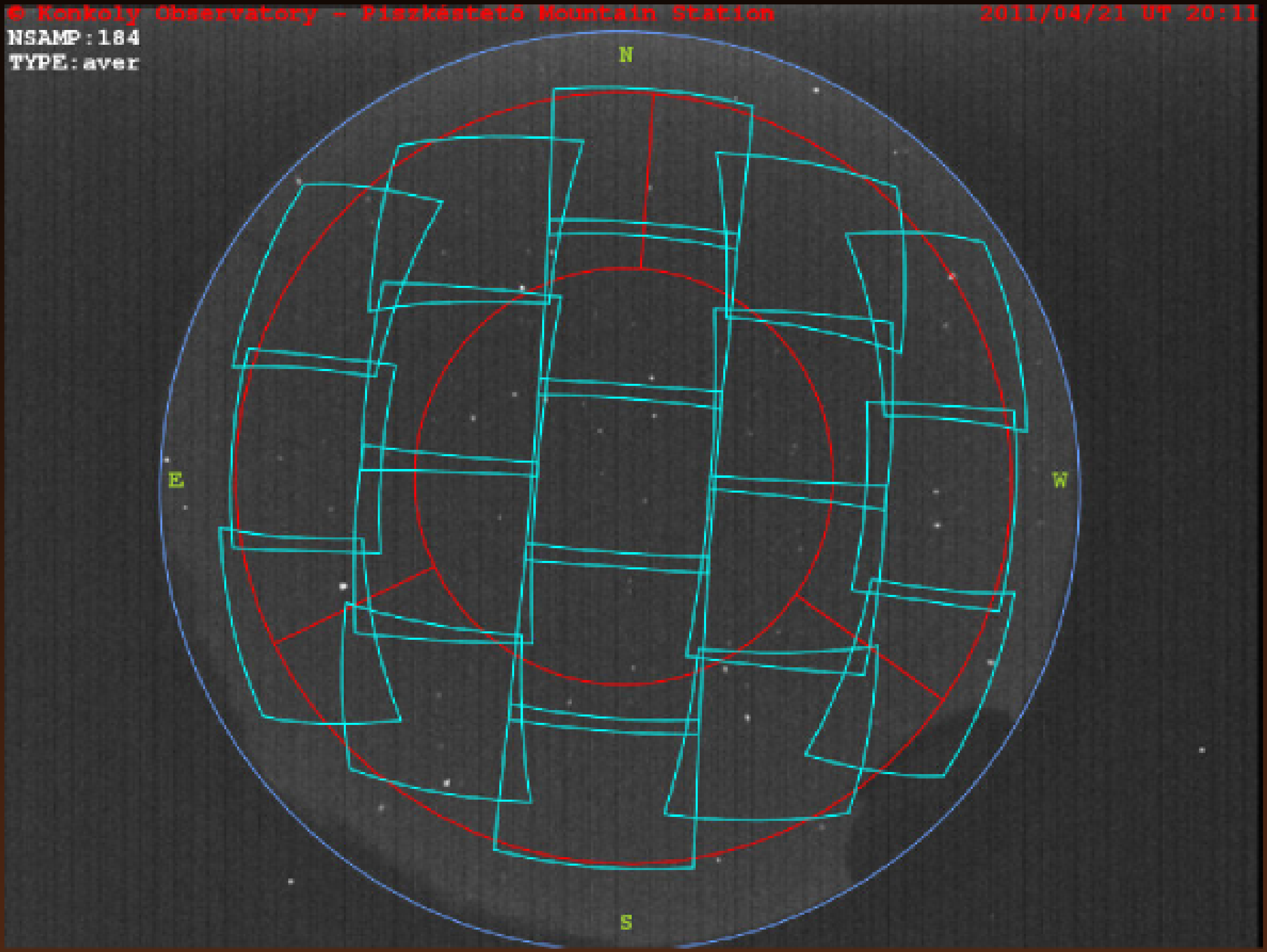

Fig. 4: *The field-of-view of the 19 cameras shown on an all-sky image. The estimated FOV of each camera-lens pair would be roughly 26°. The placement and field orientation of the cameras are exactly the same as it is implied by the previous figure.*

Data acquisition

Data acquisition schemes:

- 3 sidereal minutes of exposures (+ readout) $\rightarrow$ duty cycle is roughly 91%.
- Image expositions are scheduled via "global" (Greenwich) sidereal time, so all instruments of the future network will measure the same area at the same time.
- Filter sequences: periodic in all filters, every second is Sloan r' (highest quantum efficiency, central both in *ugriz* and *gri*.

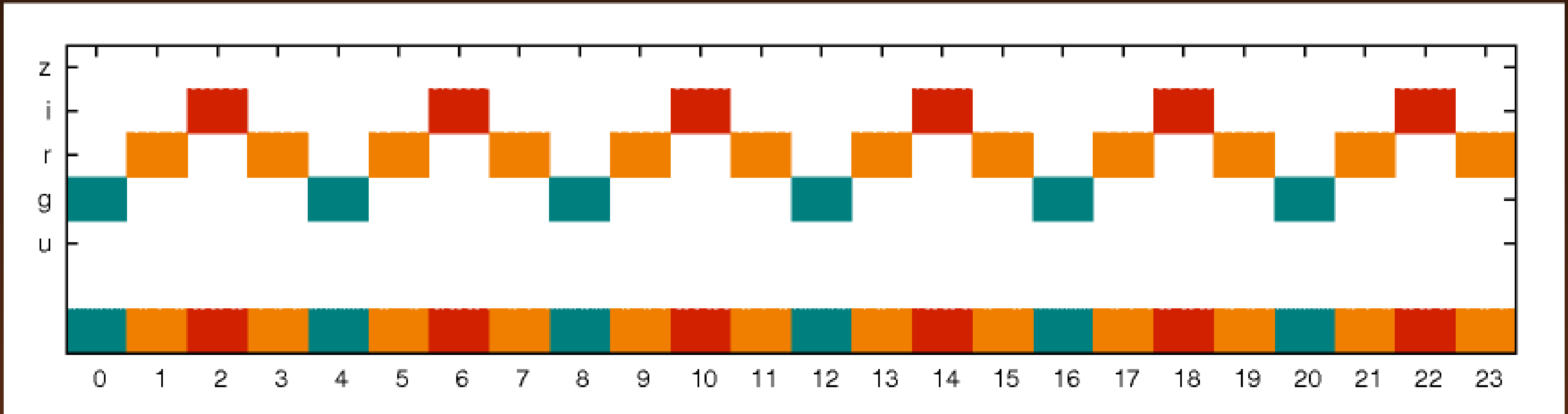

Fig. 5: *Filter sequences of g/r/i = 1/2/1, period: 4 frames (12 minutes). This is the preliminary filter subset and sequence.*

Data acquisition

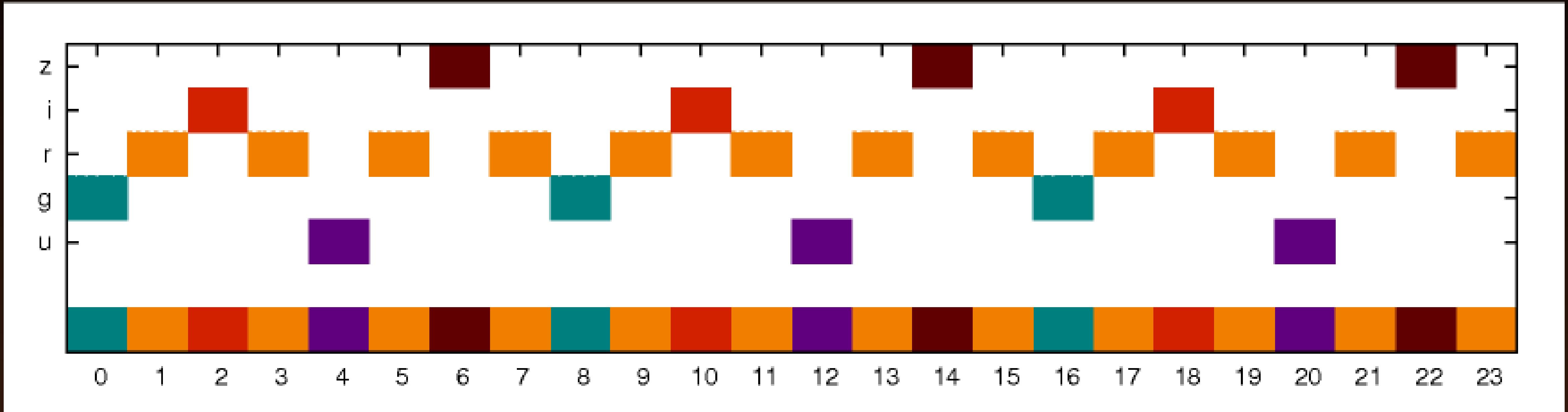

Fig. 6: *Filter sequences of u/g/r/i/z = 1/1/4/1/1, period: 8 frames (24 minutes).*

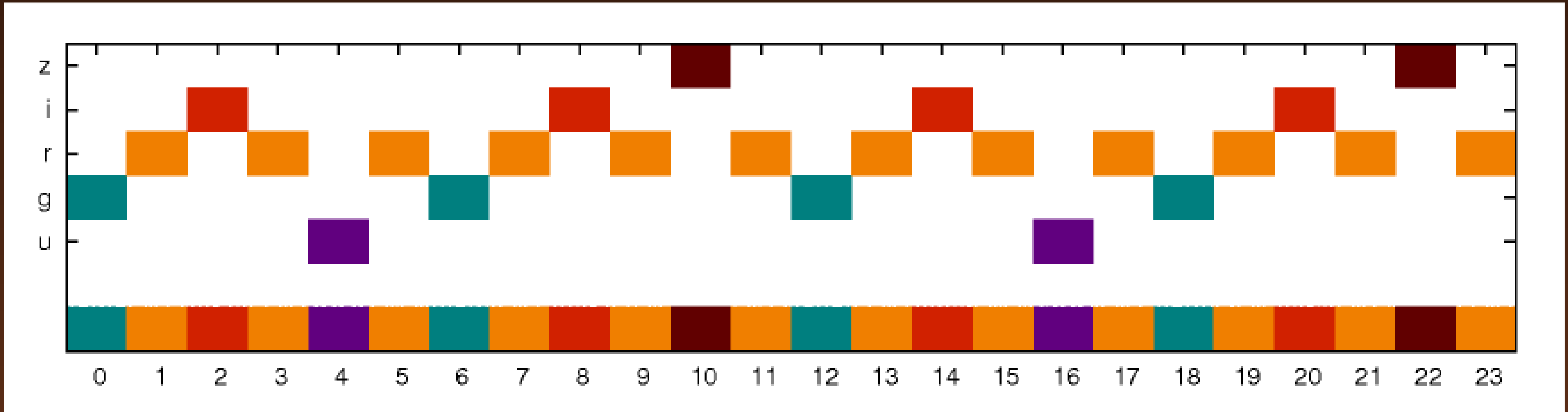

Fig. 7: *Filter sequences of u/g/r/i/z = 1/2/6/2/1, period: 12 frames (36 minutes). This is the planned final filter set and sequence.*

The advantages of a network

Similar camera systems placed on various locations:

- 7 – 8 of such camera systems yield a total étendue similar to LSST.
- Persistent time domain survey.
- Monitoring the whole sky in the bright ($r \lesssim 15^{\rm m}$) magnitude regime.
- Cadence: few minutes (LSST or Pan-STARRS: few days). Co-location: higher phase coverage, less aliases.
- The expected data flow rate also implies special techniques.
- Currently planned locations: Konkoly Observatory (initial development, performance tests and verifications, etc.); Tenerife, Teide Observatory. . . ? Negotiations are underway, informal contact with some sites (Chile, Canadian Arctic) are initiated – any further suggestions/possibilities/offers are most welcome!

The advantages of a network

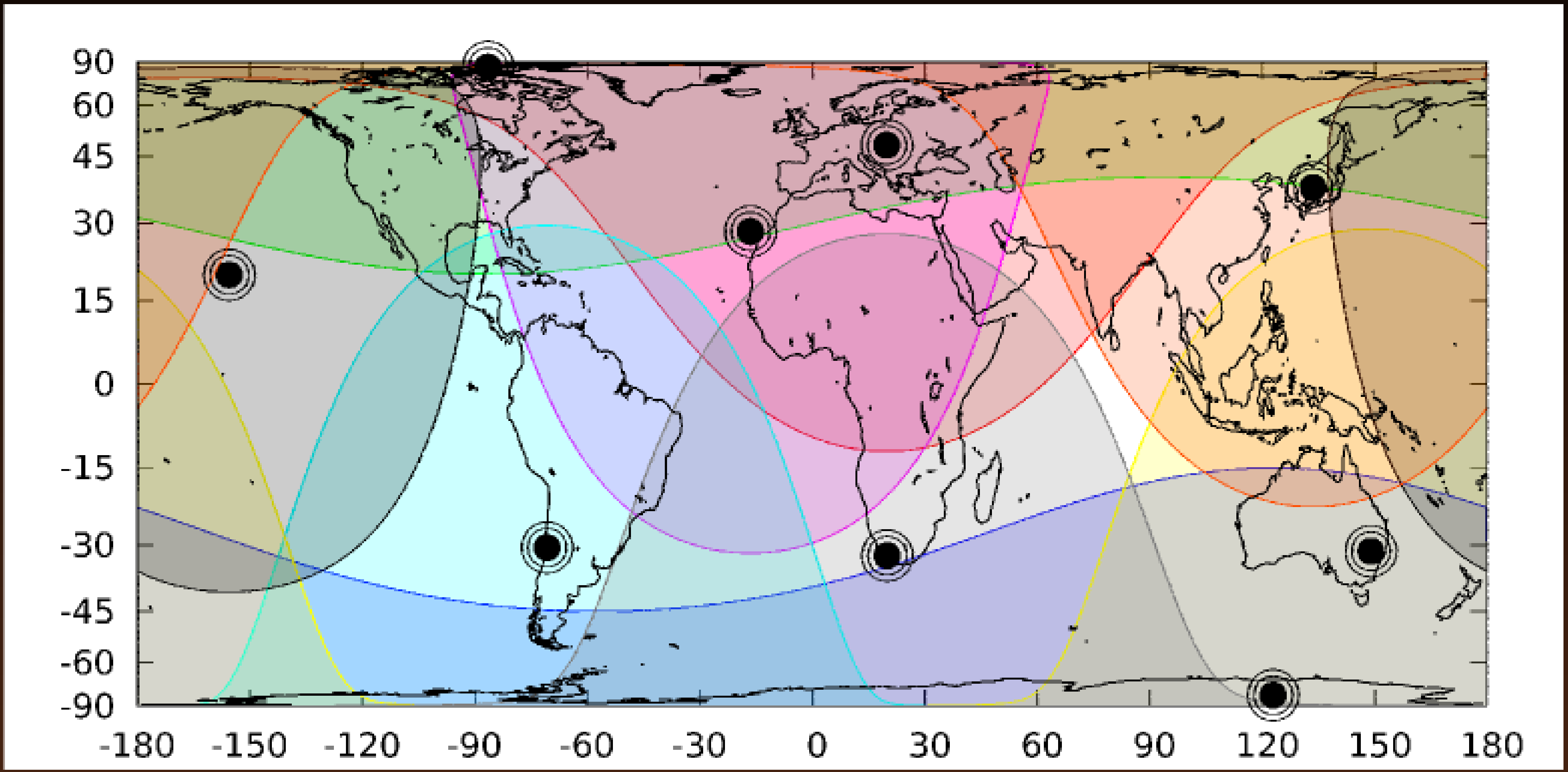

Fig. 5: *A long-term plan: Projected coverage areas of 9 Fly's Eye units, located in various places.*

Other advantages

Some additional advantages of the current design concepts:

- "open design, open source and open data" model
- robust mechanical design:
  - an enclosure with optical windows;
  - regulated temperature and humidity inside the enclosure;
  - $\Rightarrow$ suitable for harsh environment;
  - lack of unique mechanical and optical components;
  - redundancy in the hexapod: 3 out of 6 legs could completely be stuck
  - similar instrument independently from the geographical location;
  - simple installation: no need for polar alignment;
- cost-effective: one instrument has an estimated cost roughly $300 - 330$ k€ ($360 - 400$ k\$).

Scientific key projects

Some of the currently discussed scientific 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"

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 (contact list at the poster at "late posters" at the back of the poster room/me!).

Milestones

Some more relevant milestones in the timeline of the project:

- 2011 summer: the first design initiatives of the Fly's Eye camera system;
- 2012 February: a proposal has been submitted to the Hungarian Academy of Sciences (HAS), applying for funds to build a full working instrument;
- 2012 April –: theoretical and mechanical design of the hexapod platform;
- 2012 June: the proposal has been accepted by the HAS;
- 2012 fall: seeking for grants to build two other Fly's Eye devices;
- 2012 December: the hexapod platform is expected to be ready and working;
- 2013 summer: the first measurements using a reduced number of cameras (5 out of 19), covering the full declination strip between $45 - 55^{\circ}$ and partially the strip $35 - 65^{\circ}$.
- 2013 winter: the assembly of the housing and tests in harsh environment;
- 2014 summer: and increasing the number of cameras (up to 10 – 12);
- until the end of 2015: purchasing and assembling the remaining cameras.

Thank you

See also the poster at "renegade posters" – at line 17 in the end of the poster room