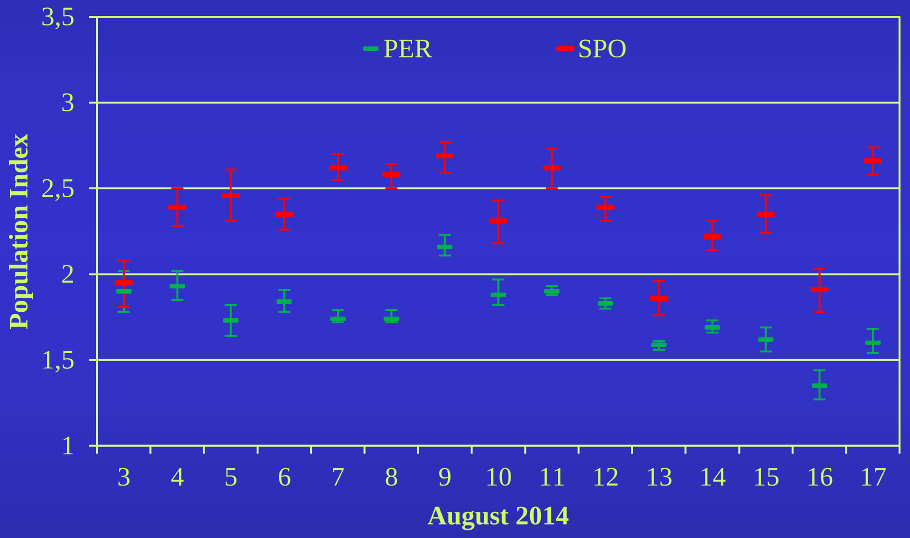
Population Index Reloaded



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Agenda

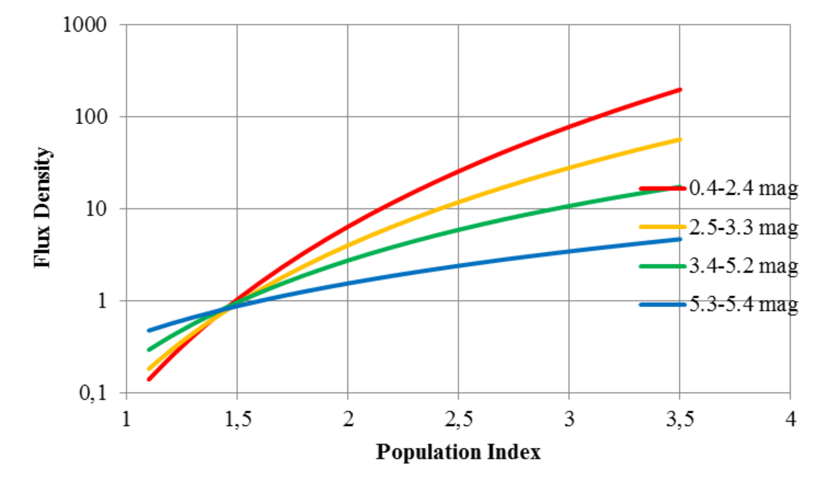
- Recap: Population Index
- Recent Results
- Analysis
- Alternative Approach

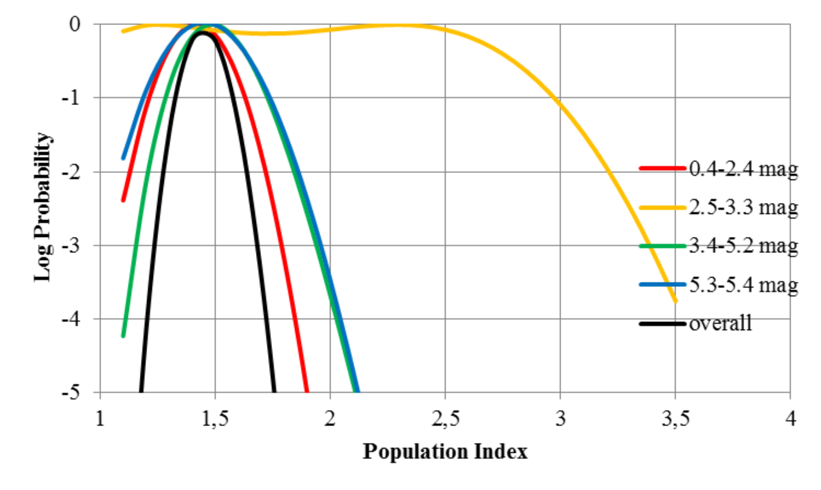
Recap: Population Index (I)

- The population index (r-value) describes the brightness distribution of a meteor shower.
  - Increase in total meteor count when lm improves by one mag.
- Population index is vital for the calculation of ZHR and flux densities. So far it was only obtained from visual observations.
  - The population index can be directly transformed into the mass index, which describes the particle size distribution in a meteoroid stream.
- In 2014 a procedure was presented to calculate the population index from video meteors.
  - It was not based on meteor counts in different brightness classes as in the traditional approach, but rather on meteor counts of observing intervals with different limiting magnitude.

Recap: Population Index (II)

- Approach presented last year
  - Sort all observing intervals of all cameras by their lm.
  - Split the data set into lm classes such that each class has about the same effective collection area.
  - Calculate flux density vs. population index graphs for each lm class.
  - Select the population index that fits best to all classes (using the Poisson distribution to weight the contribution on each class).

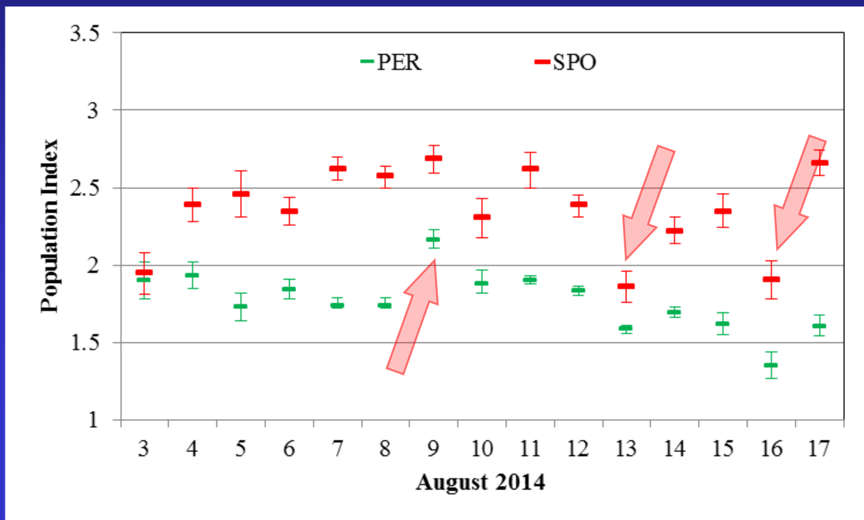




Recent Results (I)

- In the past 12 months, population index profiles have been calculated for different meteor showers and compared with the population index of sporadic meteors.
- Typically the population index for sporadic meteors was 2.5 or below in fall 2014, and above 2.5 in spring 2015.
- The population index for meteor showers is normally smaller than for sporadic meteors.
- The r-profile is often smooth over several days, but there are also significant outliers.
- For smaller meteor showers with fewer meteors, the individual lm class graphs intersect often better than for major showers.

Recent Results (II)

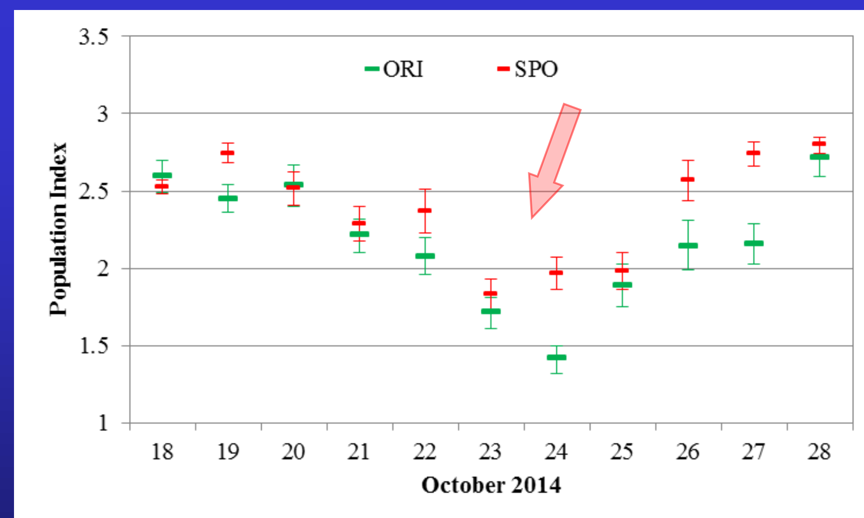


Perseids 2014

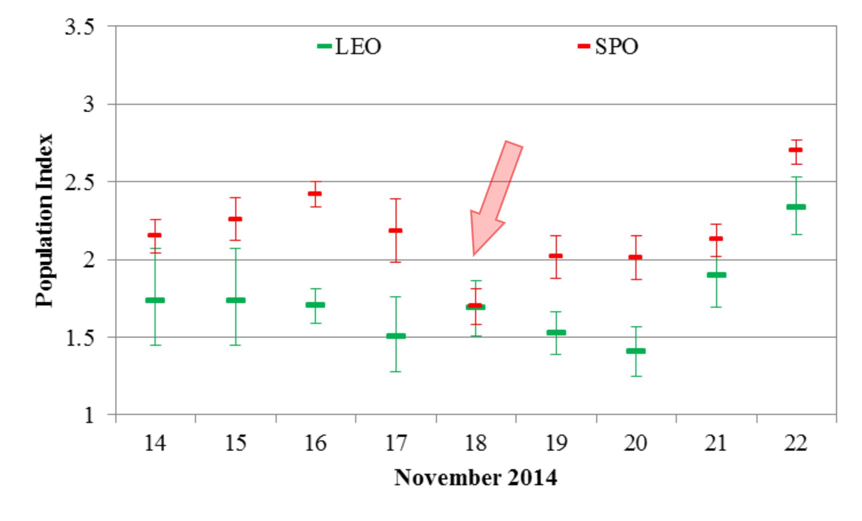
- Population index of Perseids below 2.0 all the time.
- Significant outlier on Aug 9 even though perfect data set.
- Sporadic population index below 2.0 on Aug 13 and 16.

- Population index of Orionids and sporadic meteors almost identical in all nights up to the peak.
- Nice dip in the r-profile of Orionids, but sporadic meteors show the same dip.

Orionids 2014



Recent Results (III)

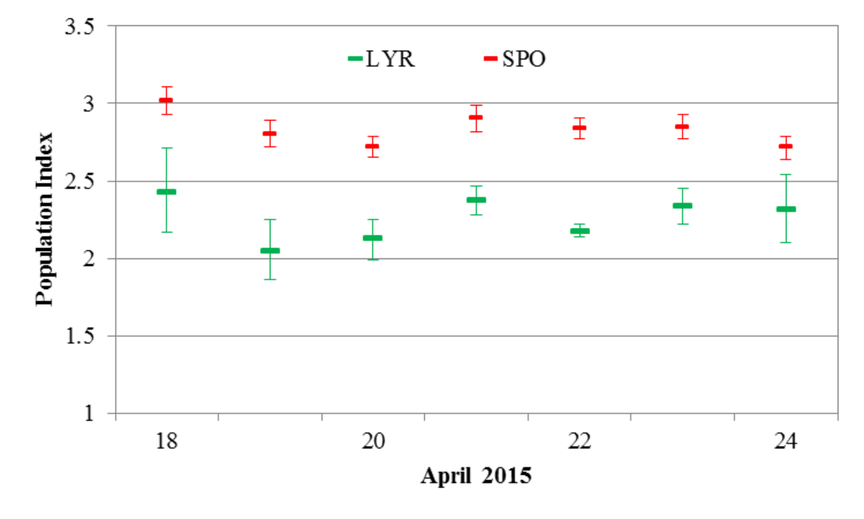


Leonids 2014

- Leonids clearly brighter than sporadic meteors in all nights but the maximum (Nov 18).
- Sporadic population index very low (near 2.0 all the time).

- Lyrids with significantly lower population index than sporadic meteors all of the time.
- Population index of sporadic meteors increased to almost 3.0.
- Both profiles show the same tendency (up and down).

Lyrids 2015



Analysis (I)

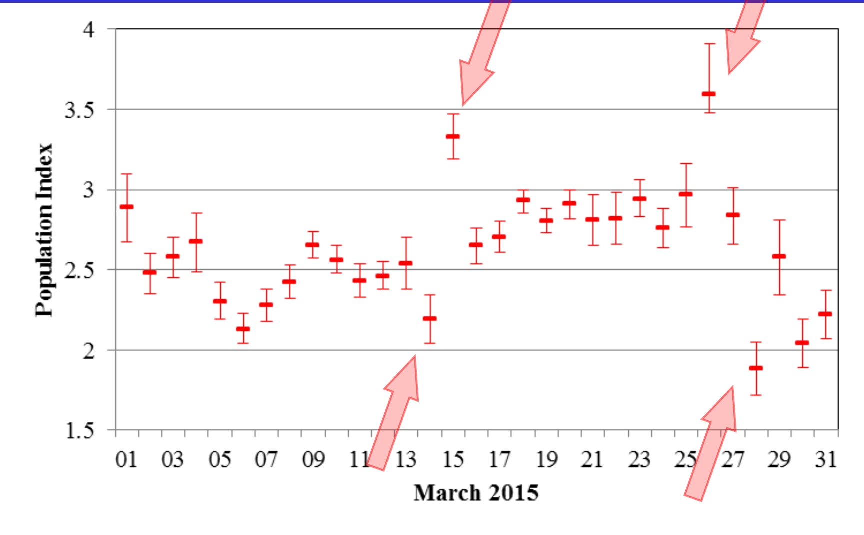
- Searching for the root cause in the algorithm and data …
  - Shortcomings of the algorithm like number of lm classes, inaccurate lm under poor conditions: testing with different number of classes, fixing the lm boundaries, introducing a lower lm limit → no impact.
  - Impact of individual cameras: leaving-one-out analysis, taking only cameras active in all nights → no impact.
  - Quality of data set (too small, poor observing conditions) → not the case.
- … or looking for independent confirmation for the outliers?
  - Comparing the profiles for shower and sporadic meteors → sometimes correlation, but not always.
  - Comparing with other observations → no visual results available.
  - Analyzing the same video data set in a different way→ let's try!

Analysis (II)

- Traditionally the population index is estimated from meteor magnitudes.
  - Large errors in the determination of individual meteor magnitudes (based on the pixel sum in noisy video frames, impacted by bright stars nearby, no correction for stellar lm in case of clouds/haze).
  - What to compare with if the true r-profile is unknown (no reference results)?

→ Taking the sporadic meteors from March, where r should be roughly constant and unbiased from meteor showers.

→ It also contains outliers.



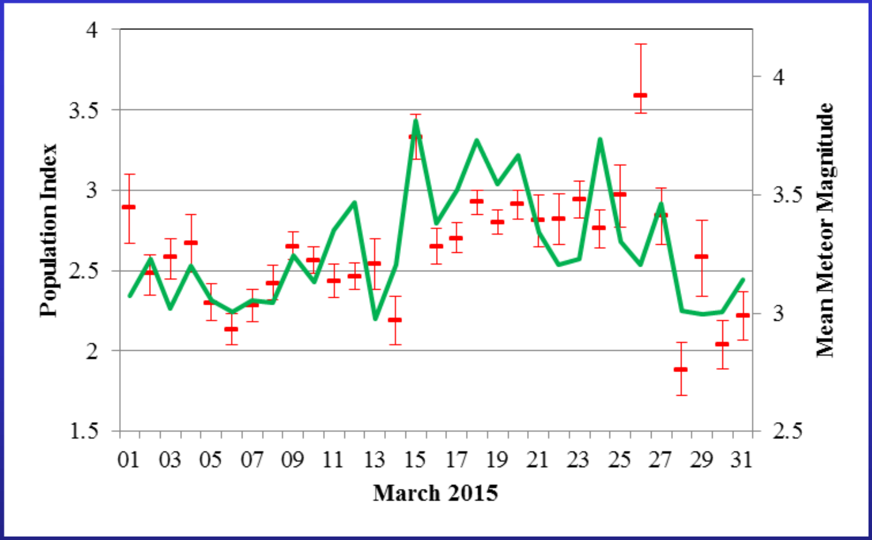
Population index of sporadic meteors March 2015

Analysis (III)

- Step 1: Comparison with the mean sporadic meteor magnitude.
  - Very rough measure (as if we would compute a visual ZHR without lm correction) with the advantage, that is does not depend on the calculation of lm or the effective collection areas.
  - Secondary y-axis scaled such that mean and variance of both graphs are the same.

→ Remarkably good agreement with correlation factors between 0.5 to 0.7 for different spring months.

→ Same overall shape, some outliers disappeared.



Population index vs. mean sporadic meteor magnitude.

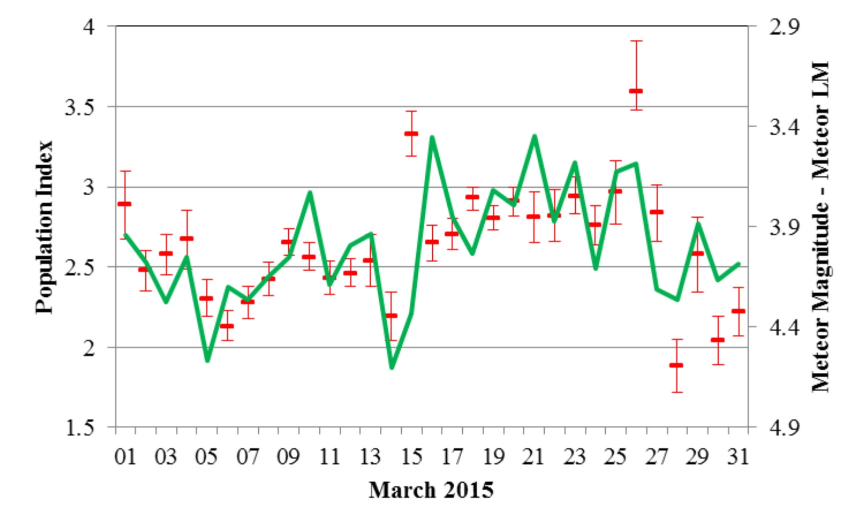
Analysis (IV)

- Step 2: Comparison with the mean difference between sporadic meteor brightness and meteor limiting magnitude.
  - Similar to the visual procedure where the mean difference between meteor magnitude and lm is taken.
  - Incorporates lm calculation.

→ Seem to adapt slightly better to the profile, but correlation coefficient is about the same.

→ Significant deviation to first step for some outliers.

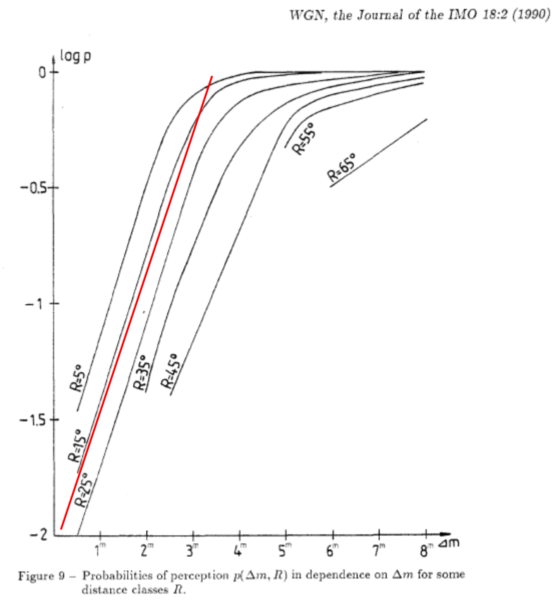
→ Open point is still the scaling, i.e. the transformation to r values.



Population index vs. meteor brightness difference from lm.

Analysis (V)

- Step 3a: Transformation of mean difference between meteor brightness and lm (Δm) into the population index r.
  - Transformation depends on the detection probability of meteors.
  - For visual observations, the probability depends on the distance from the center of fov and Δm (as obtained from double-count observations).
  - For video observations, only Δm is relevant.
  - Assumption: Same linear dependency between log probability and Δm as for visual observers without cutoff (red line).



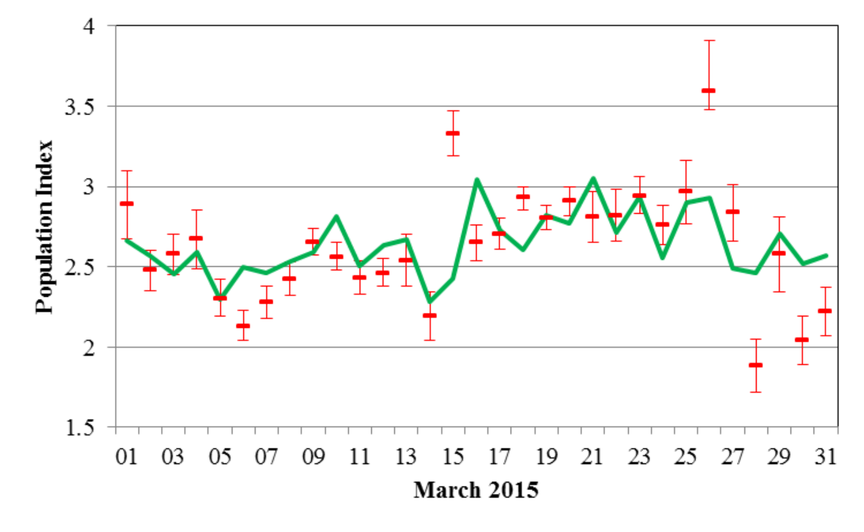
Detection probability of meteors for visual observers.

Analysis (VI)

- Step 3b: Applying the transformation function.
  - Transformation for visual observation has the simplified functional form $r = a * \Delta m^{b}$. Since b is close to -1, it can be simplified to $r = a / \Delta\text{m}$.
  - Varying parameters a and b for video observations to minimize the mean squared error yields that b is close to -1 as well:

→ $r = a / \Delta\text{m}$ with a = 10.5.

→ Double-check with April data: reasonable match for sporadic meteors, but very poor match for Lyrids, so it seems the approach cannot be generalized.



Population index based on transformation r=10.5/ Δm.

Analysis (VII)

- Conclusion.
  - Lm calculation is based on segmenting stars in the field of view and sensitive to the segmentation threshold and other factors.
  - Obstruction by clouds, extinction near the horizon, lunar glare are all "transformed" into a loss of lm which introduces systematic errors.
  - Limiting magnitude for meteors additionally depends on the lm loss by the angular motion of the meteor.
  - There is by definition no "sporadic radiant", hence no radiant altitude and no flux; the empirical approach used by MetRec (weighted sum of five sporadic sources) has never been revised.

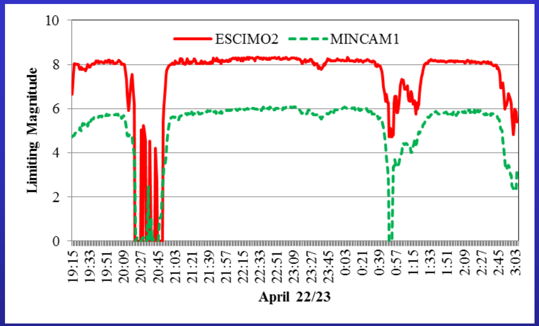
  → These potential errors sources make it difficult to identify the root cause for outliers in the complex algorithm.

Alternative Approach (I)

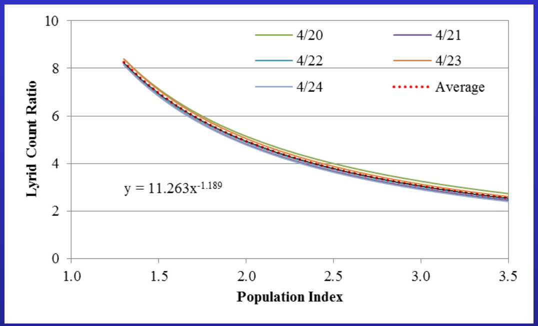
- Is there a method where these error sources cancel each other out?
  - Take two cameras with the same center of fov (hence same radiant distance, angular meteor velocity, lunar distance, extinction, cloud coverage, …) but a different lm.
  - The ratio of the effective collection area of both cameras (resp. the expected meteor count) depends only on the population index, as all the other factors are identical.
  - From the ratio of the meteor count, the population index can be directly derived (which is no surprise given the definition of r).

Alternative Approach (II)

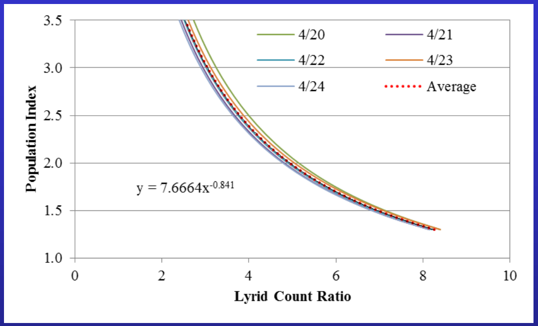
- Test setup for Lyrids 2015.
  - MINCAM1 (8mm f/0.8 lens, fov 43x32°, stellar lm 6 mag) and ESCIMO2 (25mm f/0.85 lens, fov 14x11°, stellar lm >8 mag) mounted in parallel.
  - Lm of both cameras shows a fixed offset and dependency of collection area ratio from r is constant for all nights (as expected).
  - Inverse function : $r = 7{,}66 * (n_{MINCAM1} / n_{ESCIMO2})^{-0{,}841}$



Lm profile of ESCIMO2 and MINCAM1 on April 22.



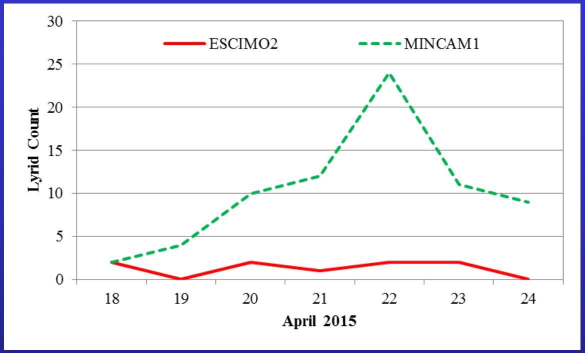
Dependency of the collection area ratio from r.



Dependency of r from the collection area ratio.

Alternative Approach (III)

- Test result.
  - Total failure because Lyrid count of ESCIMO2 remained constant between 0..2 in all nights.
  - Repetition during Perseids 2015 failed for technical reasons.
- Possible explanations.
  - Poor statistics (method is limited by the low meteor detection efficiency of ESCIMO2, which has a very small fov).
  - Breakdown of the population index concept, which assumes that the increase of meteors by the factor r remains constant over a given magnitude range (there seem to be no really faint Lyrids, so r is approaching 1.0 for fainter magnitudes).



Number of Lyrids recorded by ESCIMO2 and MINCAM1 in April 2015

Alternative Approach (IV)

- Further ideas.
  - The current setup still introduces uncertainties since only the center fov is the same, but not the size. So effects like radiant distance, meteor velocity (pixel/s), lunar distance, ... do not exactly cancel each other out.

  → Instead of using two lenses with the *same* f-stop but *different* focal lengths one could use two lenses with *different* f-stops but the *same* focal length.
  - Wouldn‘t it be a waste of equipment to point two cameras with the same fov at exactly the same point in the sky?
  - Could the same be achieve by a single camera, where an algorithm decides for each meteor, if it would have also been detected with a lower f-stop (i.e. simulating the second camera)? That would require no camera pairs and it could be done with every single camera.

Summary

- So far no better algorithm for the population index determination from video observations was found.
- The algorithms seems to be quite robust for different parameters.
- It seem to reflect the overall shape of the r profile quite well, but we should be cautious with short-term features (outliers).
- We should analyze how the algorithm behaves when the population index is not constant in the covered lm range.
- It would be helpful to have reference r-values from other observations.

Thanks for your Attention

Questions?