Current and future MicroFUN data reduction

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Outlines

• Current and future strategy for u-FUN data reduction
  – Current two step strategy using DoPhot and DIA pipeline for monitoring and light curve analysis
  – Future strategy using DIA pipeline for monitoring and light curve analysis

• Pipelines using image subtraction
  – Image subtraction using division of PSF in FFT space
  – Solving linear problem using LU decomposition in a sense of least square
  – Modified DIA pipeline for MicroFUN

• Examples
  – Results of DoPhot, ISIS and DIA
  – DoPhot vs. DIA of blended target
  – Examples of other observatory
Current and future strategy for MicroFUN data reduction
Current data reduction strategy for MicroFUN

Alert

Observation A

DoPhot

Light curve

More?

Dataset from A

DIA

Light curve

Analysis
MOA 2008 BLG 031 at CTIO

Observed image

MOA 2008 BLG 031

Subtracted image
Results from DoPhot and DIA
Current data reduction strategy for MicroFUN
Future data reduction strategy for MicroFUN

Alert → DIA → Observation A → Light curve → More? → Analysis
Image subtraction
Basic idea

PSF matching algorithm using FFT

Optimal image subtraction Using LU decomposition
Image subtraction using PSF matching

\[
Ker = \mathcal{F}^{-1} \left( \frac{\mathcal{F}(PSF_1)}{\mathcal{F}(PSF_2)} \right)
\]
Image subtraction based PSF matching algorithms

- **Number of implementations**

- It involves division in Fourier space
- Requires exactly same seeing for good result
- It has limited number of bright and uncrowded stars with sufficient high S/N ratio
- Difficult to handle
Optimal image subtraction

**Observations** - **Kernels** \(\otimes\) **Templates** + **Background**

\[
[A] = [L][U] \text{ Decomposition}
[A][X] = [B]
[A][X] = ([L][U])[X] = [L]([U][X]) = [B]
[L][Y] = [B]
[U][X] = [Y]
\]

\boxed{\text{Subtracted images}}
Optimal image subtraction

\[ Im(x, y) = Ker(x, y; u, v) \otimes \text{Ref}(u, v) + Bkg(x, y), \]
\[ m_i = C - 2.5 \log(f_0 + \Delta f_i). \]

- **Implementation in real image space**
- **ISIS by Alard**
  [http://www2.iap.fr/users/alard/package.html](http://www2.iap.fr/users/alard/package.html)
- **DIA by Wozniak**
- Approaches in the least square sense
- LU decomposition to solve Linear problem
- Spatial variability of local kernel coefficient to be a function of \(x, y\)
- The DIA code is well written and more convenient to read than ISIS
### DIA routines

<table>
<thead>
<tr>
<th>Routine</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cross</td>
<td>Calculate big shift of each image</td>
</tr>
<tr>
<td>Sfind</td>
<td>Find star</td>
</tr>
<tr>
<td>xymatch</td>
<td>Calculate shifts</td>
</tr>
<tr>
<td>Xygrid</td>
<td>Calculate coefficients for image transformation</td>
</tr>
<tr>
<td>Resample</td>
<td>Image transformation</td>
</tr>
<tr>
<td>Mstack</td>
<td>Stacking best seeing frames for reference image</td>
</tr>
<tr>
<td>Getpsf</td>
<td>Global PSF on REF (used in getvar and phot)</td>
</tr>
<tr>
<td>Aga</td>
<td>Do image subtraction</td>
</tr>
<tr>
<td>Getvar</td>
<td>Finds variable candidates</td>
</tr>
<tr>
<td>Phot</td>
<td>Photometry on the difference images</td>
</tr>
<tr>
<td>Do.pl</td>
<td>Photometry pipeline for u-FUN data reduction</td>
</tr>
</tbody>
</table>
MOA 2008 BLG 096

- Photometric observation at Mt. Lemmon
- Blue : DoPhot
- Red : DIA
- Green : ISIS
MOA 2008 BLG 031 at Bromberg Obs.
OGLE 2008 BLG 271 at WISE Obs.
Effect of seeing at WISE Obs.

OGLE 2008 BLG 271
Effect of different refraction

Fig. 5a

Fig. 5b

Fig. 5.—Effect of differential refraction on difference images. (a) Difference image without applying any correction for differential refraction effects. (b) Same image with our correction technique applied. The scale of the noise structures is much reduced, although not completely removed. The two images are 100' × 100'. The residual object in the center is due to a variable star.

Alcock et al. 1999
Data production

• Image and file size
  – Raw image: $20k \times 20k \times 2$ bytes = 840MB
  – Processing files: 5 times of raw images
    • $256 \times 256 \times 6400$ sub images (bitpix = 16)
    • Resampled images (bitpix = -32)
    • Subtracted images (bitpix = -32)

• Daily data acquisition and processing
  – Raw images: 200GB / day
    • 4 regions, every 10 minutes, for 10 hours (600 minutes)
      • $840MB \times 4$ fields $\times 60 = 200$ GB
  – Processing files: 1TB
  – A total of 1.2TB
Computing time and pipeline

• **Processing time**
  – On a Pentium IV processor
    • subimage of $256 \times 256$ : 0.8 secs
    • image of $20k \times 20k$ : $6400 \times 0.8 = 85$ min
  – For real time data reduction
    • $20k \times 20k$ image at every 2.5 minutes
    • At least 34 Linux PCs ($85 / 2.5 = 34$)

• **Data reduction pipeline**
  – Two systems for two sites
  – Hardware
    • Cluster PC: at least 34 ($85 / 2.5 = 34$)
    • Storage: 1.8PB ($1.2TB \times 300$ nights $\times 5$ years)
  – Software
    • Modified DIA pipeline
Making master templates

Best seeing Images → Image slice → Image stack → Master templates