2008 MicroFUN Workshop

Current and future MicroFUN data reduction

15–18 Dec 2008 @NZ

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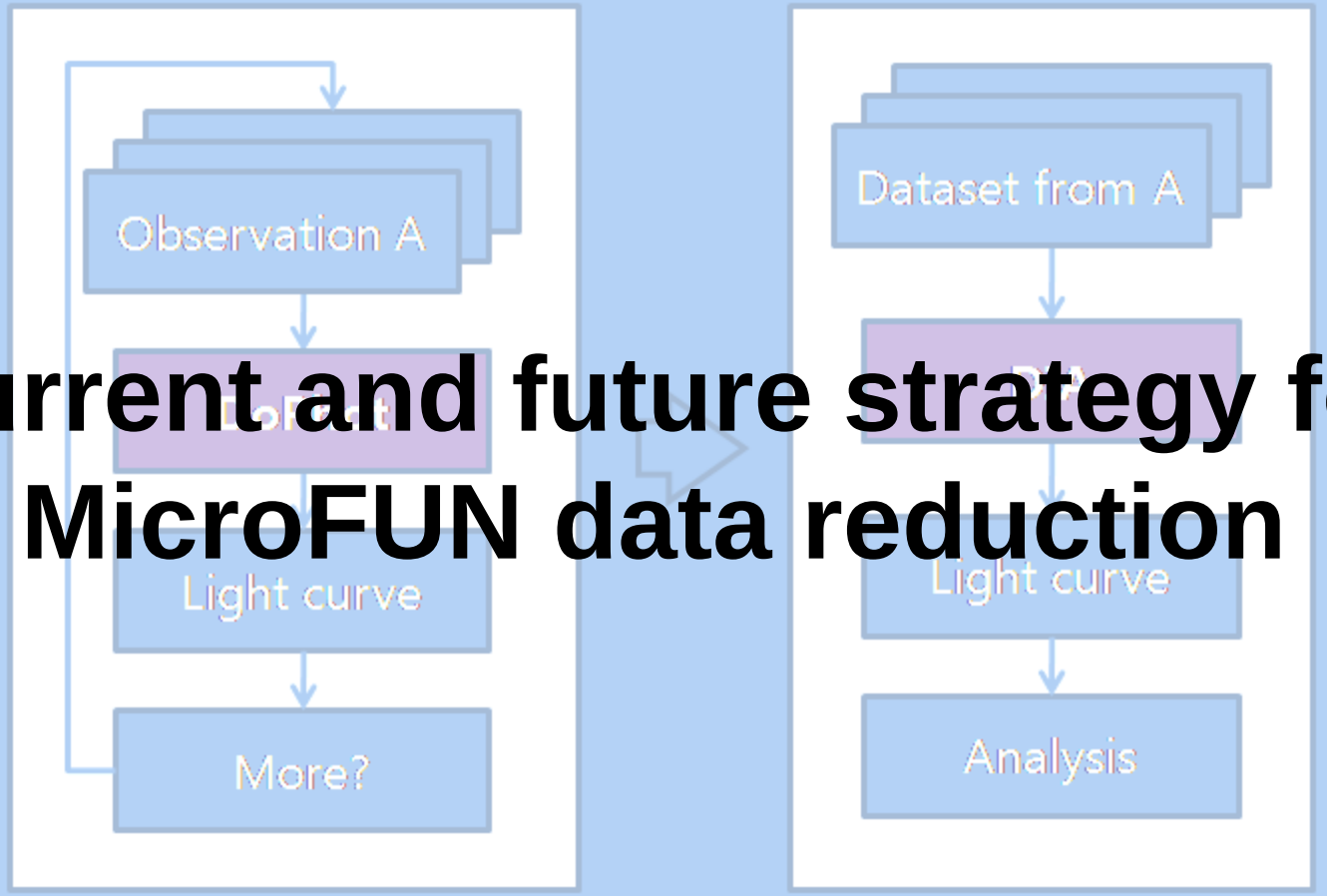
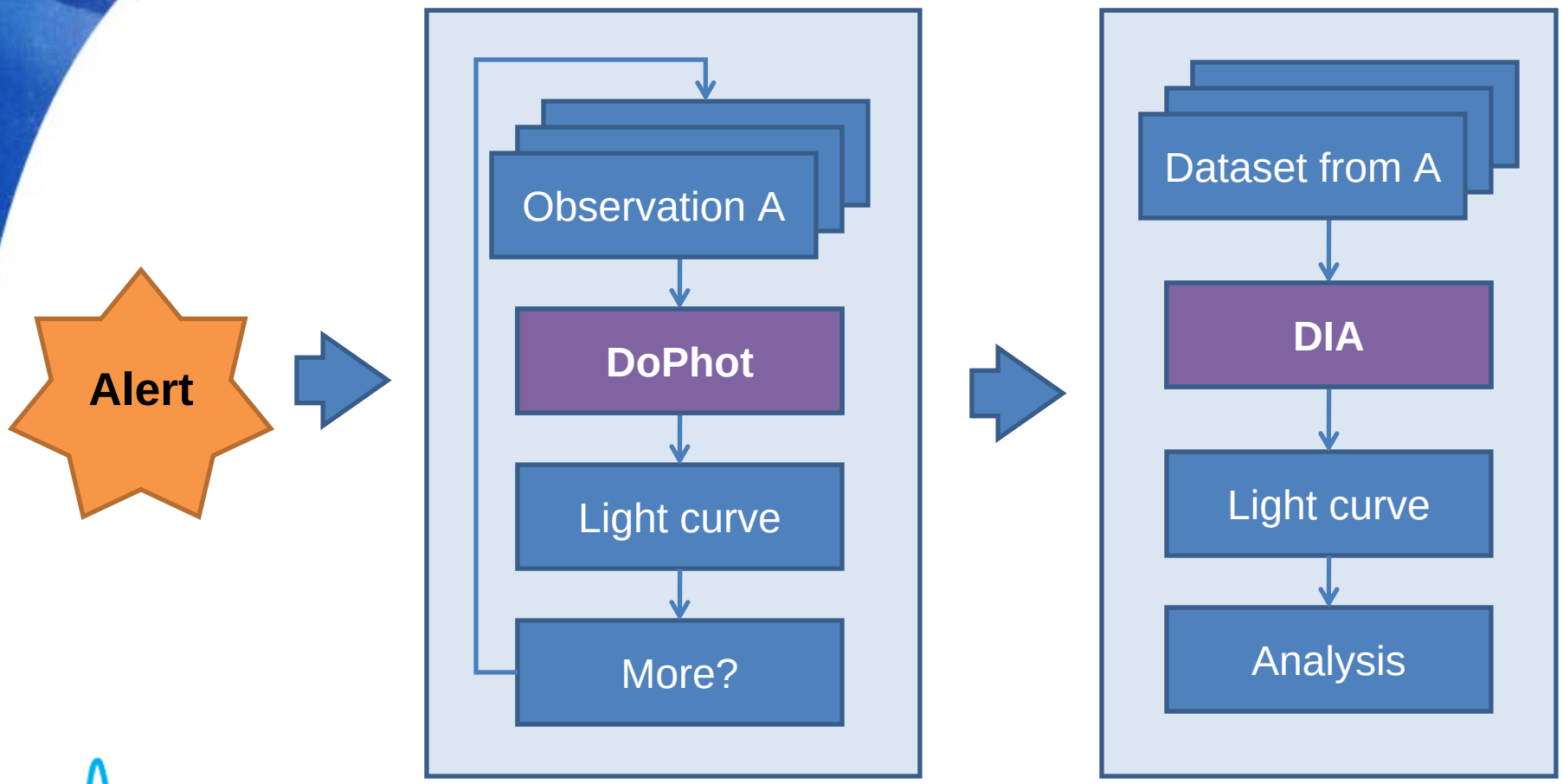
Outlines

- **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

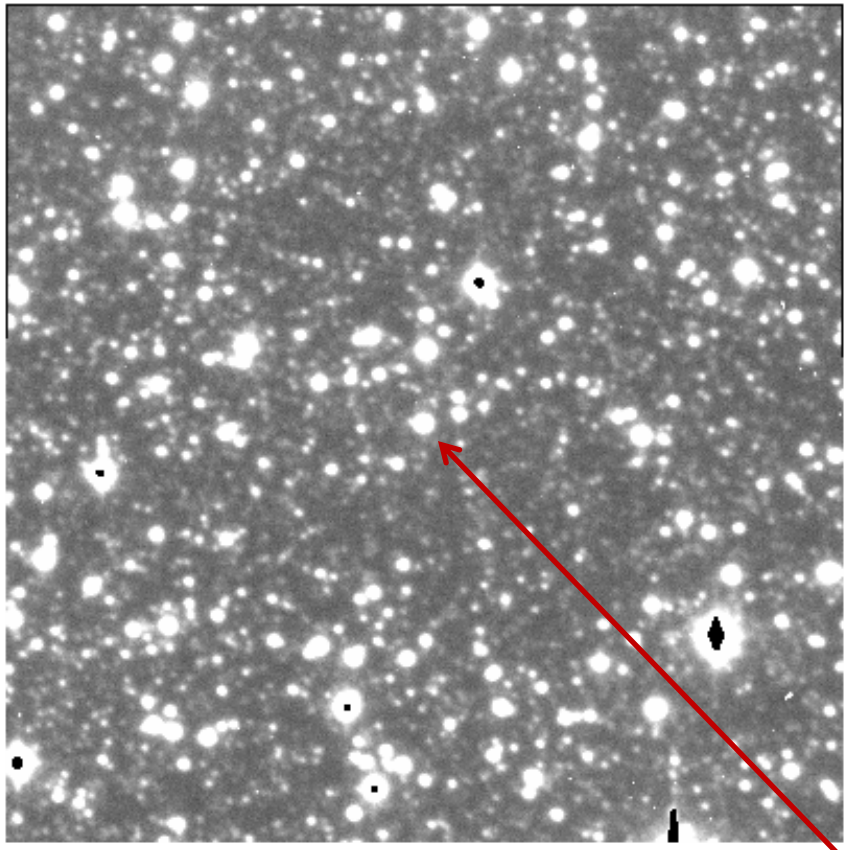
Current and future strategy for MicroFUN data reduction

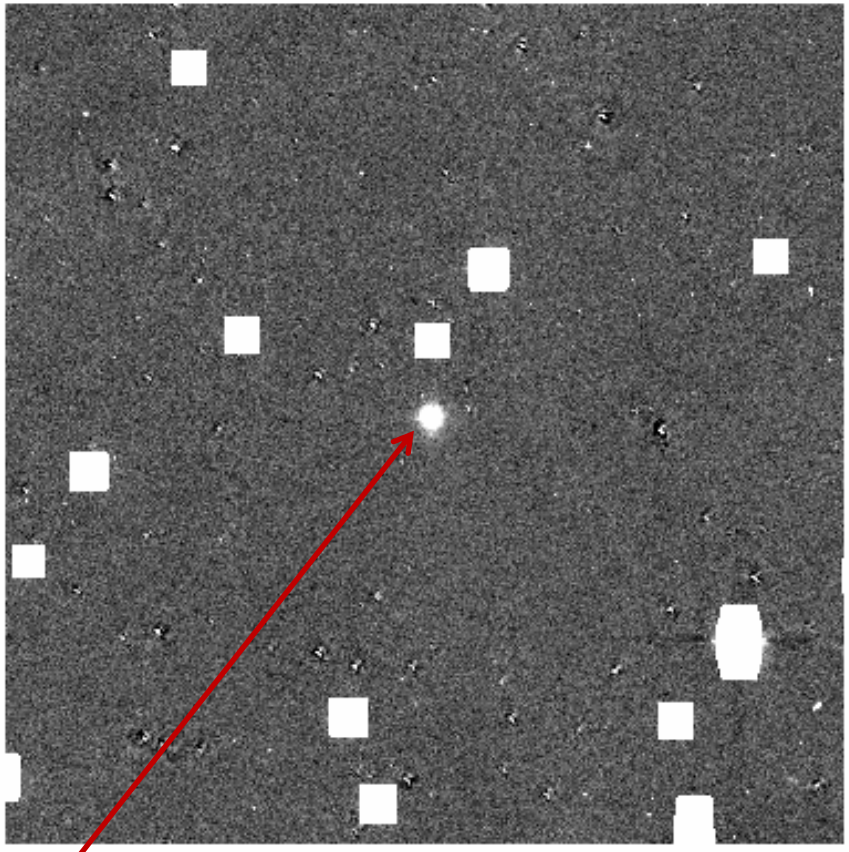


Current data reduction strategy for MicroFUN



MOA 2008 BLG 031 at CTIO





Observed image

Subtracted image

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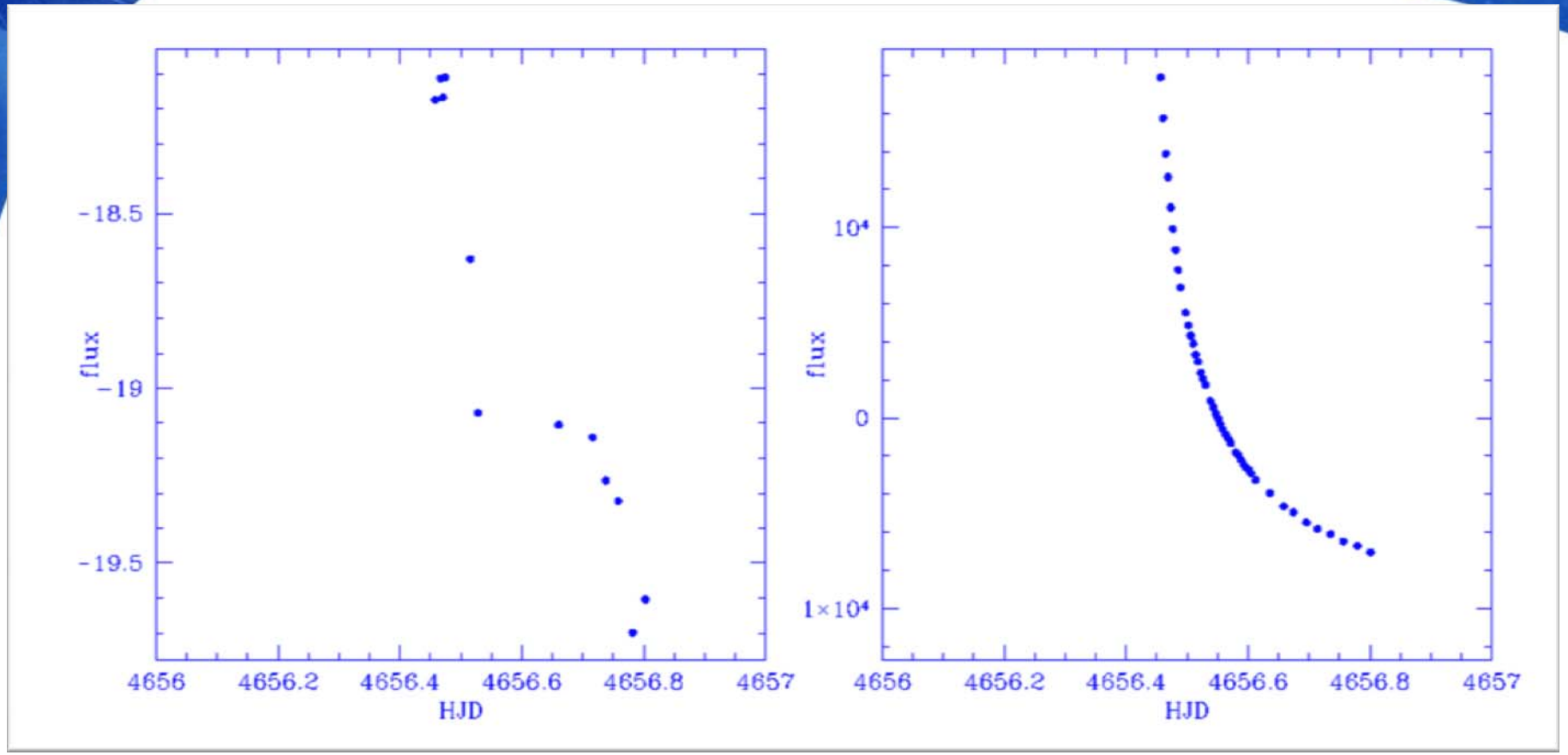
Results from DoPhot and DIA



Current data reduction strategy for MicroFUN

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CMB06105  COB06153  COB06215  COB06294  COB06414  COB06479  LOB06174  LOB06347
CMB06131  COB06154  COB06221  COB06297  COB06416  COB06491  LOB06177  LOB06357
CMB06132  COB
CMB06133  COB
CMB06137  COB
CMB06142  COB
CMB06145  COB
COB06023  COB
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COB06109  COB
COB06123  COB
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CMB07174  CMB0
CMB07176  CMB0
CMB07189  COB0
CMB07196  COB0
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CMB07321  COB0
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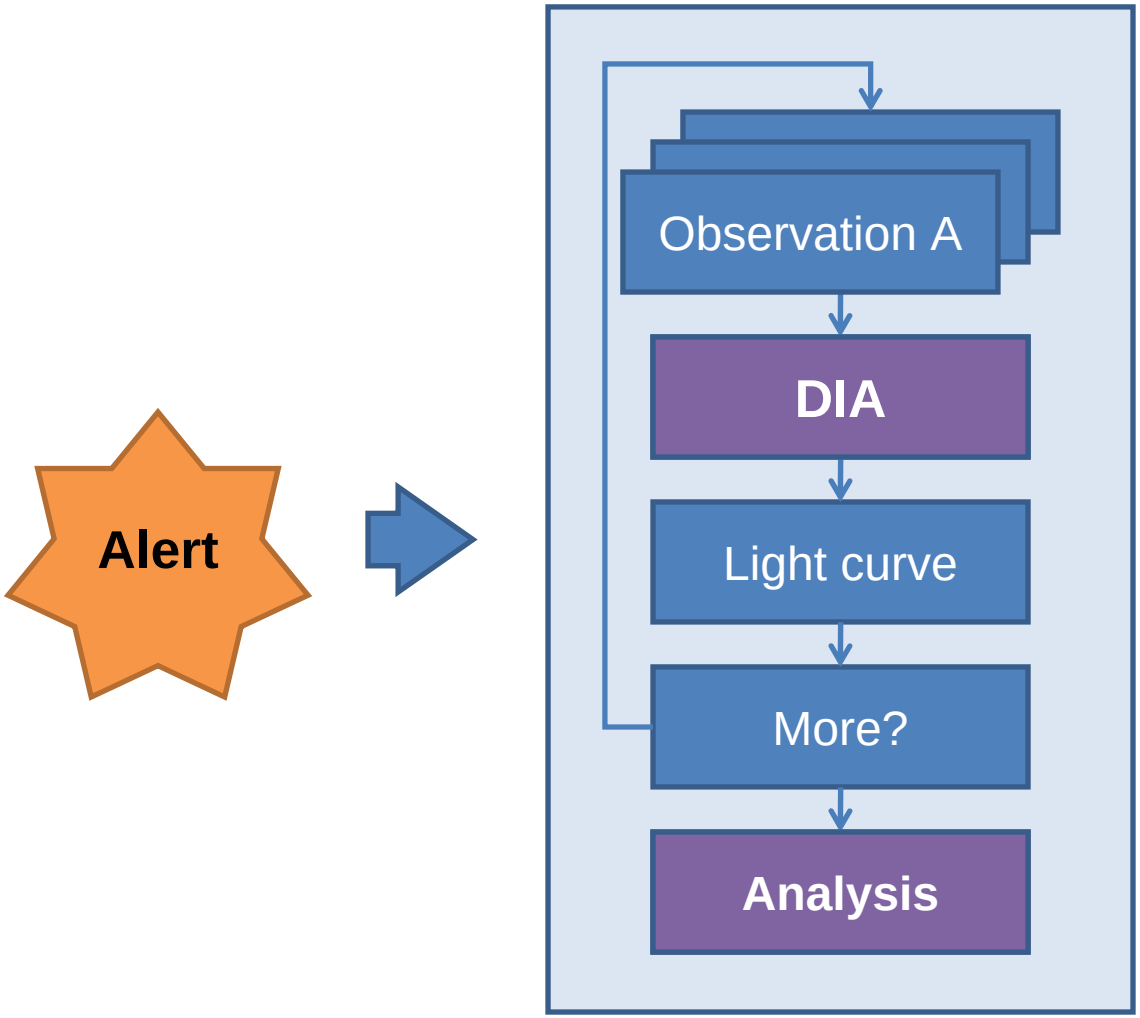
Future data reduction strategy for MicroFUN



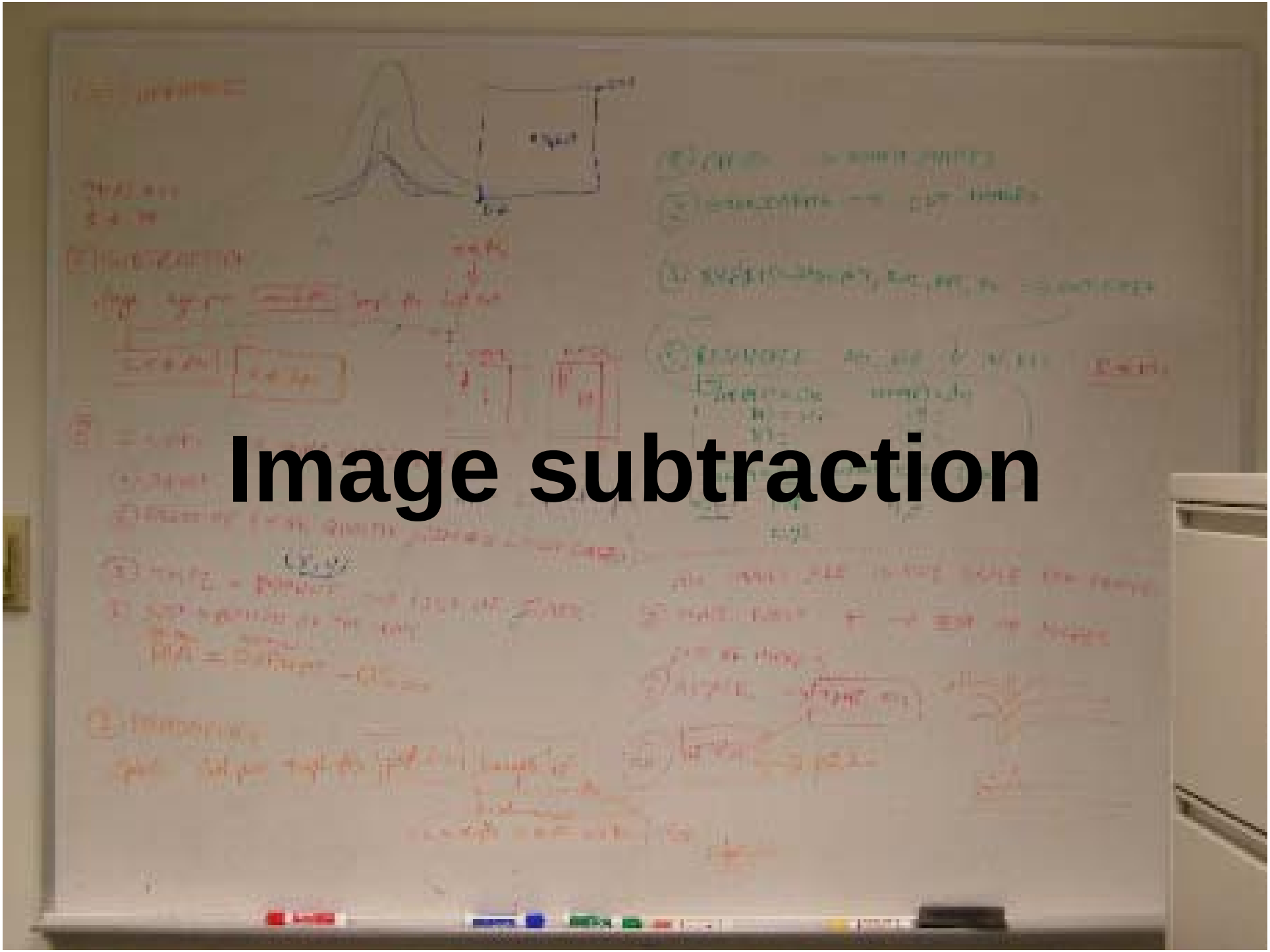
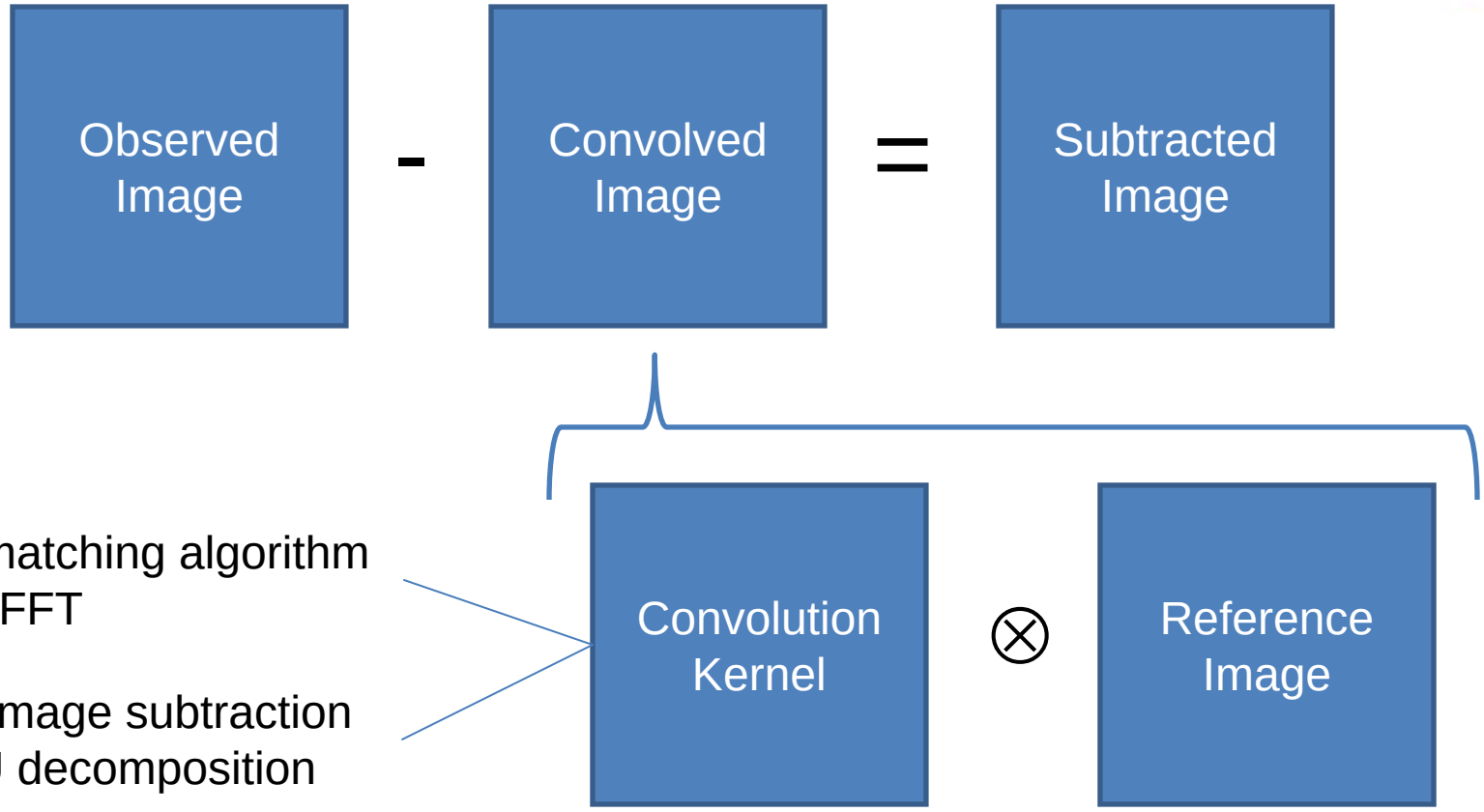


Image subtraction

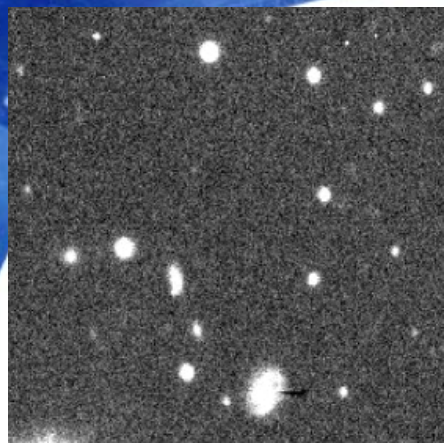
Basic idea



PSF matching algorithm using FFT

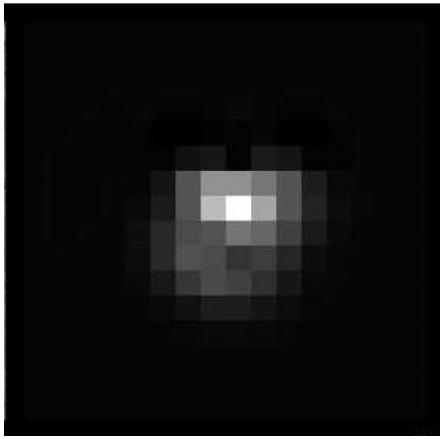
Optimal image subtraction Using LU decomposition

Image subtraction using PSF matching



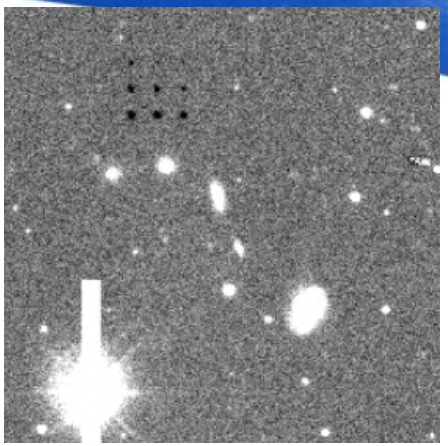
Observed image

-



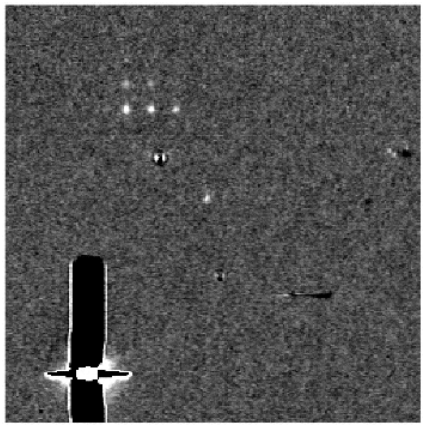
Kernel

⊗



Templates

=



Subtracted images

PSF Matching

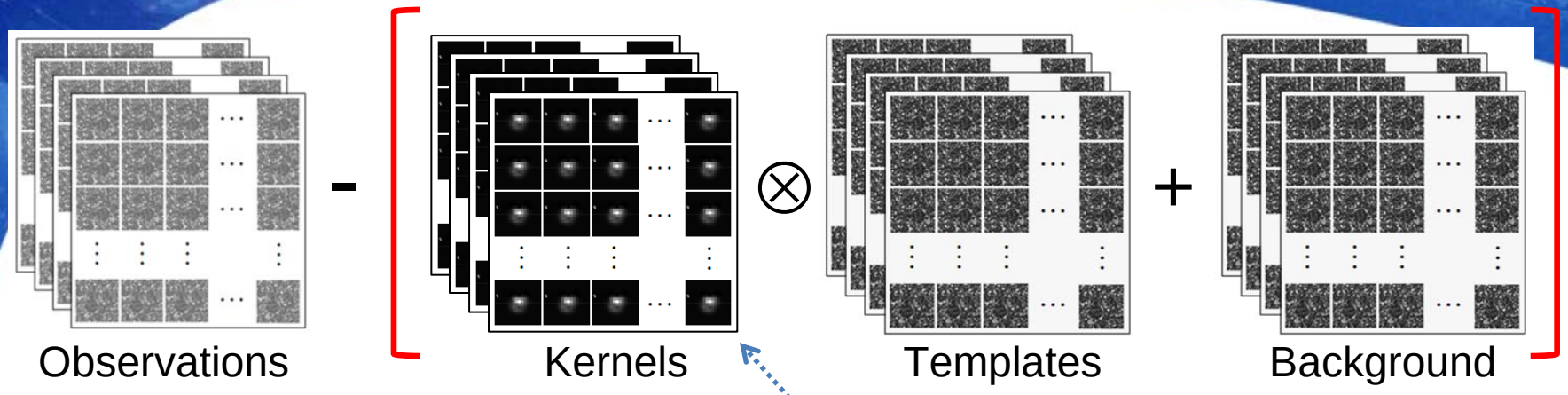
$$Ker = FFT^{-1}\left(\frac{FFT(PSF_1)}{FFT(PSF_2)}\right)$$

Image subtraction based PSF matching algorithms

- **Number of implementations**

  Crotts 1992, Phillips and Davis 1995, Tomaney and Crotts 1996, Riess et al. 1998, Alcock et al. 1999
- **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



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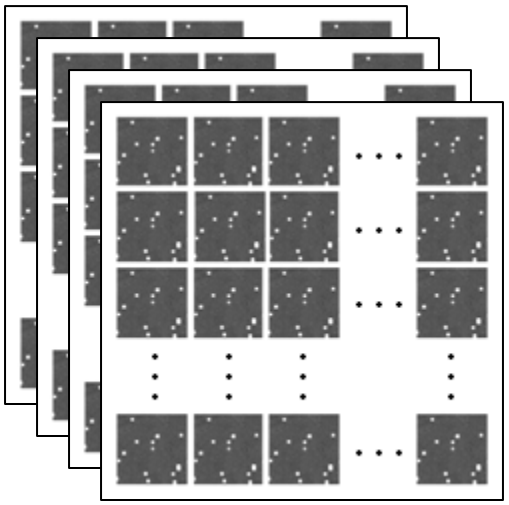


Subtracted images

LU decomposition *

[A]=[L][U] Decomposition
[A][X]=[B]
[A][X]=([L][U])[X]=[L]([U][X])=[B]
[L][Y]=[B]
[U][X]=[Y]

Optimal image subtraction

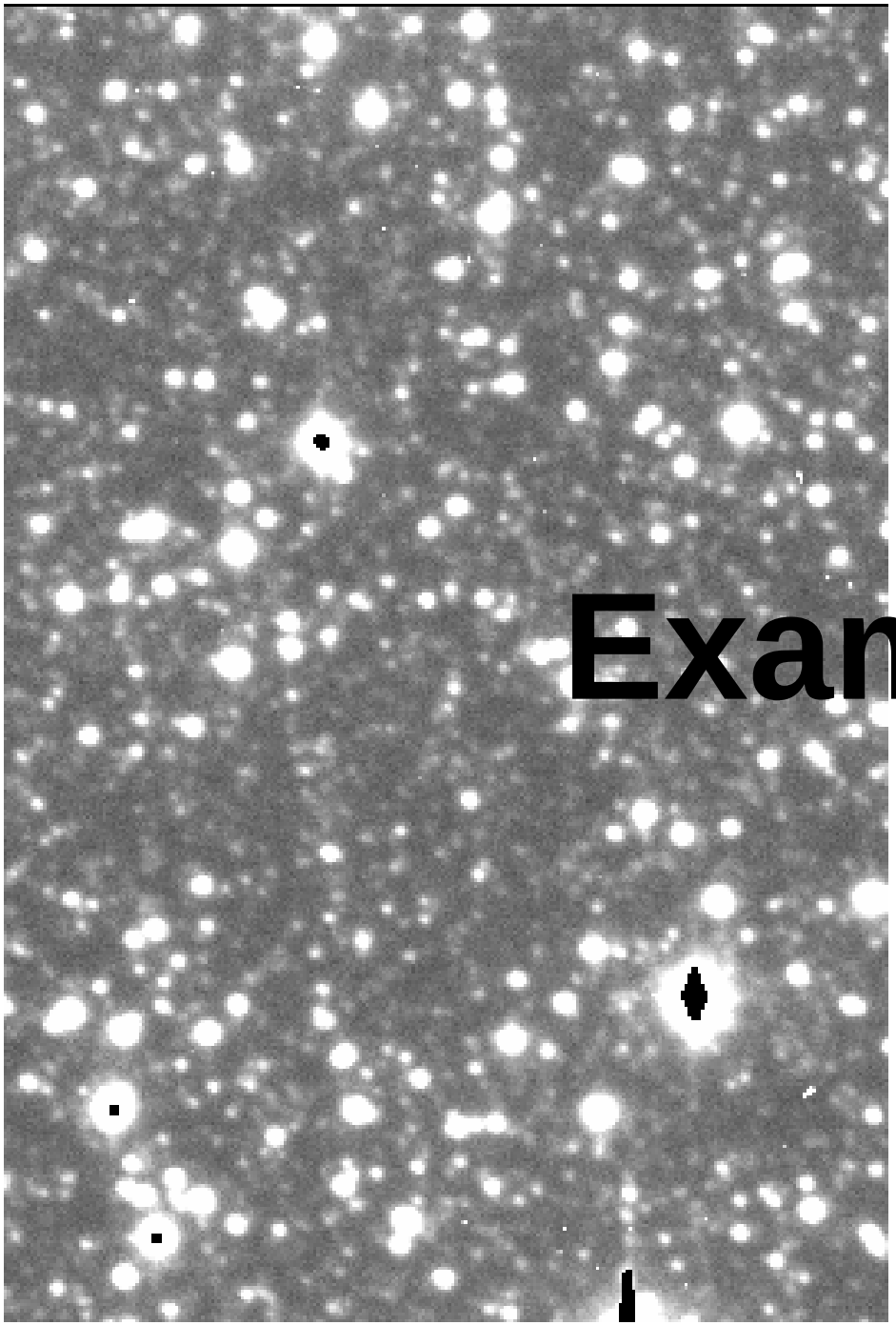
$$Im(x,y) = Ker(x,y;u,v) \otimes Ref(u,v) + Bkg(x,y),$$

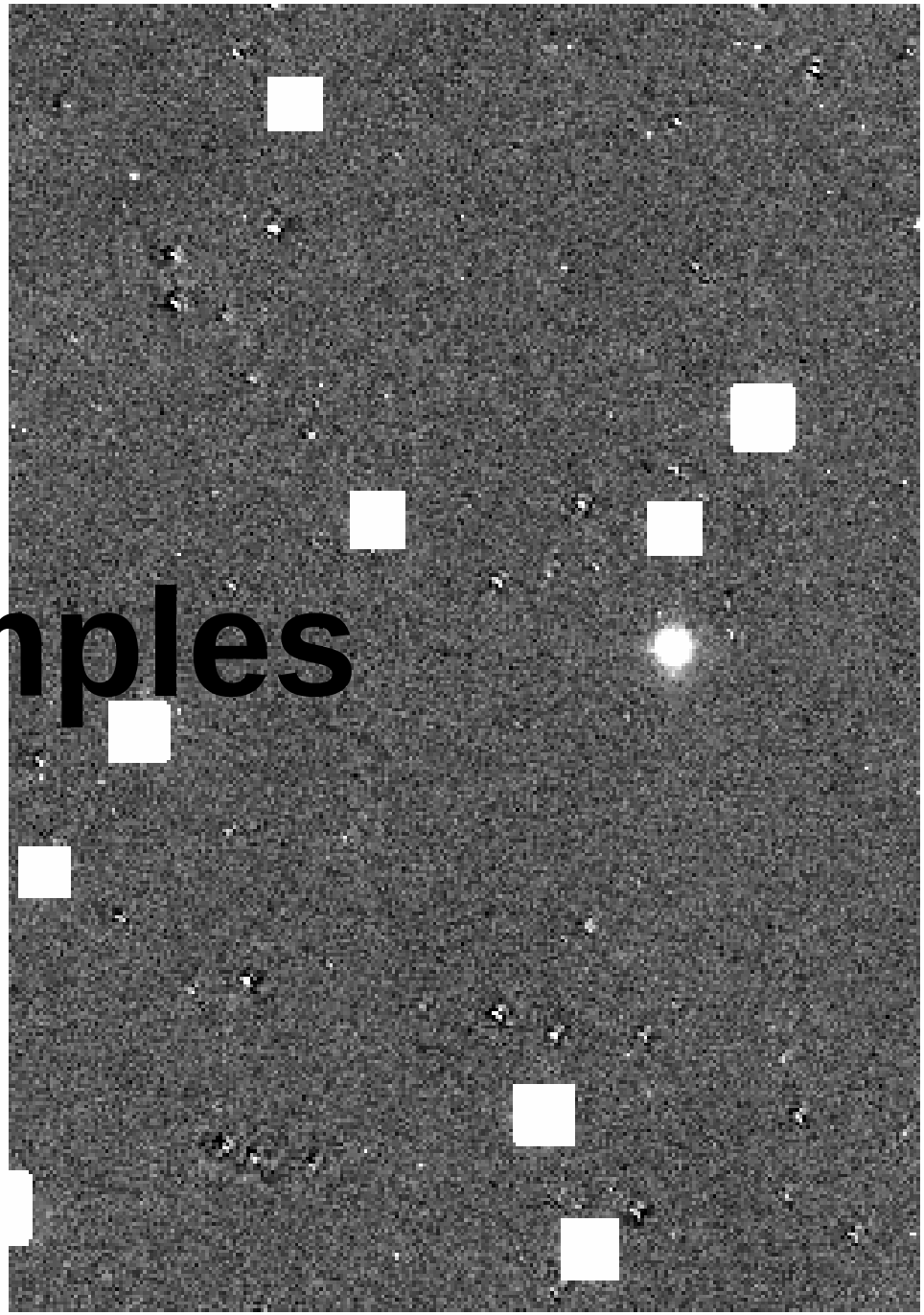
$$m_i = C - 2.5\log(f_0 + \Delta f_i).$$

- **Implementation in real image space**
  Alard and Lupton 1998, Alard 2000, Wozniak 2001
- **ISIS by Alard**
  http://www2.iap.fr/users/alard/package.html
- **DIA by Wozniak**
  http://www.astro.princeton.edu/~wozniak/dia/
- **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

Cross	Calcurate big shift of each image
Sfind	Find star
xymatch	Calcurate Shifts
Xygrid	Calcurate coefficients for image transformation
Resample	Image transformation
Mstack	Stacking best seeing frames for reference image
Getpsf	Global PSF on REF (used in getvar and phot)
Aga	Do image subtraction
Getvar	Finds variable candidates
Phot	photometry on the difference images
Do.pl	photomrtry pipeline for u-FUN data reduction





Examples

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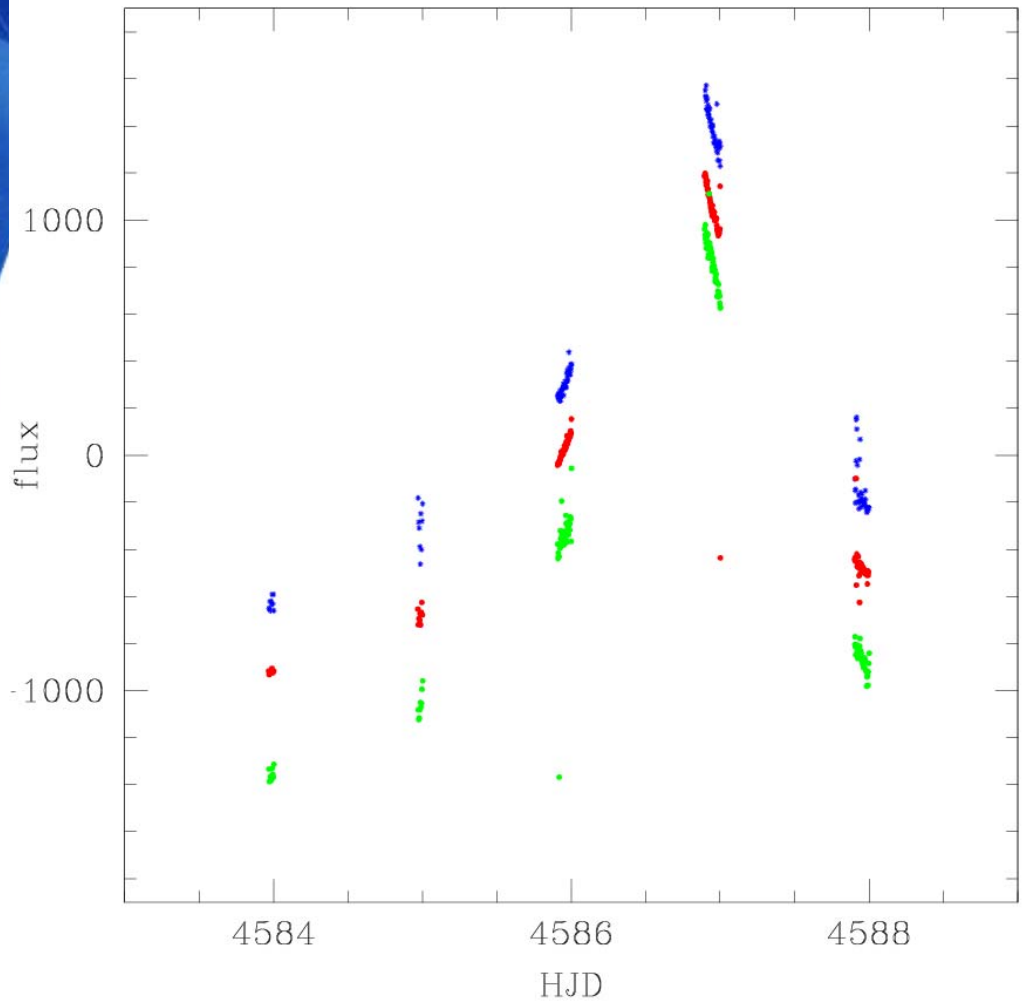
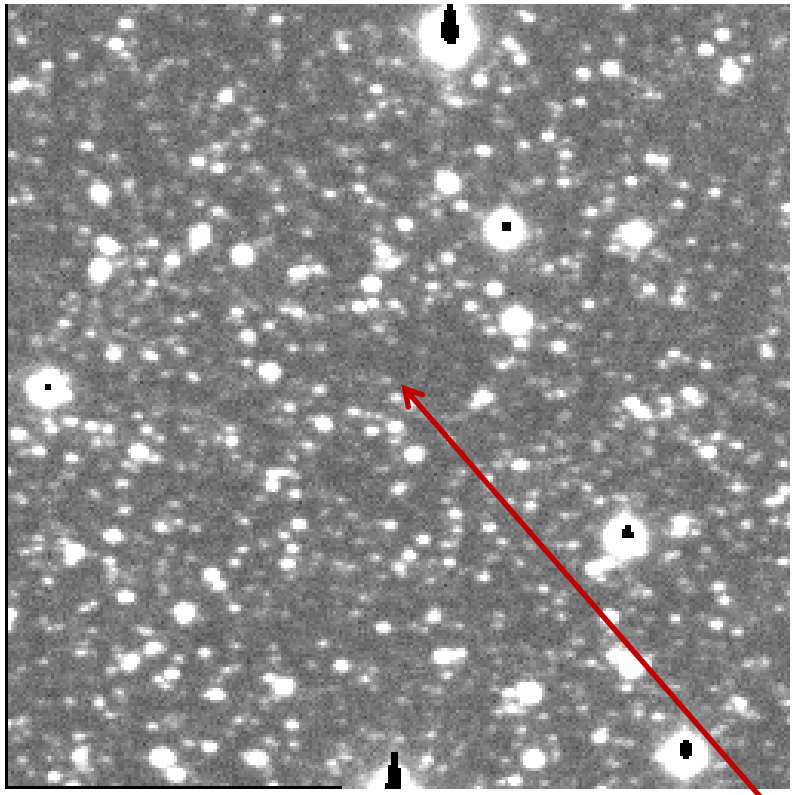
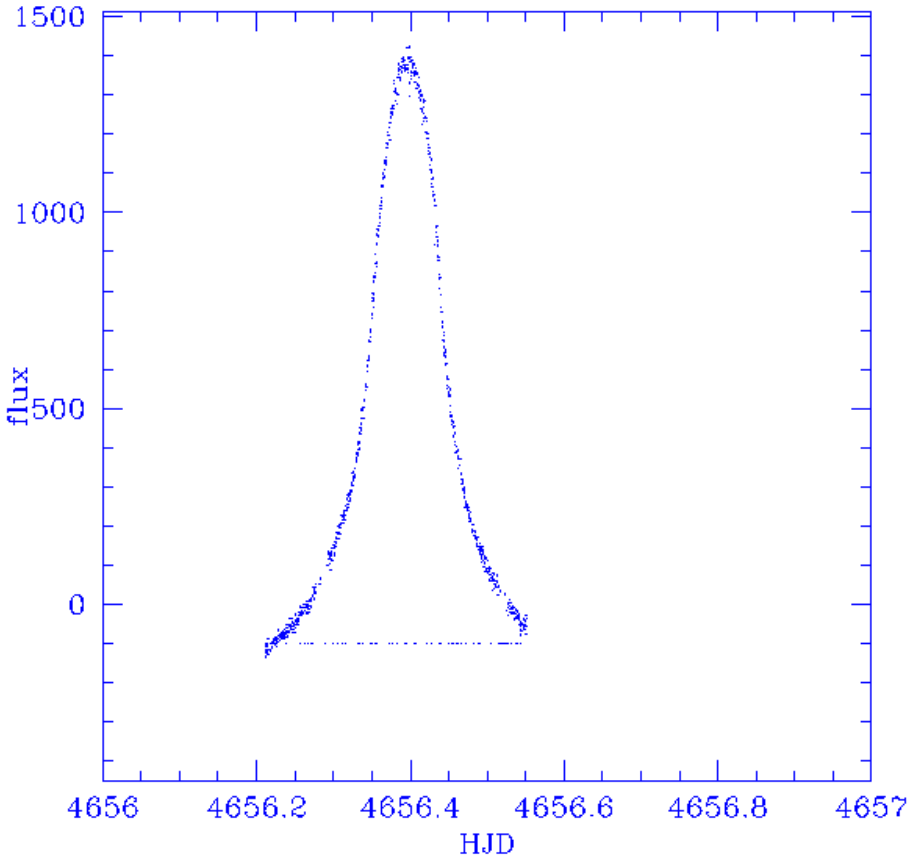


- Photometric observation at Mt. Lemmon

- Blue : DoPhot
- Red : DIA
- Green : ISIS

MOA 2008 BLG 031 at Bromberg Obs.





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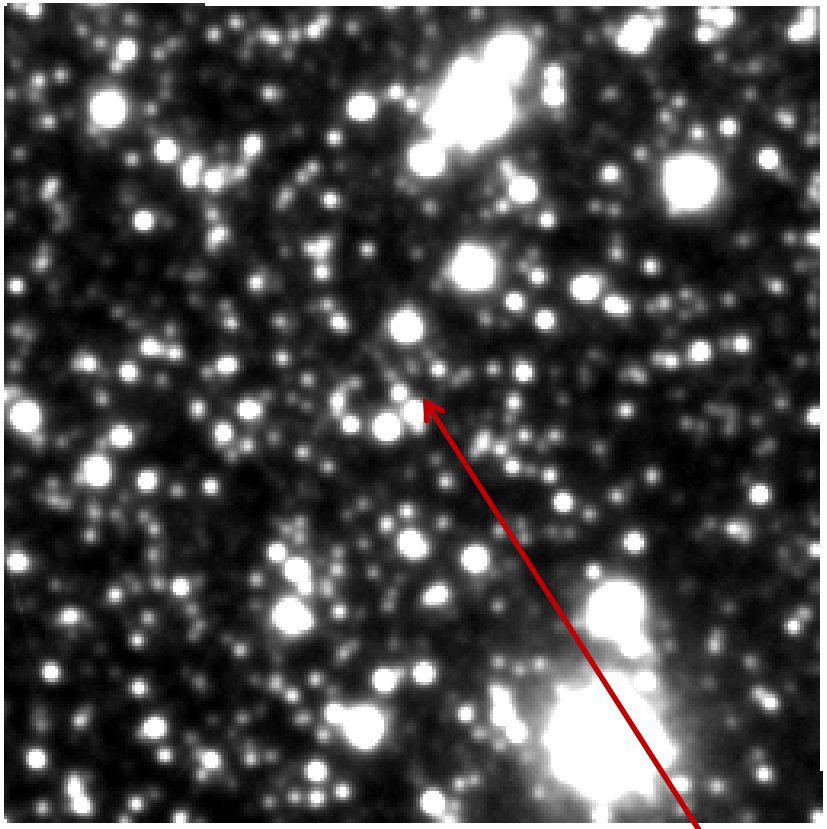
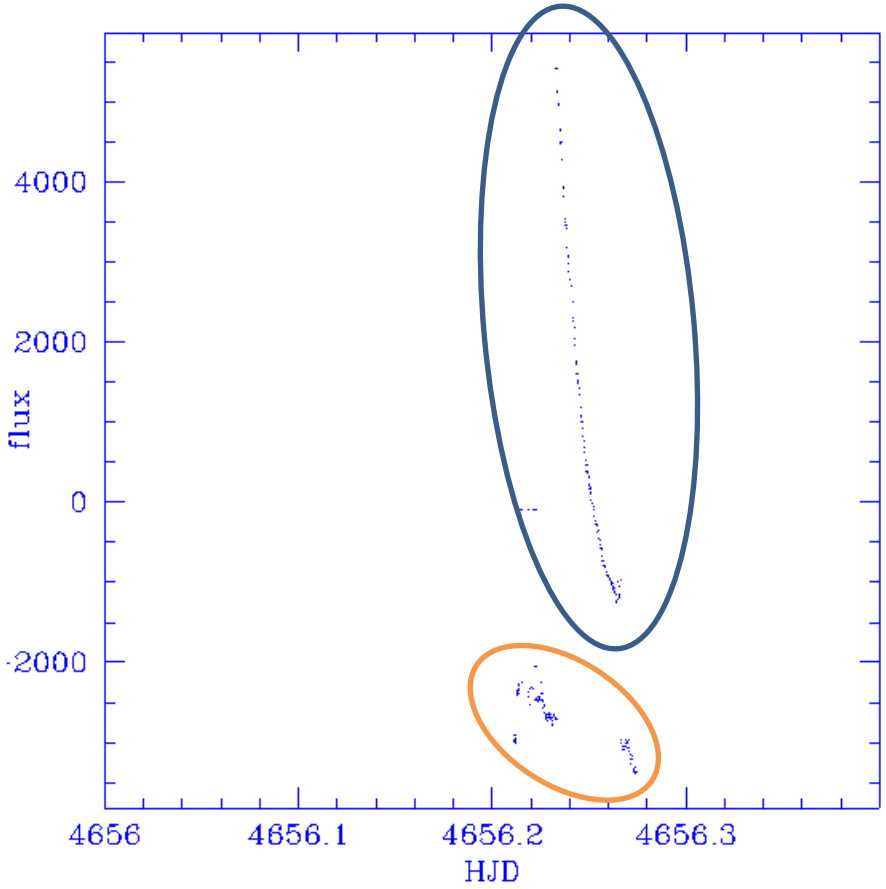
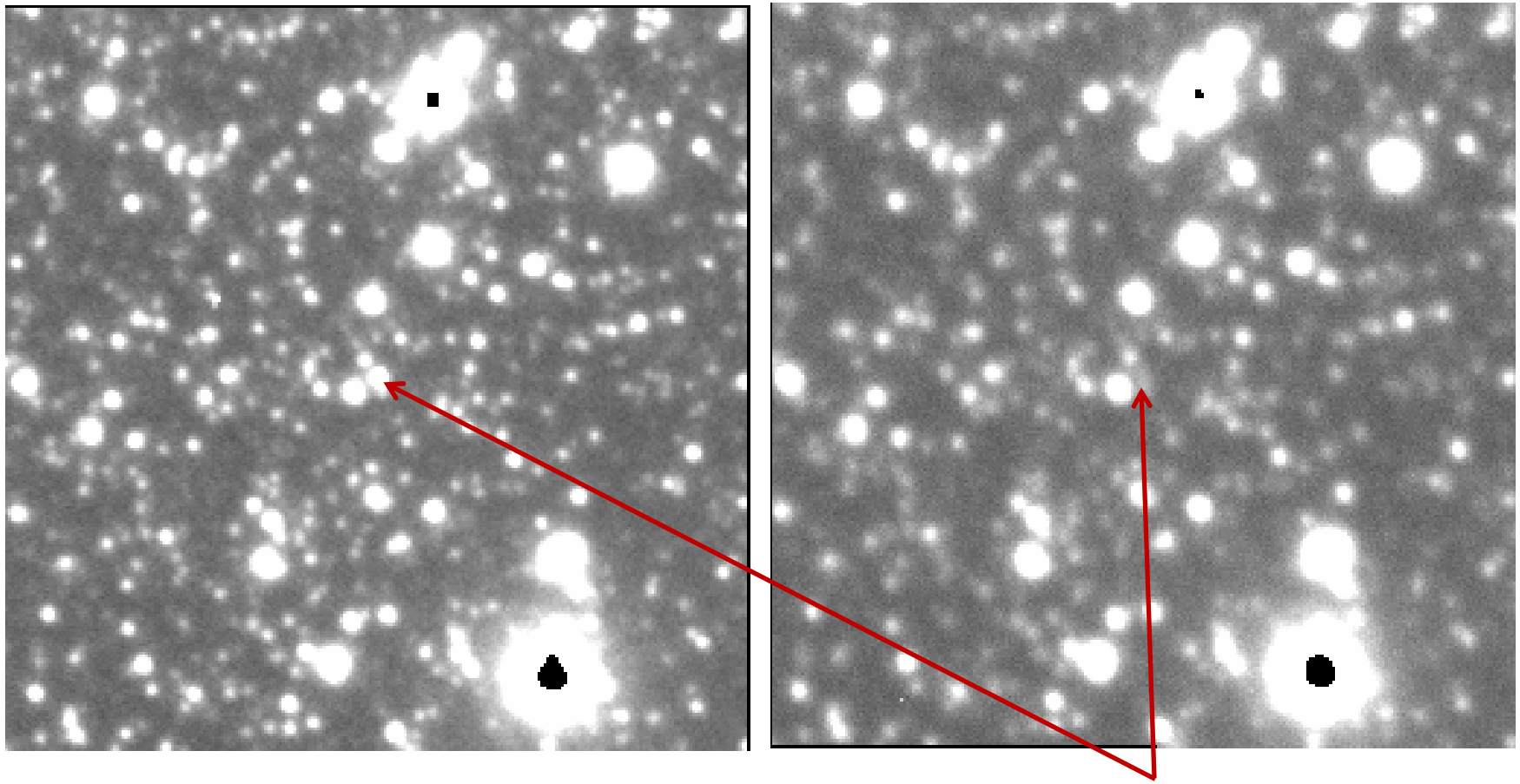
OGLE 2008 BLG 271 at WISE Obs.





OGLE 2008 BLG 271

Effect of seeing at WISE Obs.



OGLE 2008 BLG 271

Effect of different refraction

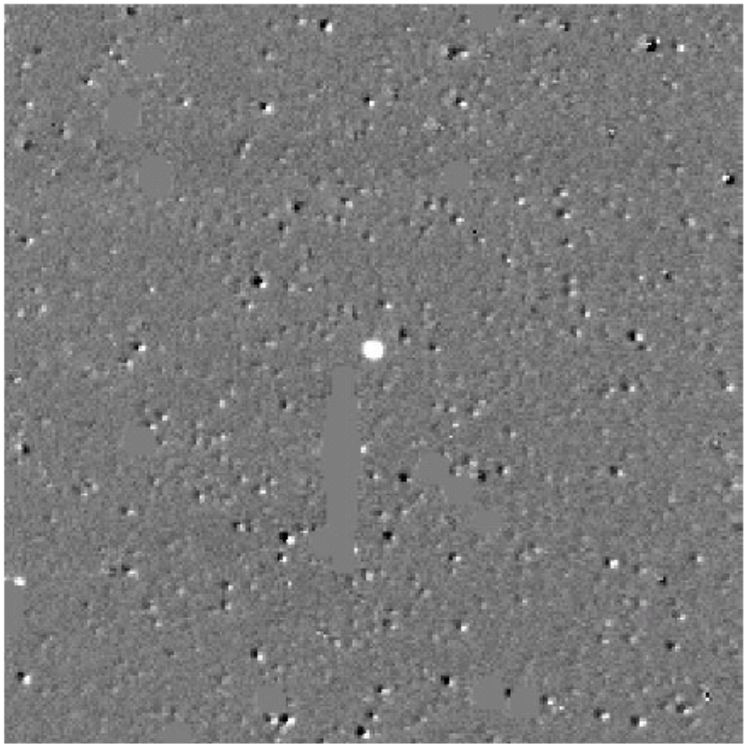


FIG. 5*a*

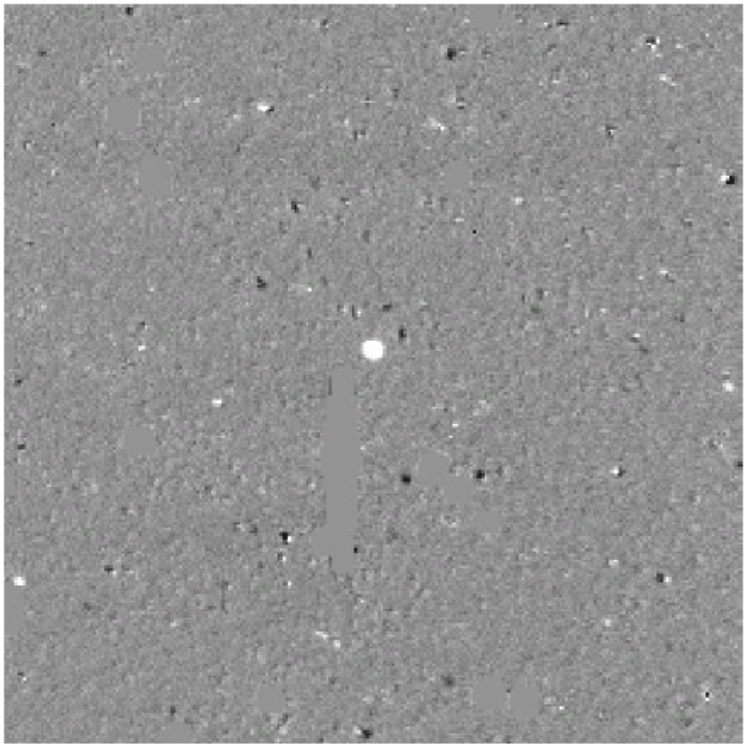


FIG. 5*b*

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 × 20k × 2bytes = 840MB
  - Processing files : 5 times of raw images
    - 256 × 256 × 6400 sub images (bitpix = 16)
    - Resampled images (bitpix = -32)
    - Subtracted images (bitpix = -32)

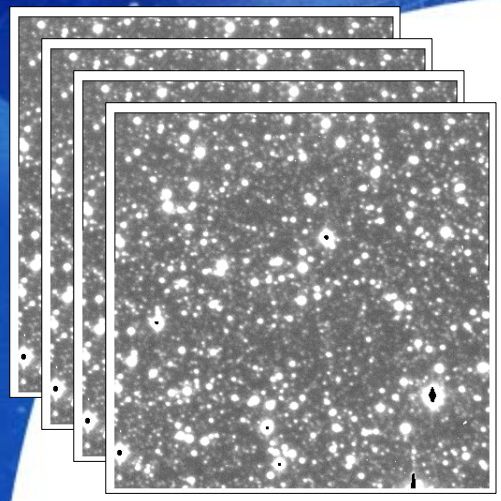
- **Daily data acquisition and processing**
  - Raw images : 200GB / day
    - 4 regions, every 10 minutes, for 10 hours (600 minutes)
    - 840MB × 4fields × 60 = 200GB
  - Processing files : 1TB
  - A total of 1.2TB

Computing time and pipeline

- **Processing time**
  - On a Pentium IV processor
    - subimage of 256 × 256 : 0.8secs
    - image of 20k × 20k : 6400 × 0.8 = 85min
  - For real time data reduction
    - 20k × 20k image at every 2.5minutes
    - 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 × 300nights × 5years)
  - Software
    - Modified DIA pipeline

Making master templates



Best seeing Images

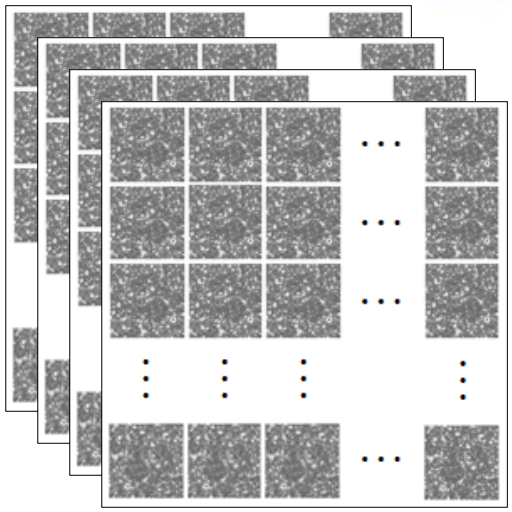


Image slice

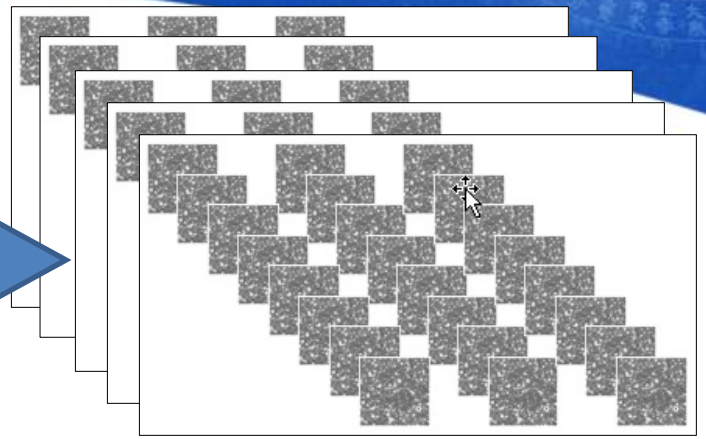
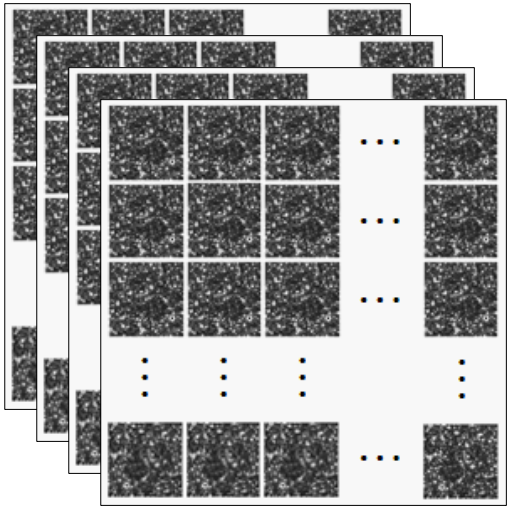


Image stack



Master templates