Streaming Multiframe Deconvolution on GPUs
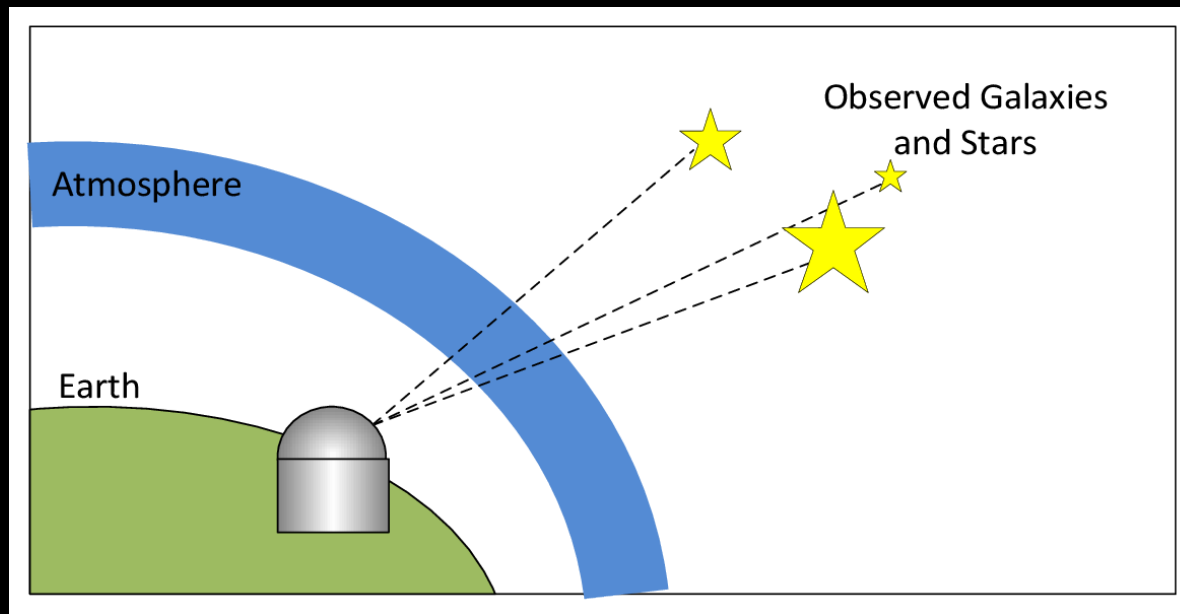
Matthias A. Lee & Tamás Budavári
Johns Hopkins University
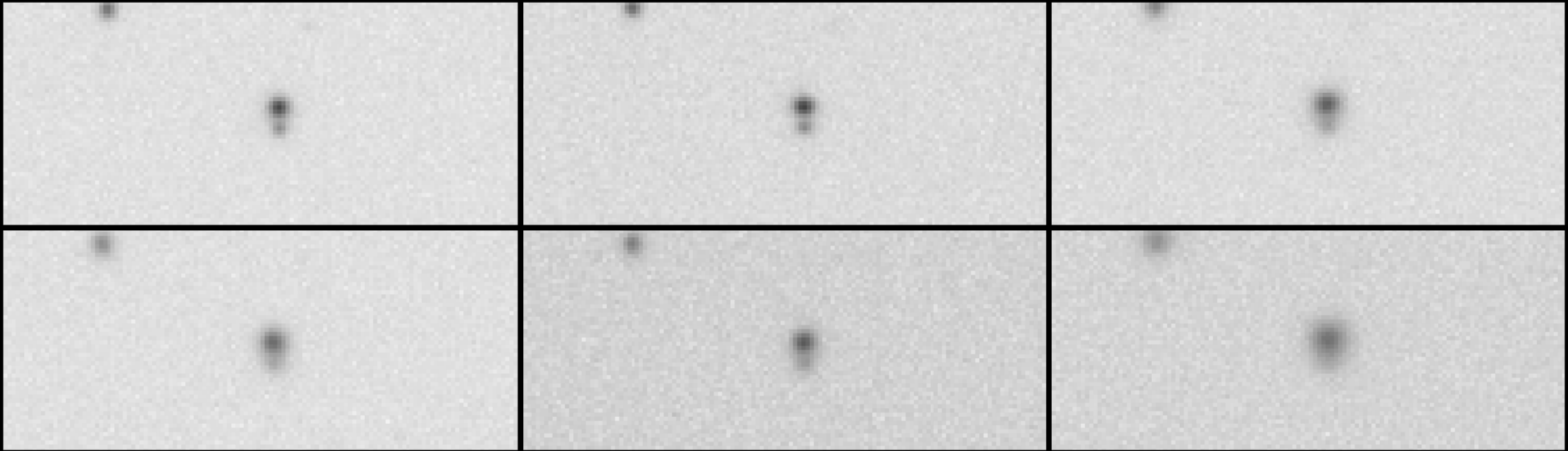
Variable Point Spread Function

- Atmospheric turbulence introduces blur

- Unpredictable & constantly changing
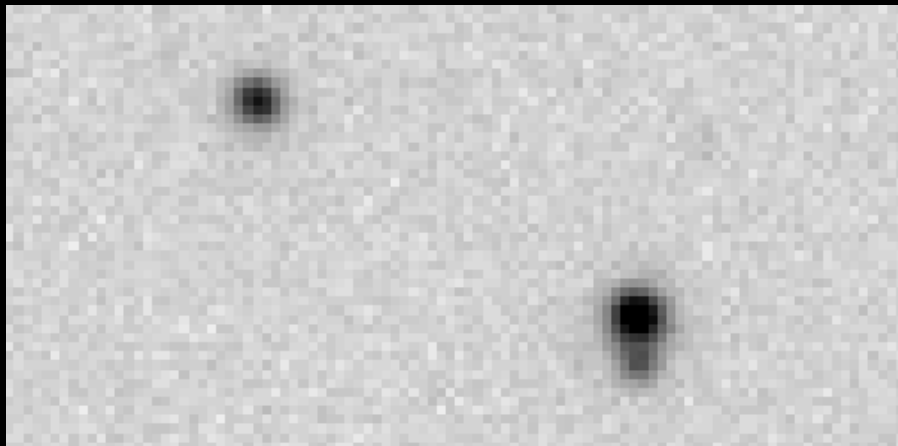
- Hard to measure and remove PSF

SDSS Stripe 82

- Stripe 82 – multi-epoch survey
  - approx 270 deg^2
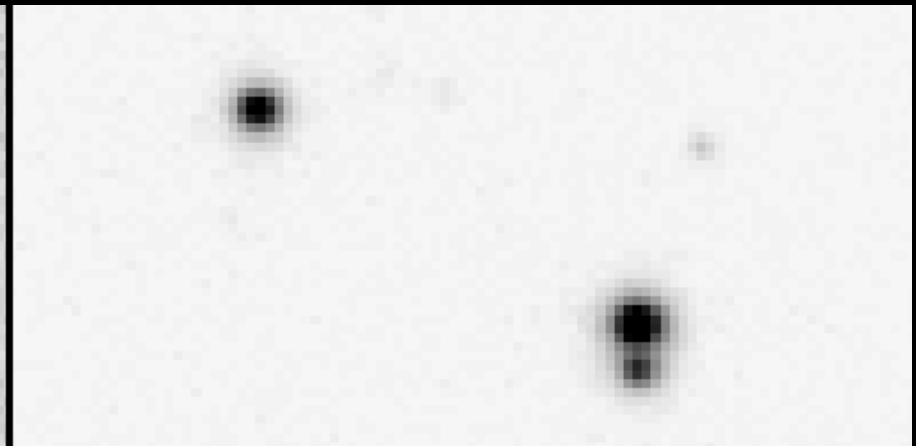 - ~80x coverage over 7 years

State of the Art

- Lucky imaging: keep best ~2% images only

- Co-adding multiple images w/ PSF matching
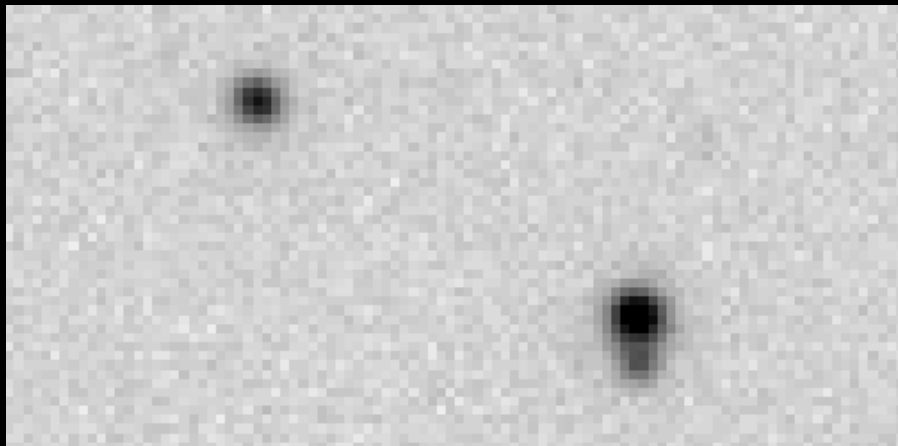
  - Increases signal to noise but blurry

Single sample frame

Official Stripe 82 Co-Add

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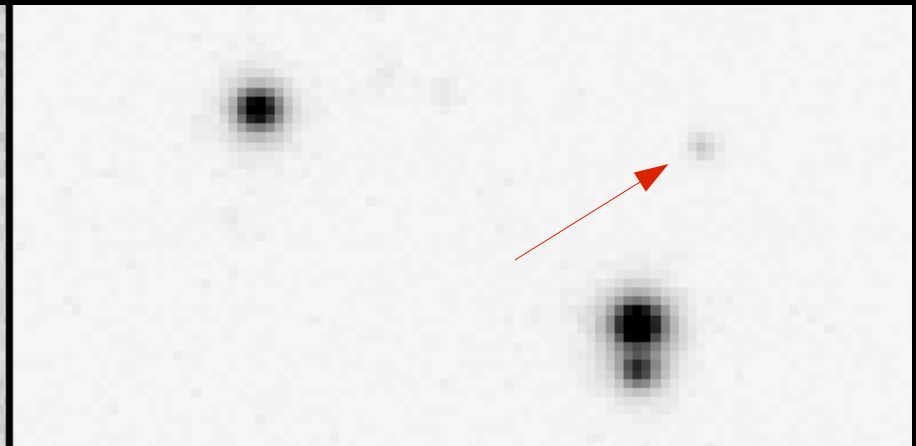
Single sample frame   Official Stripe 82 Co-Add

Our Approach

- Solve for the underlying "true" image
  - Multiframe Blind deconvolution
  - GPU acceleration
  - Streaming implementation
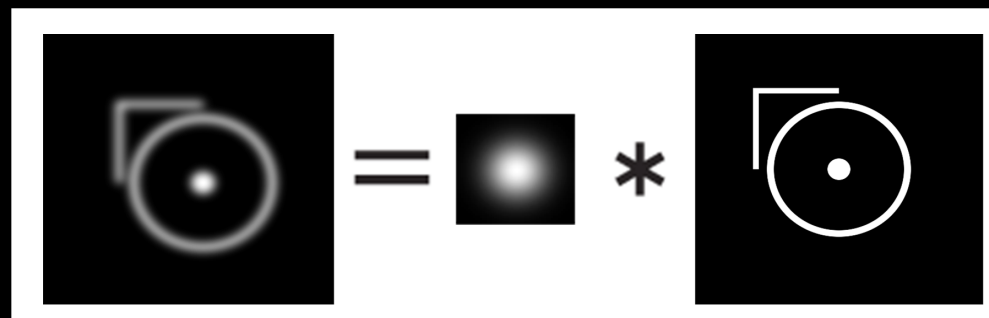
Formalizing the Problem

- Model the observed image

  y : Observed Image

  x : Underlying "true" image

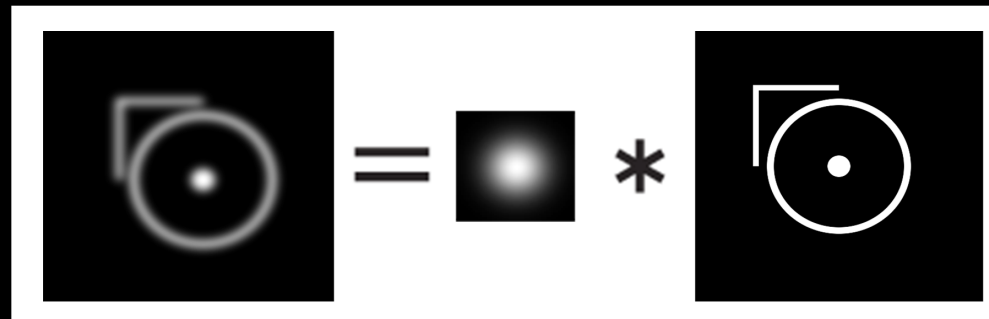 f : Point Spread Function

$$y = f * x$$

Formalizing the Problem

- Model the observed image

    y : Observed Image

    Fx: Convolution of f and x

$$y = Fx$$

Approaches to Deconvolution

- Correcting HST optics w/ Richardson-Lucy
  - Single frame processing
    - White (1994), Starck+ (1994), Fruchter+ (1997)

- Multiframe blind deconvolution
  - Helps break degeneracies
    - Harmeling+ (2009)

Multiframe Blind Deconvolution

- Gaussian limit
  - Solve for the PSF

$$f_t = \operatorname*{argmin}_{f \geq 0} \|y_t - F x_t\|^2$$

Multiframe Blind Deconvolution

- Gaussian limit
  - Solve for the PSF

$$f_t = \operatorname{argmin}_{f \geq 0} \| y_t - F x_t \|^2$$

  - Updating the image

$$x_{t+1} = x_t \odot \frac{F^T y_t}{F^T F x_t}$$

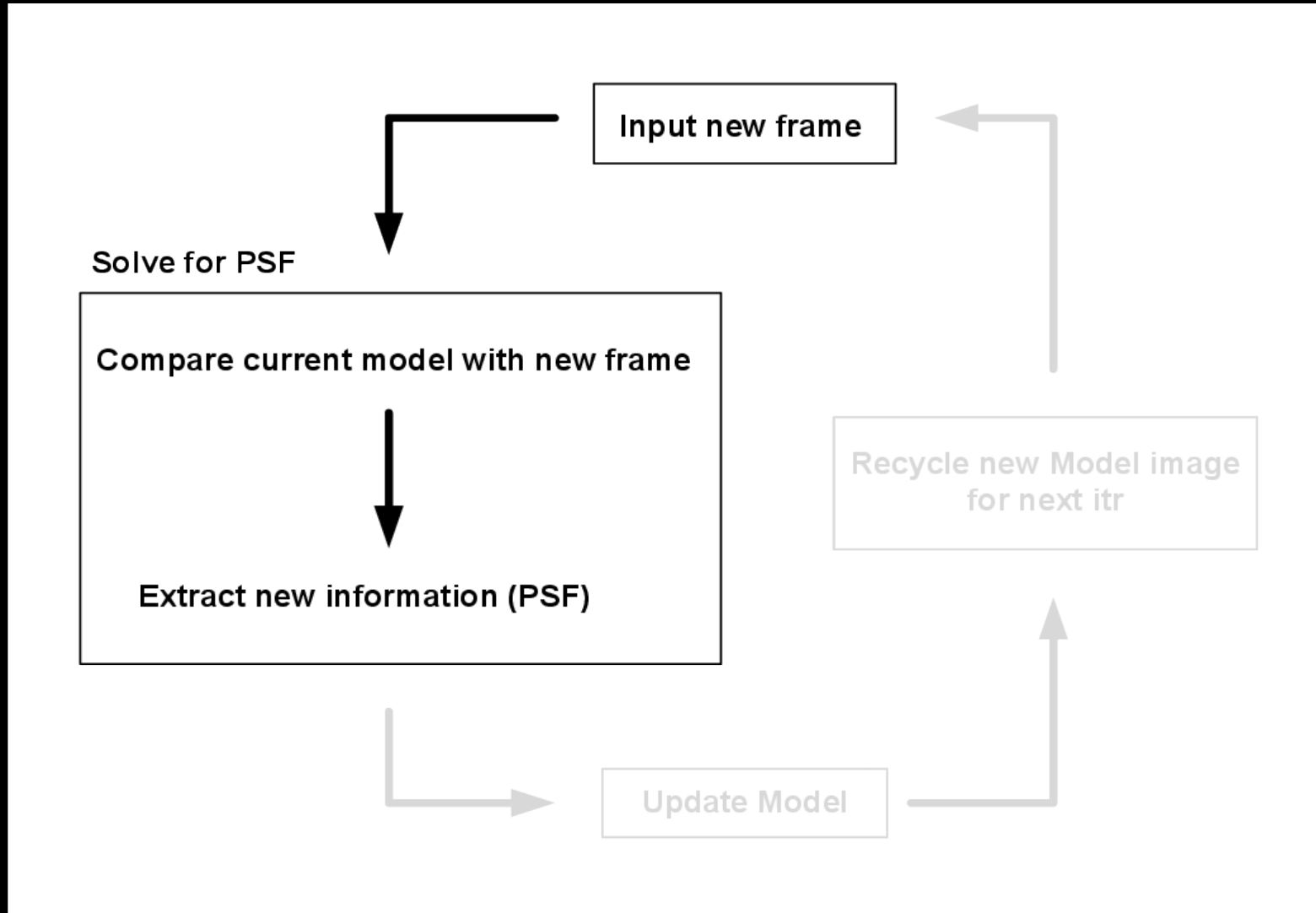# Multiframe Blind Deconvolution

- Improvements

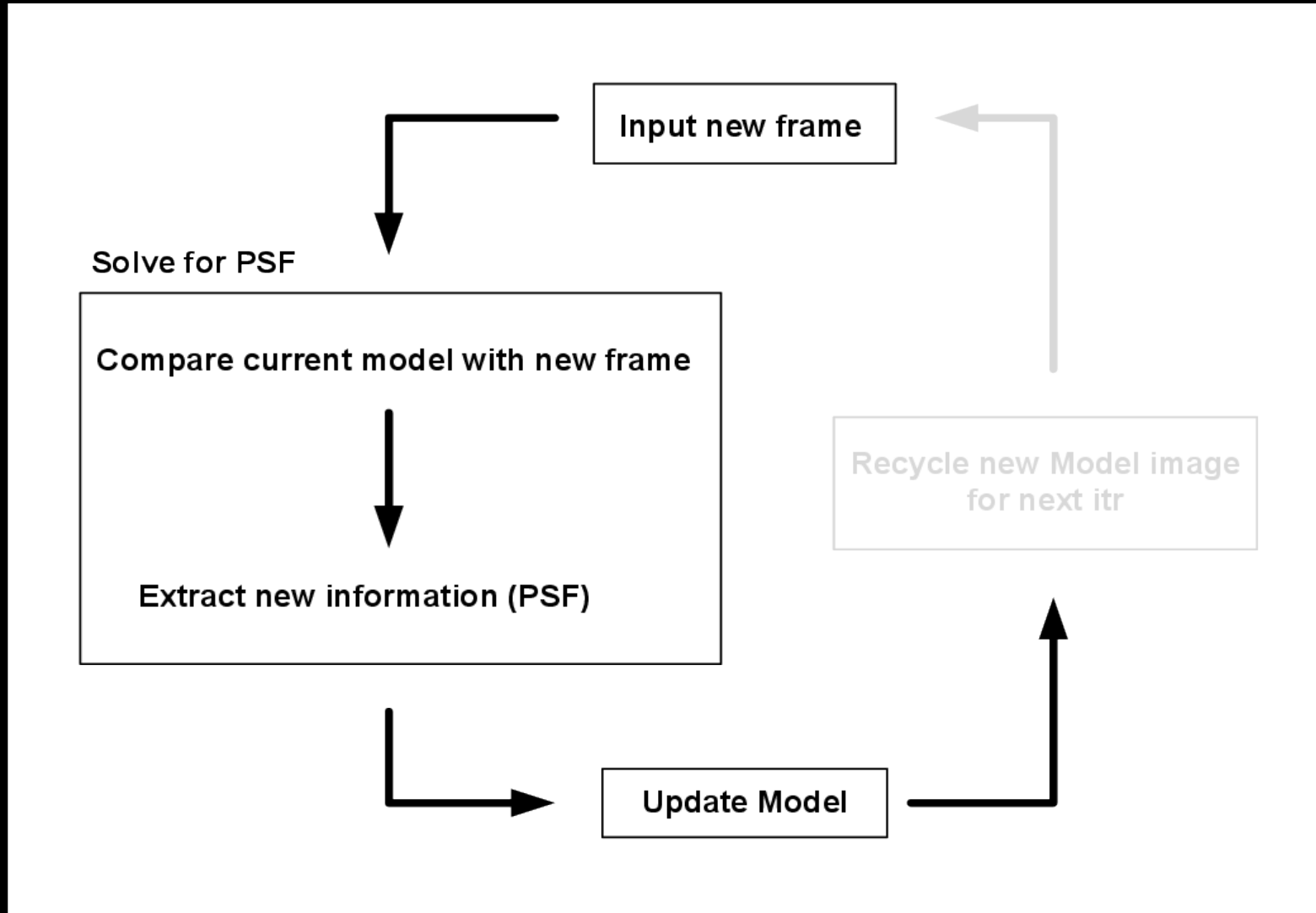   W : Robust weighting, prevent bright pixels from dominating the residual

    C : Clipping; limiting the effect of a single image

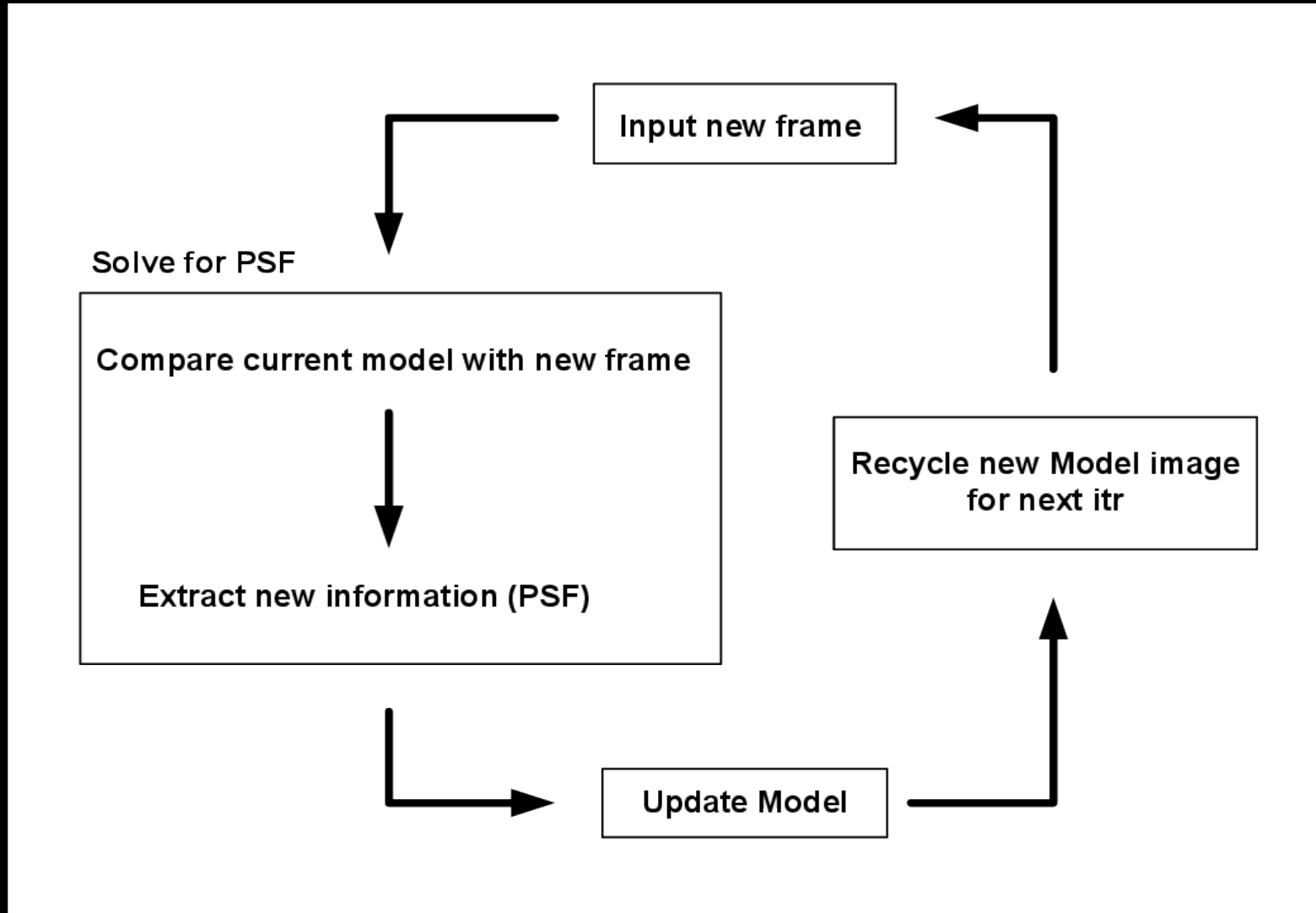$$x_{t+1} = x_t \odot C \left[\frac{F^T W y_t}{F^T W F x_t} \right]$$

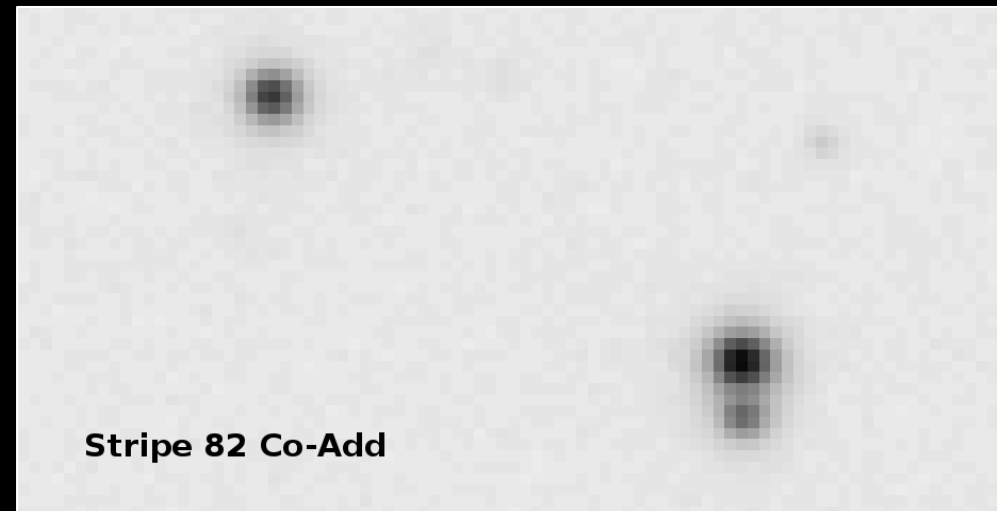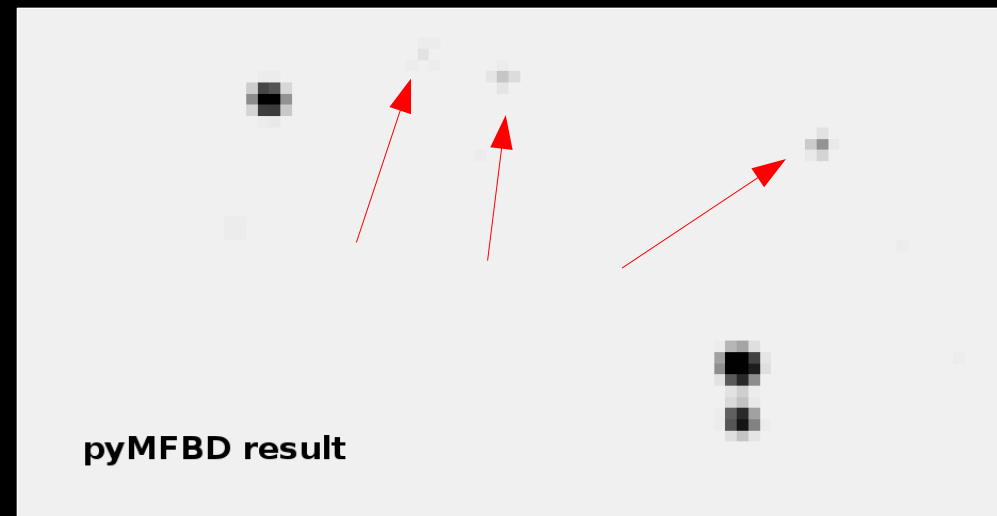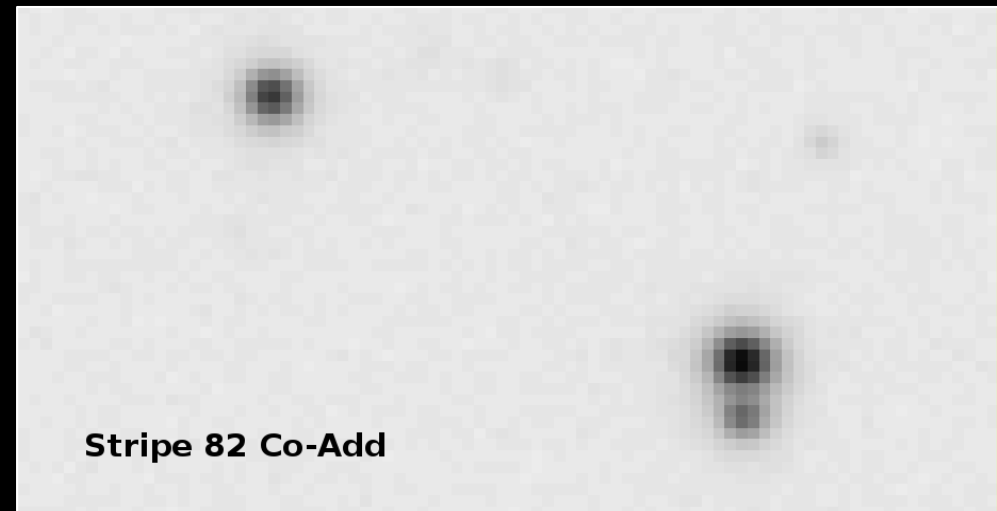# Streaming Algorithm

Streaming Algorithm

Streaming Algorithm

Input new frame

Solve for PSF

Compare current model with new frame

Extract new information (PSF)

Recycle new Model image for next itr

Update Model

Results

- Stars

Stripe 82 Co-Add

pyMFBD result

Results

- Stars

Stripe 82 Co-Add

pyMFBD result

Results

- Stars

CFHTLS - Co-Add

Ground truth

Stripe 82 Co-Add

pyMFBD result

Results

- Galaxies

Stripe 82 - Co-Add

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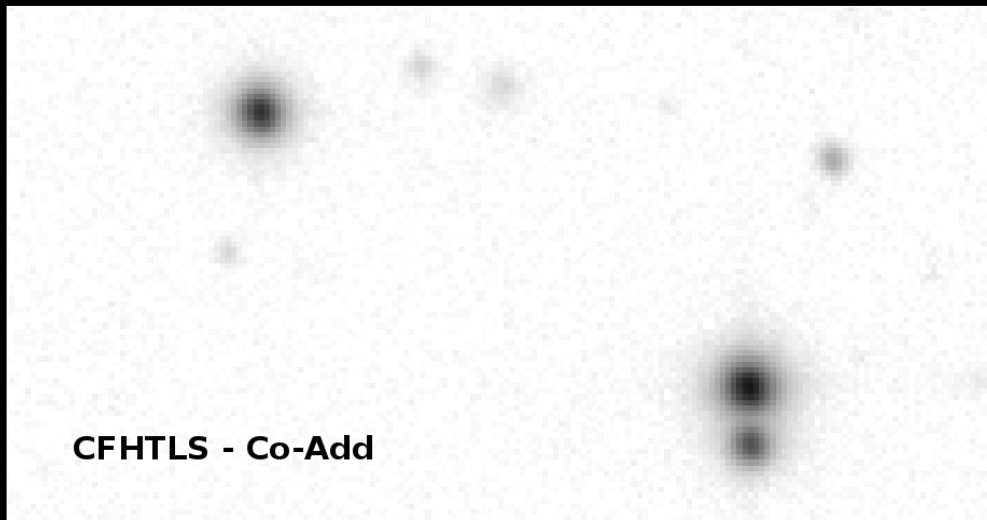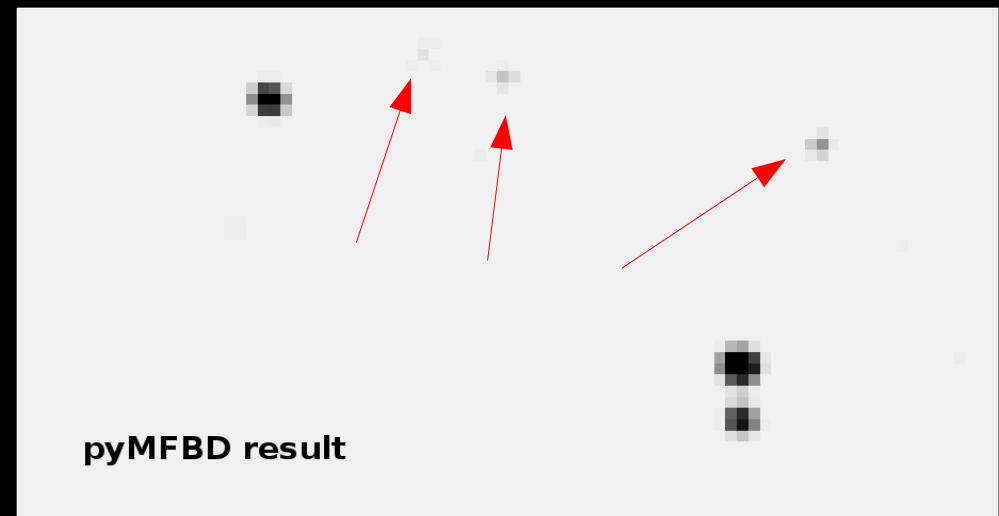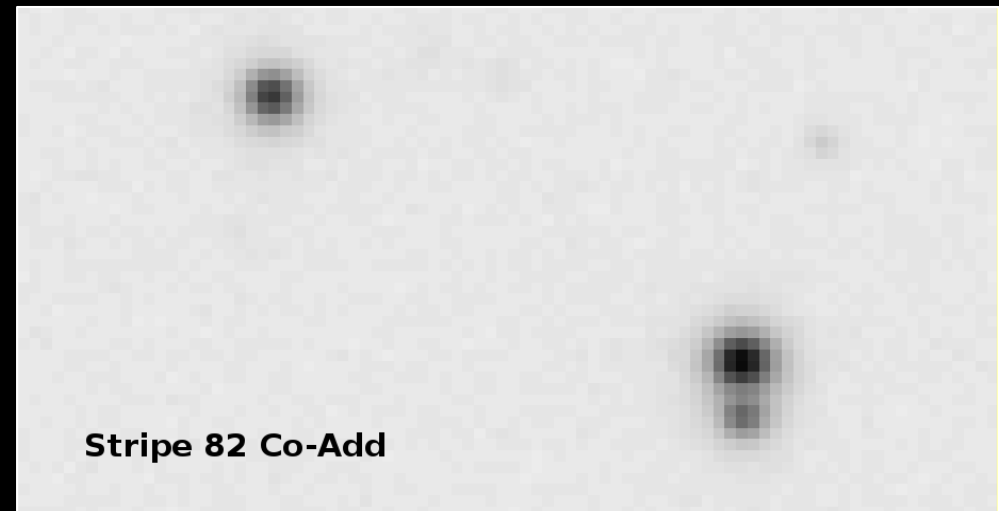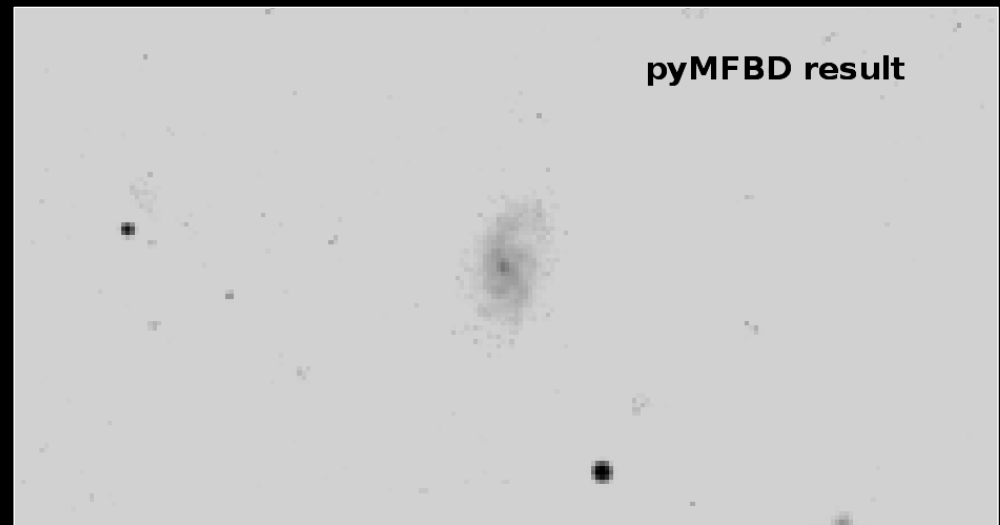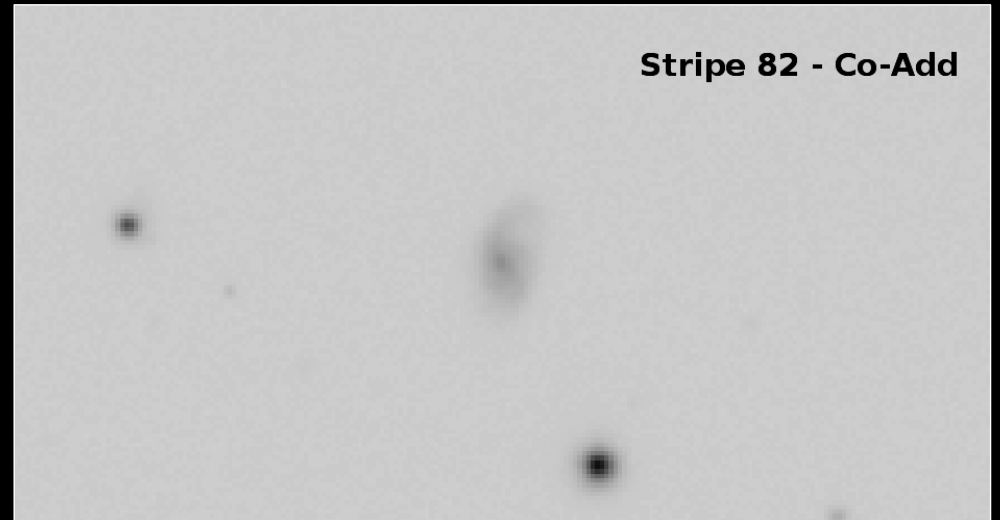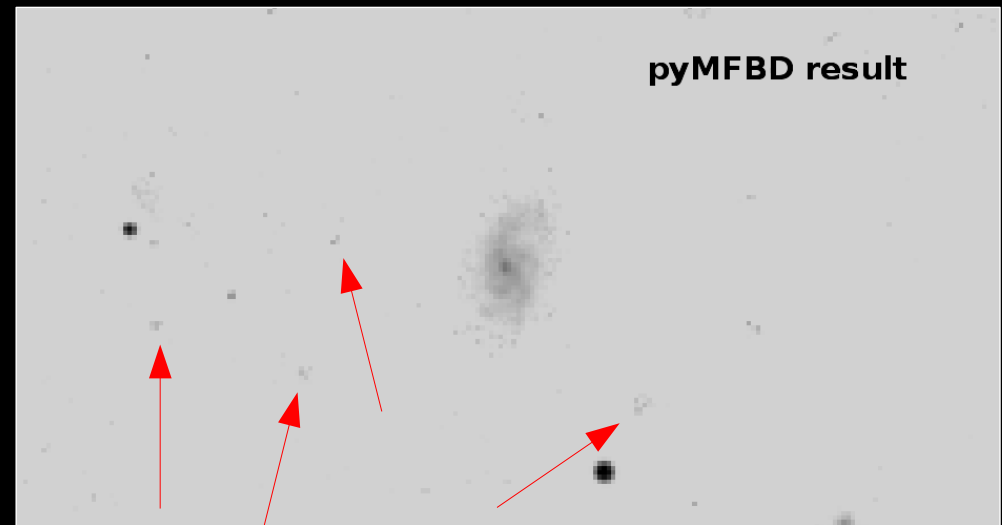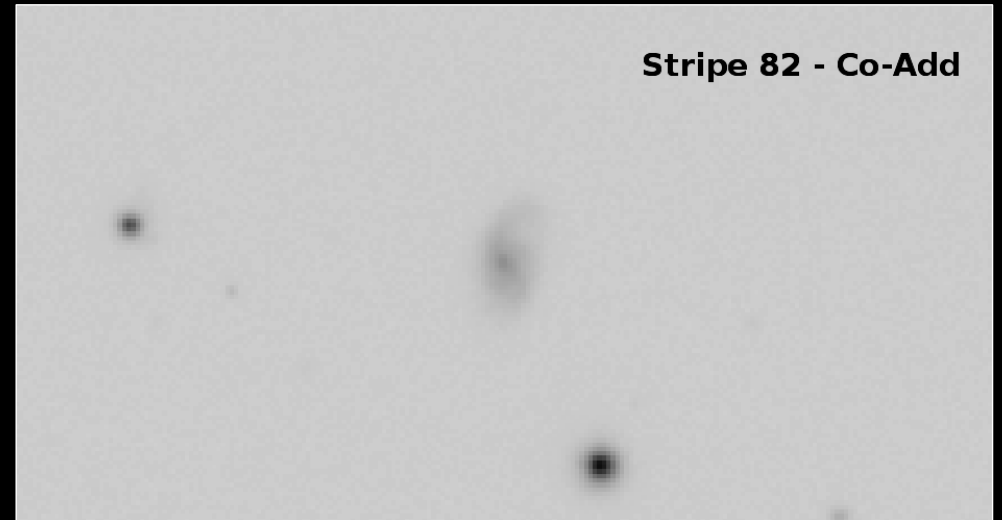
pyMFBD result
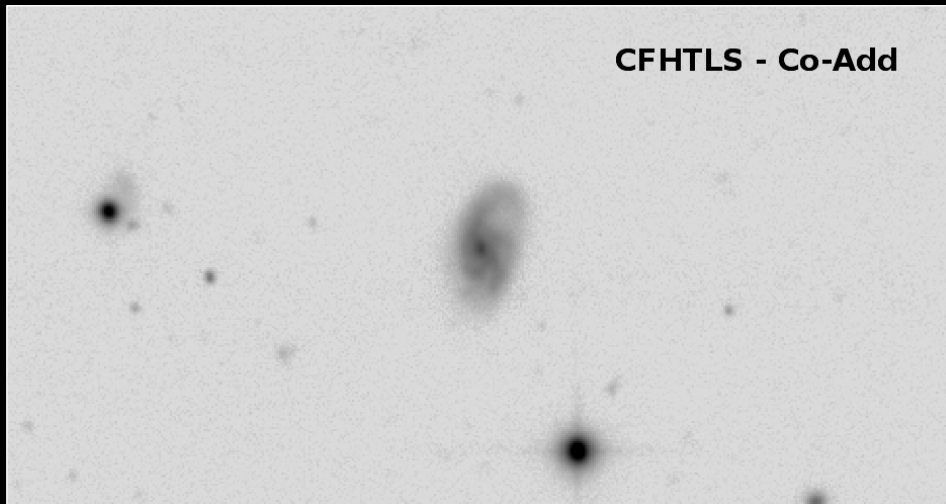
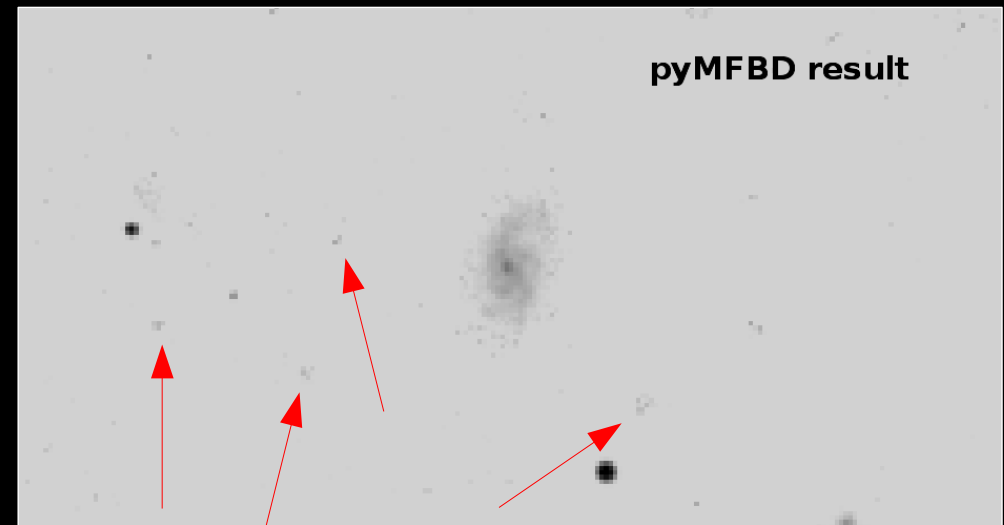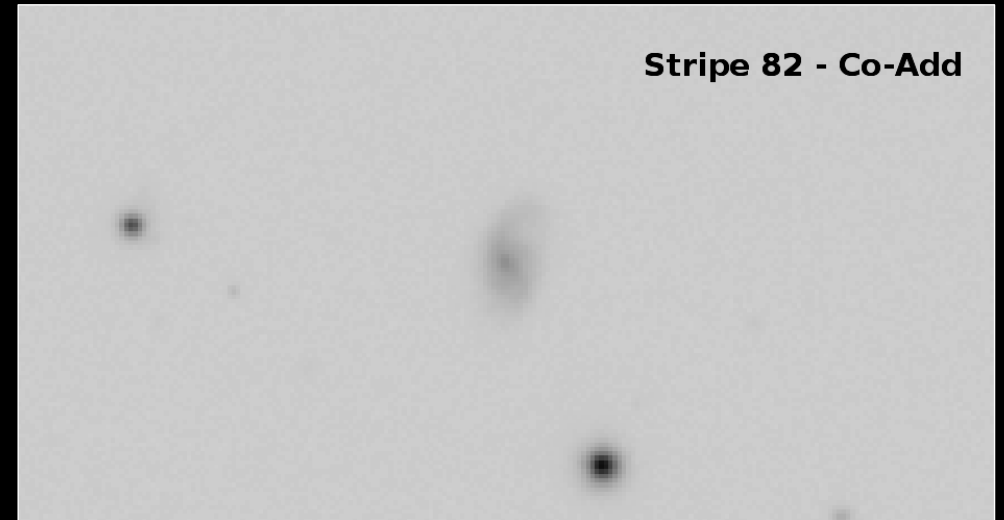# Software Tool: pyMFBD

Current Features:

- GPU – acceleration (Nvidia Tesla K20c)
  - 40x+ Speedup over CPU version
  - Processing 70 image (2k x 2k) in 5 mins

- Easily extensible Python/pyCUDA Framework

- Tested on:
  - SDSS's Stripe 82, CFHTLS and LSST images
  - Soon recently released DES images

In Summary

- Multiple frames provide new opportunities
    - Novel streaming algorithm for real images
- Scalable GPU implementation
    - Fast: modern datasets and experimentation
- Superior results to current methods

- Plans to include
    - Super resolution, background estimation, priors

Thank You

- Any questions?

- Do you have images you'd like to try?

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