

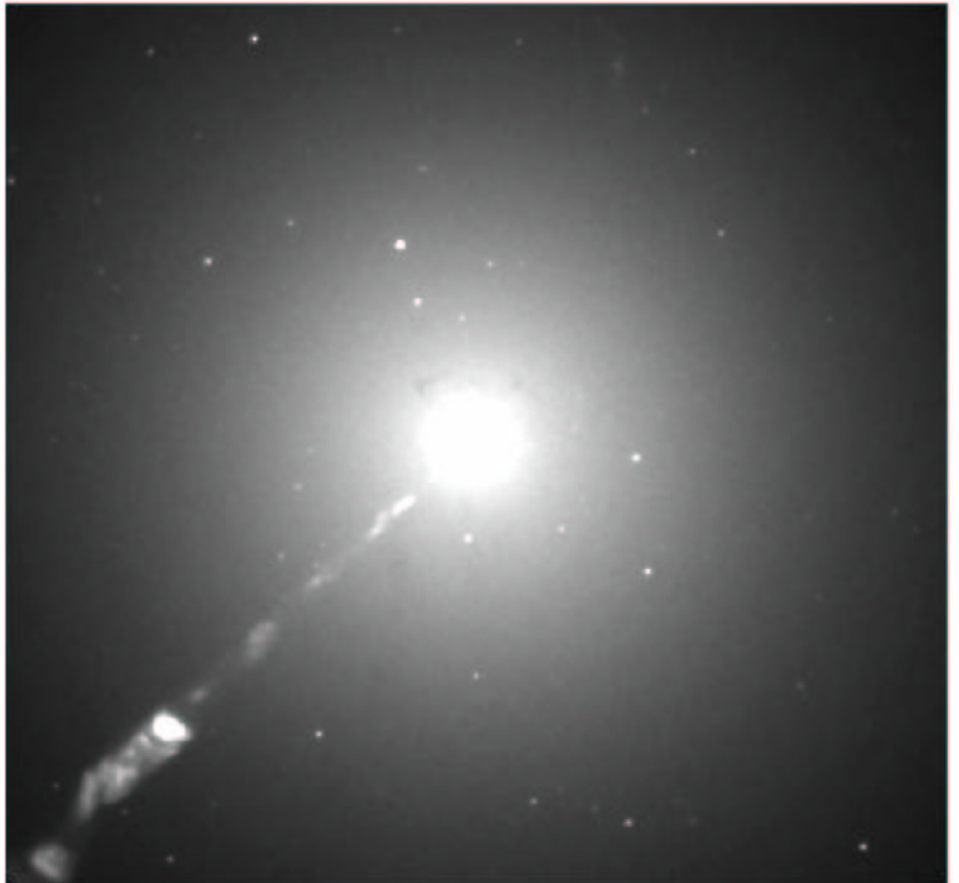
Recent Extragalactic Microlensing Results

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M31: R. Uclesich and A. Crofts

M87: T.Lauer, D.Zurek,
P.Baillon, A.Bouquet,
T.Broadhurst, S.Charlot,
Y.Geraud-Héraud, P.Gondolo,
J.Kaplan, A.Kim, E.Maoz,
M.Postman, M.Shara, J.Silk,
G.Squires, J.Tonry, S.Zepf

Kavli Institute for Theoretical
Physics, October 23, 2002

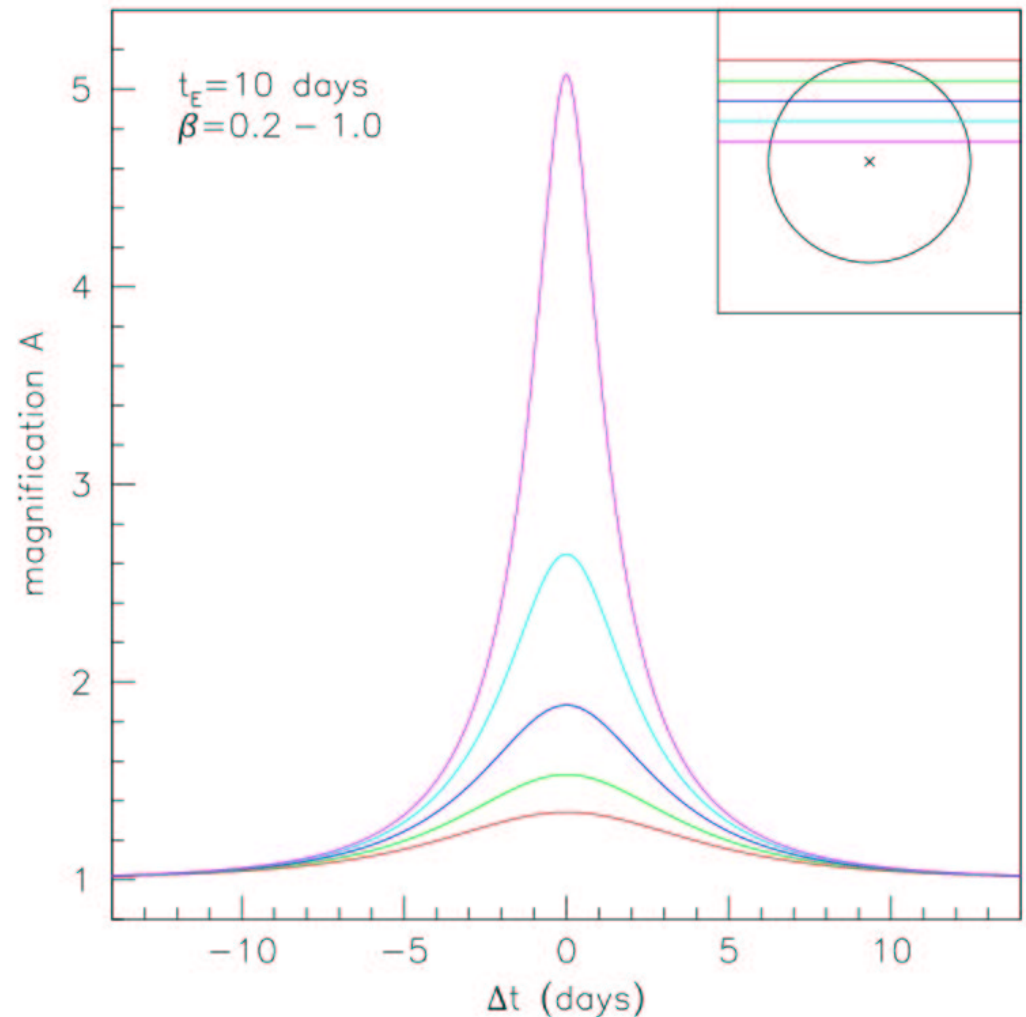


Gravitational Microlensing

- Stellar objects can act as gravitational lenses:
relative motions give transient magnifications
- Significant magnifications within Einstein radius

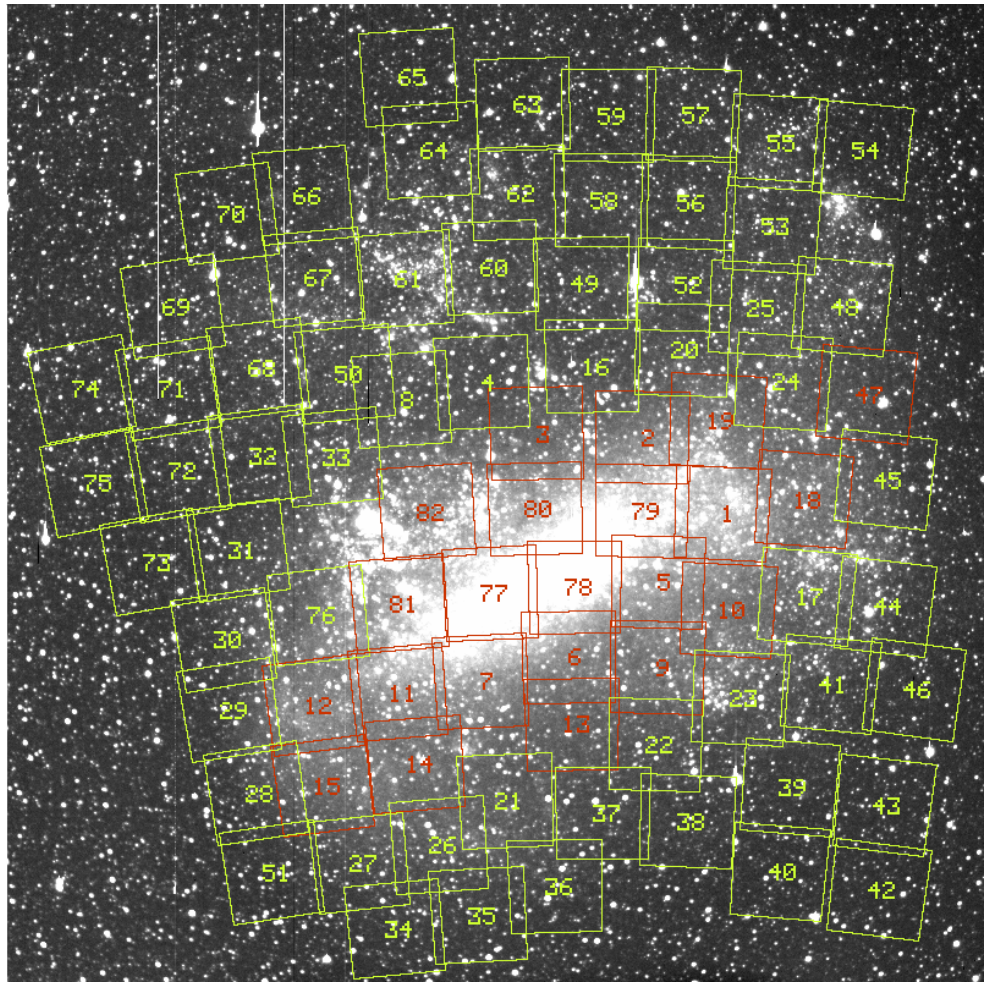
$$R_E = \sqrt{\frac{4GM}{c^2} \frac{D_L D_{LS}}{D_S}}$$

- For typical Galactic values roughly 10 AU
- For Galactic velocities, timescale is 100 days



Microlensing Surveys

- Technique sensitive to any solar mass objects (dark?)
- MACHO project searches LMC stars for microlensing and sees an excess:
20% of Milky Way Halo is lensing objects!
- This is a surprising result, needs confirmation from other lines of sight
- Survey more distant galaxies, sample more of the halo, distant halos, etc.



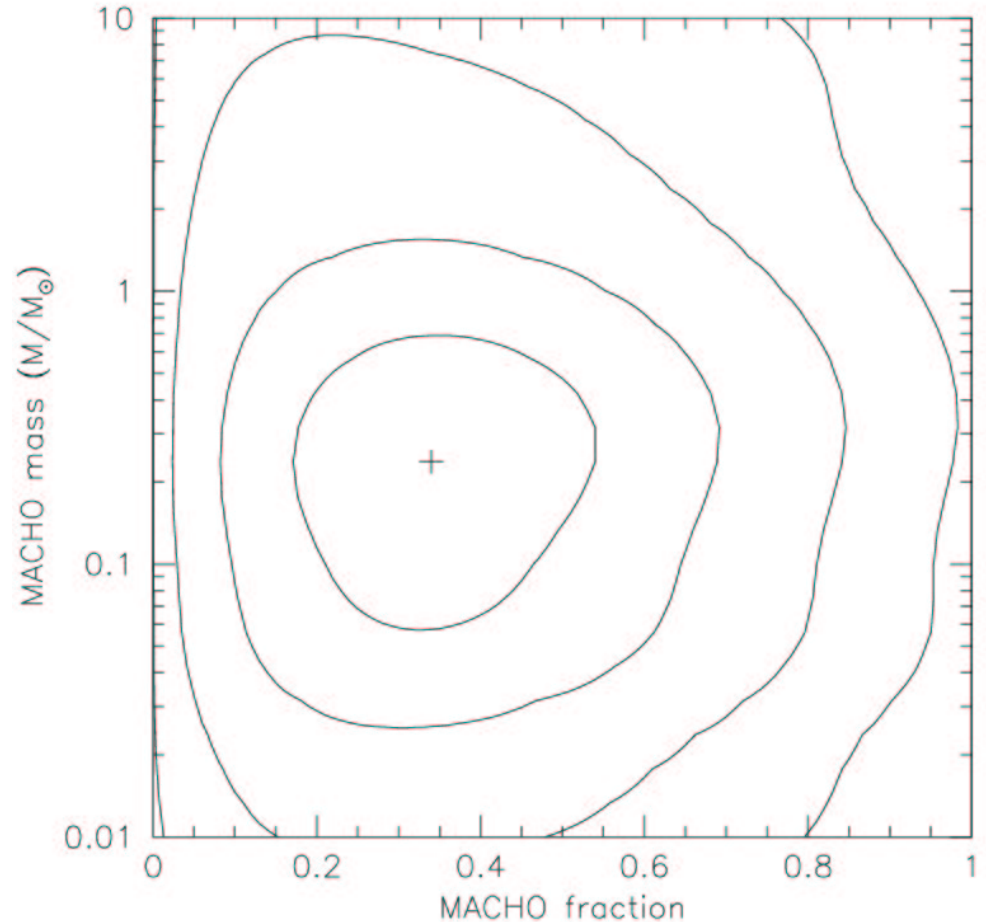
Microlensing in M31

- Andromeda (M31) is the nearest large galaxy
- Individual stars not resolved, but microlensing can be detected anyway
- Preliminary results of three season survey: 27 event candidates (8 expected)
- Consistent with LMC results: dark halo lenses exist and are numerous
- Larger survey in progress



Maximum Likelihood

- Simulate M31 event rate
- Timescale distributions
- Compute likelihood function for mass and halo MACHO fraction
- “No Halo” disfavored
- M31 is consistent with MACHO LMC results



Dataset: HST WFPC2

- 30 Orbits, once daily – month-long survey
- 4x 260 s dither F814W
- 1x 400 s F606W
- 2 reductions (Lauer, Zurek)
- preliminary analysis: WFC2,3,4 F814W frames
- CR / hot pixel subtraction
- image registration from globular clusters
- reference image from 29 frames (12th is blurred)
- noise image is PSF²-convolved from reference
- difference images constructed
- S/N image from PSF-convolved difference image and noise image
- result images searched for variable objects

Example Image Subtraction

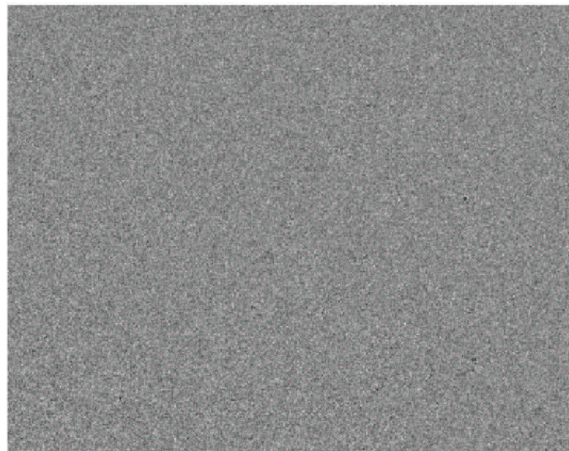
unsubtracted image

“stars” are mostly
globular clusters in
M87 halo



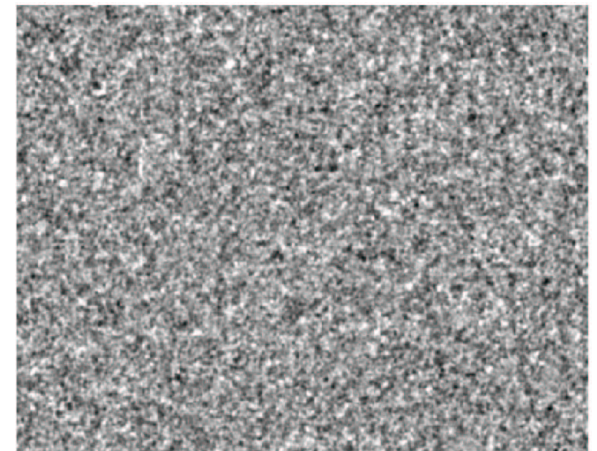
difference image

subtraction is quite
clean, with minor
artifacts around
globular clusters



result image

signal to noise
from PSF and PSF^2
convolutions of
difference and
reference images



Lightcurve Analysis

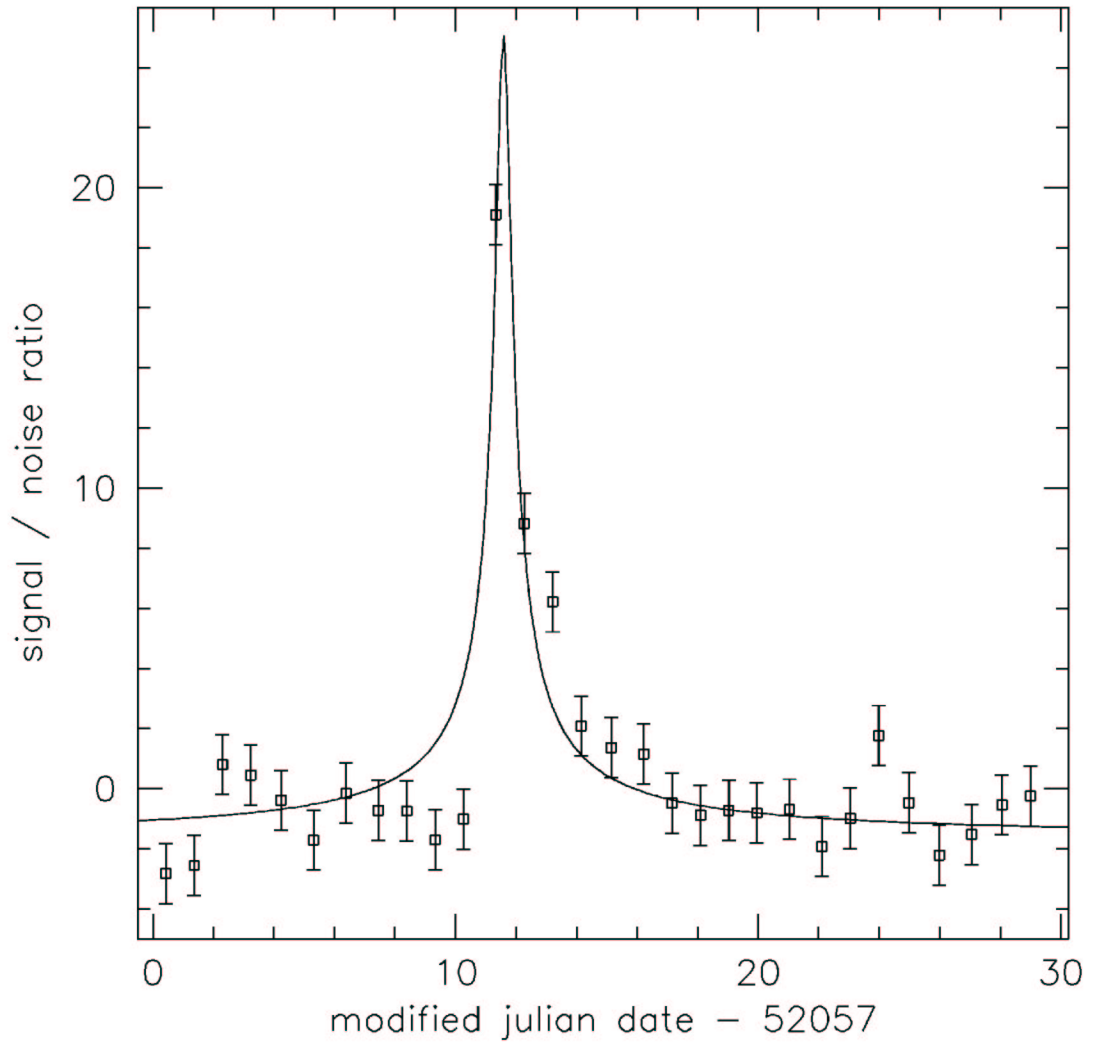
- analysis developed on WFC2 F814W subsampled frames only
- baseline: average of 10 lowest samples (events bias baseline negative)
- consecutivity: $5 \times 3\sigma$ including $1 \times 5\sigma$
- hot pixel test:
 - stack of 5 differences
 - point sources extended
- χ^2 : step function, linear, degenerate microlensing – require microlensing best fit with $\Delta\chi^2 > 0.75$
- visual inspection for subtraction artifacts: outskirts of bright globular clusters where PSF samples core but PSF² (more centrally peaked) does not

Candidate Events

- WFC2: 4 candidates (one artifact)
- WFC3: 2 candidates (two artifacts)
- WFC4: 0 candidates
- 3 excellent candidate variable sources
 - nova candidate ($M = -8$)
 - unidentified declining tail
 - microlensing candidate ($M = -6.5$)
- preliminary check: nova and microlensing candidates exist in F606W frames
- nova candidate is in a faint M87 globular cluster
- crude color for microlensing candidate: $V - I = 1.1$
troublesome variable stars are red ($V - I = 2$) or blue ($V - I = 0$)

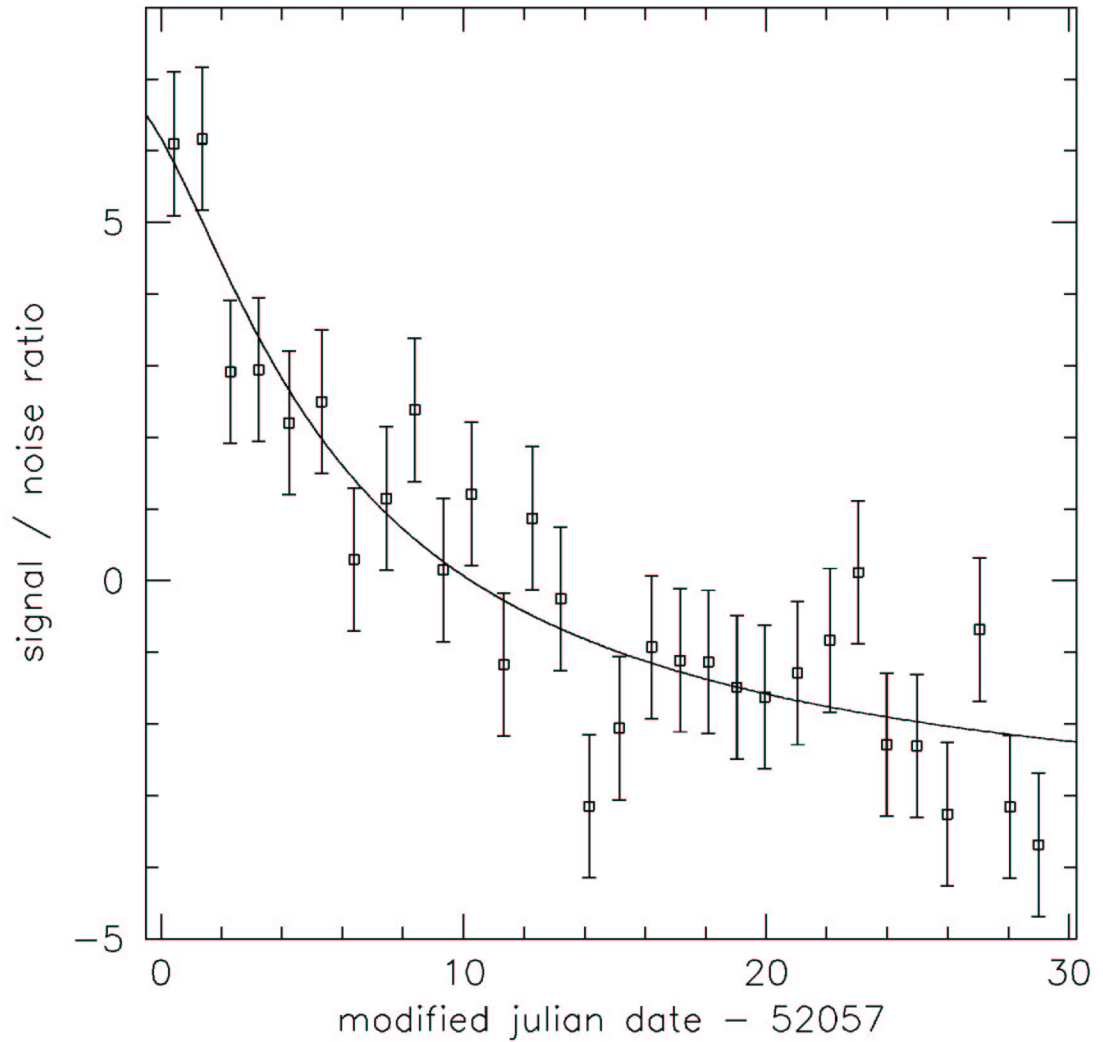
Globular Cluster Nova

- FWHM 0.93 days:
fairly typical
fast bright nova



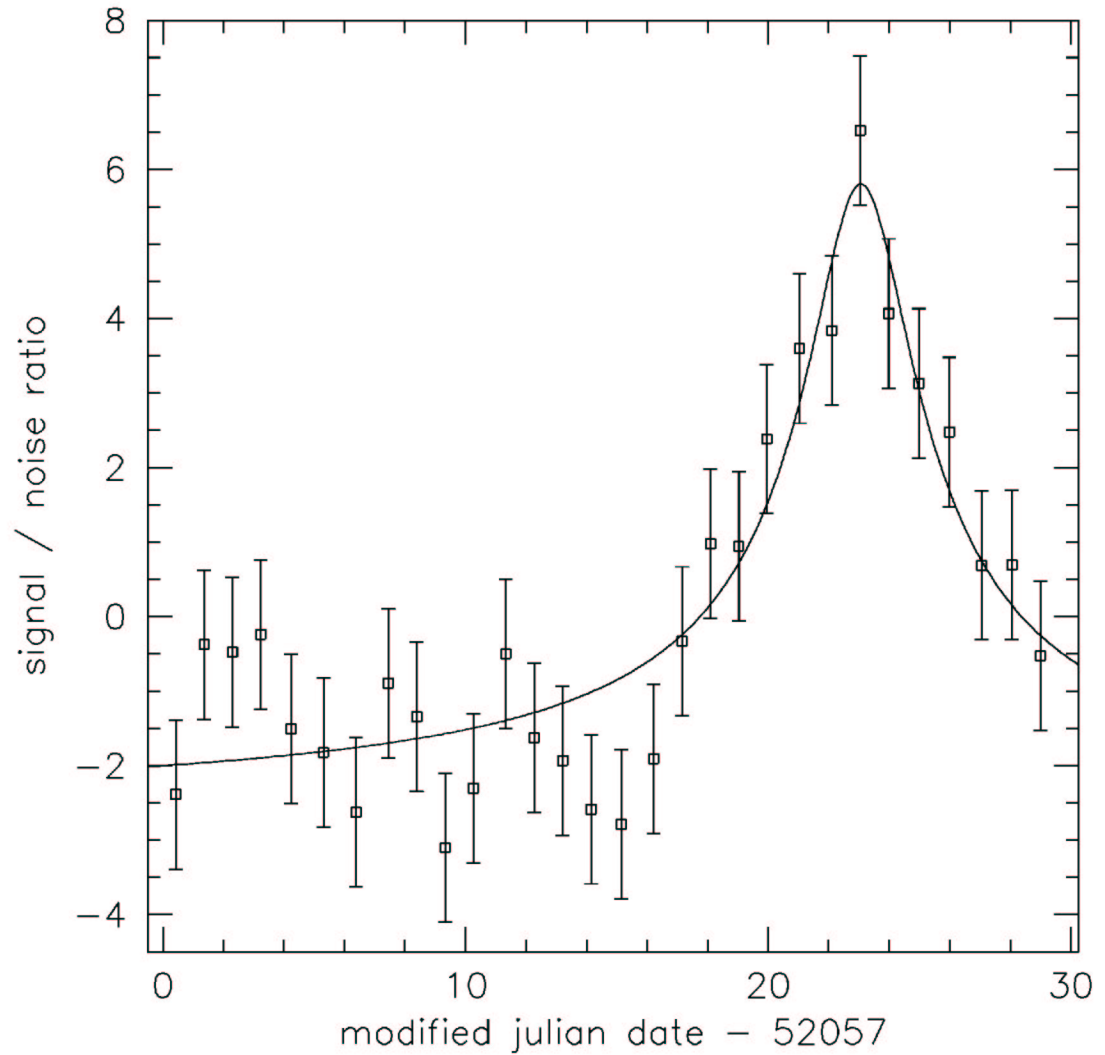
Declining Event Tail

- FWHM 15.6 days
unfortunately
peak is missing



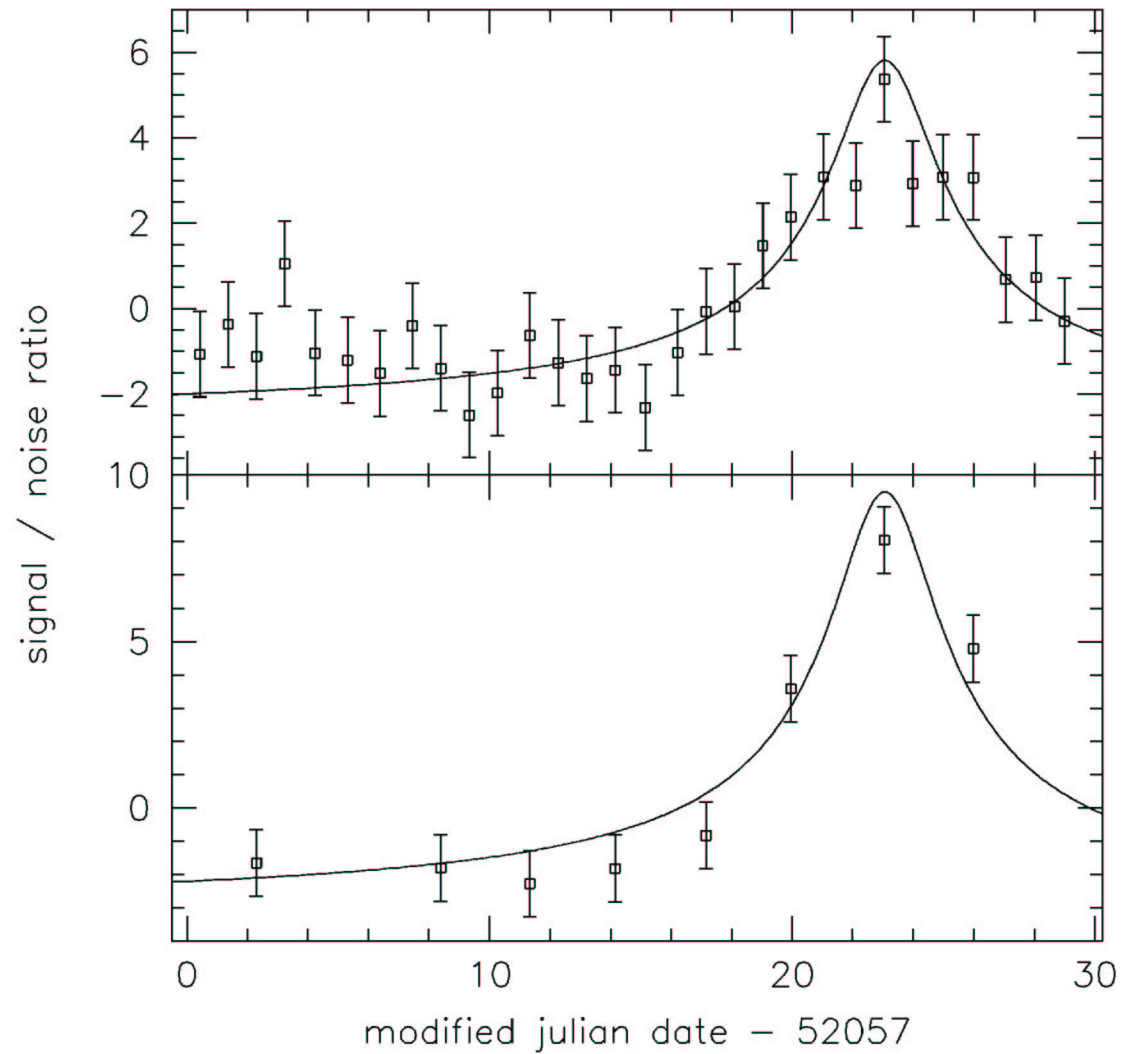
Microlensing Candidate

- FWHM 6.1 days
excellent!



Microlensing Candidate Colors

- Zurek reduction
- 3-day medians in F606W



Theoretical Modeling

- Monte-Carlo generation of microlensing lightcurves
- identical analysis at the lightcurve level
- efficiency of detecting microlensing events
- rate calculation for M87 and Virgo Cluster halos, including self lensing
 - 1.5 events expected from full halo
- lowering the threshold increases the expected rate: requiring only $3 \times 3\sigma$ including $1 \times 5\sigma$ allows 25 candidates (c.f. 6), with 2.5 expected
- lowering $\Delta\chi^2$ should help (low S/N events mistaken for step functions)
- improve hot pixel analysis: not troublesome except for variability searches!

Work in Progress

- full analysis of both filters
 - time independent color?
 - source (V-I) colors
- include PC chip
- lower threshold / improve hot pixel analysis
- artificial star tests!
 - hot pixel vs. PSF
- baseline data from archive
- complete simulation
 - maximum likelihood analysis of halo parameters
- is there a halo lens population in M87 / Virgo?
- future directions: repeat this survey with HST ACS: improved resolution, greatly improved sensitivity