Recent Extragalactic Microlensing Results

Edward A. Baltz

M31: R. Uglesich and A. Crotts


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 PSF$^2$-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  difference image  result image

“stars” are mostly globular clusters in M87 halo

subtraction is quite clean, with minor artifacts around globular clusters

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: 5x 3σ including 1x 5σ
- hot pixel test:
  - stack of 5 differences
  - point sources extended
- $\chi^2$: 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 $\text{PSF}^2$ (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