

M31 Pixel Lensing and the PLAN project

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on behalf of the **PLAN** collaboration

OUTLINE

- M31 Pixel Lensing
 - the expected signal
 - the reported candidate events and their characteristics
 - the (debated) results
- The PLAN project: an update (*work in progress*)
 - preliminary results of the 2008 and 2009 campaigns

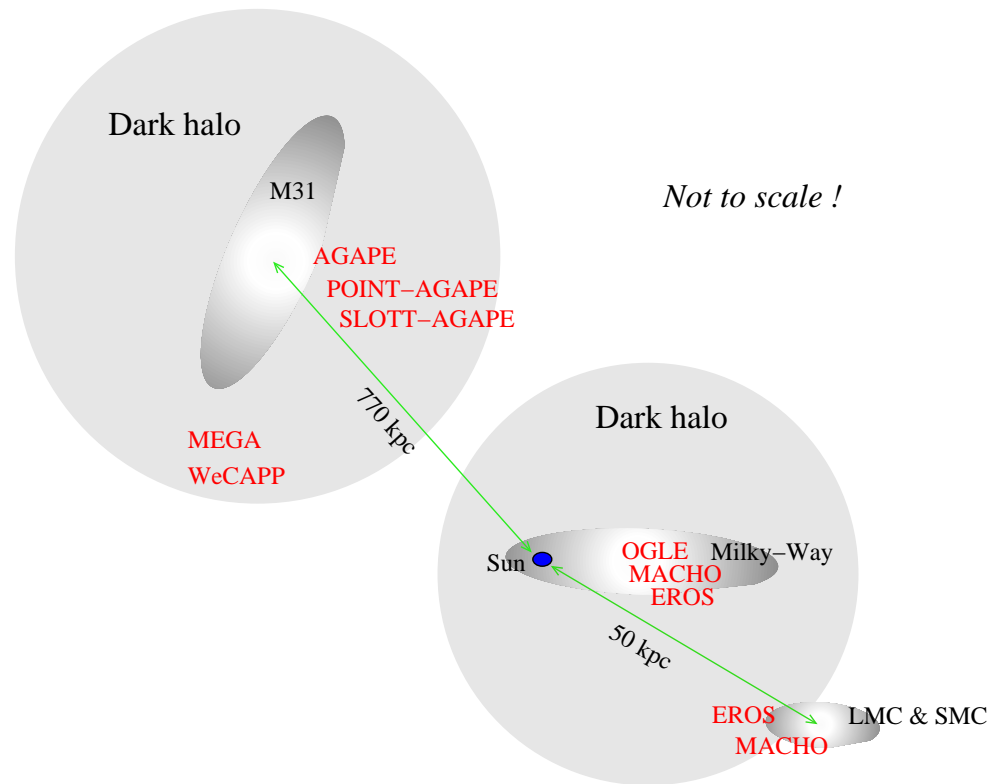
the underlying physical issue:

MACHO lensing or “self-lensing” ?

a methodological issue

single event analyses or full pipeline ?

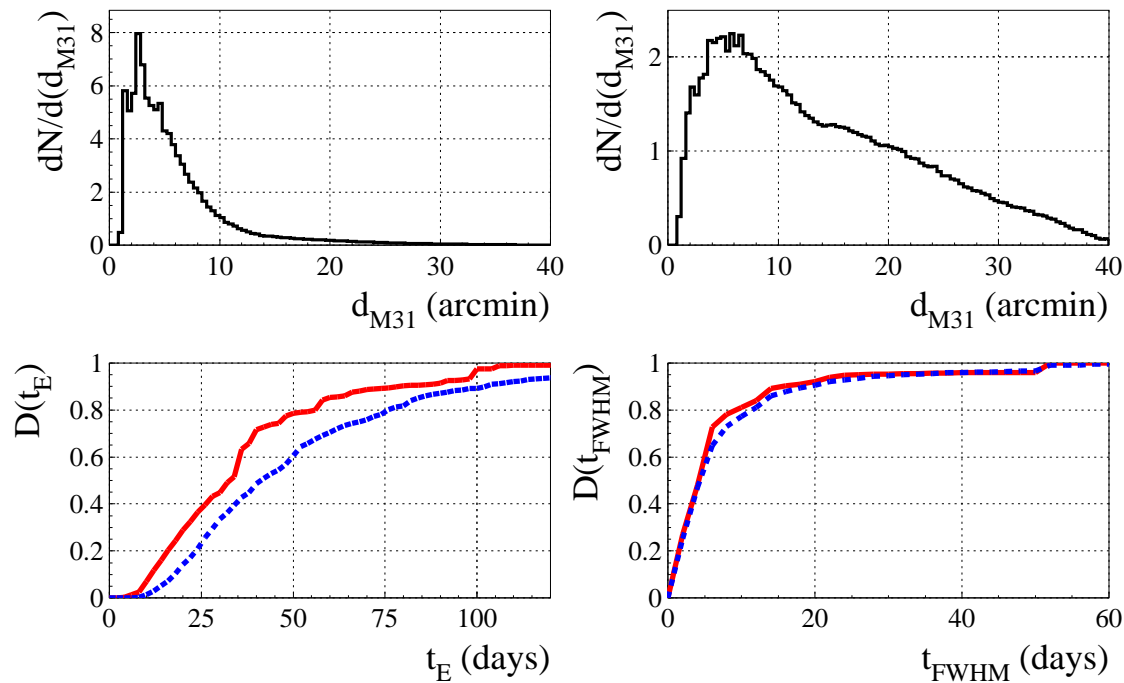
M31 “Pixel” lensing: microlensing of unresolved sources: looking for *pixel* flux variations (many sources of unknown flux): pro and cons



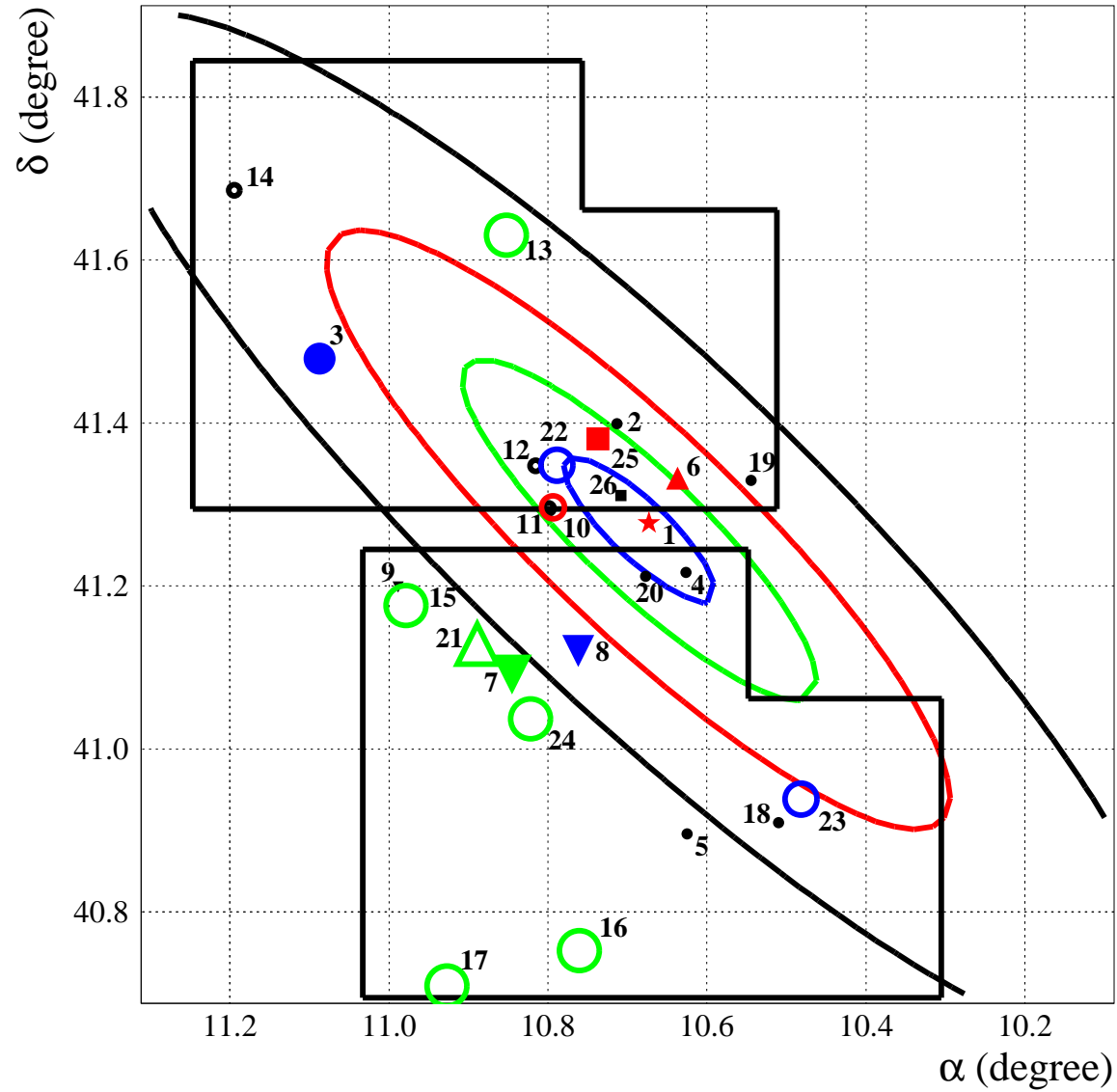
map of the **full** M31 halo - which is not possible for the MW one

The expected signal - MACHO vs self-lensing - position and duration

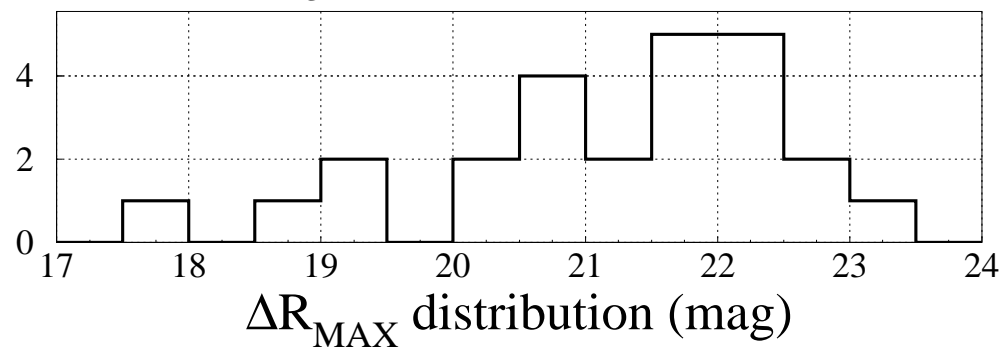
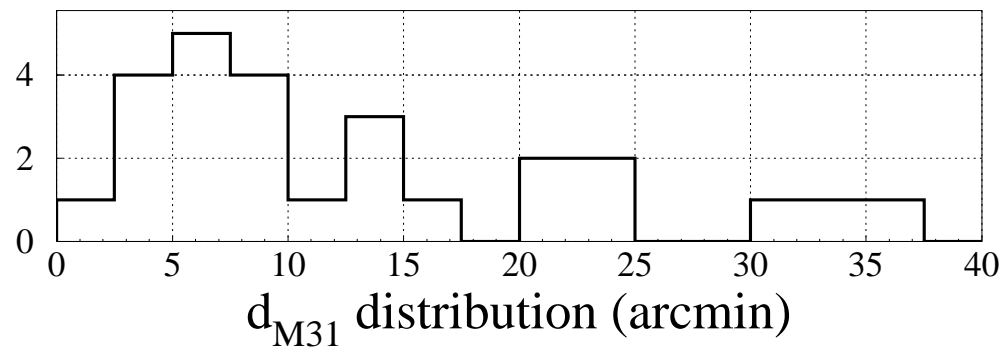
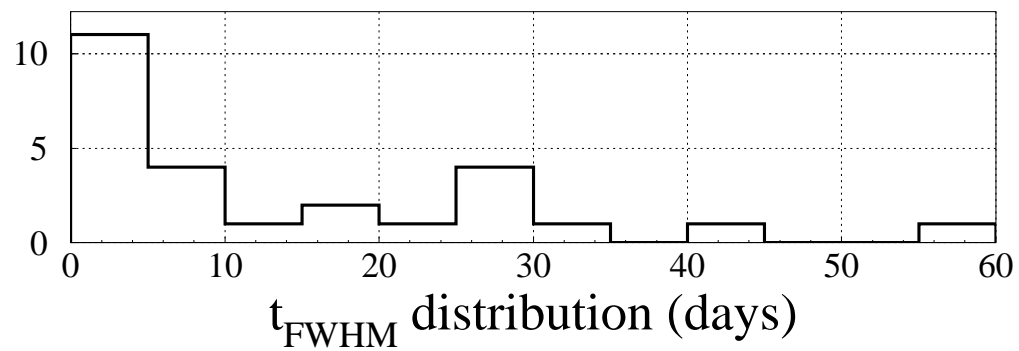
- inner region (most expected events): expected rates about the same
- outer regions: no SL, M31-MACHOs near-far asymmetry
- additional degeneracy in the parameter space: $t_{\text{FWHM}} = t_E \cdot f(u_0)$



27 reported candidate events - position



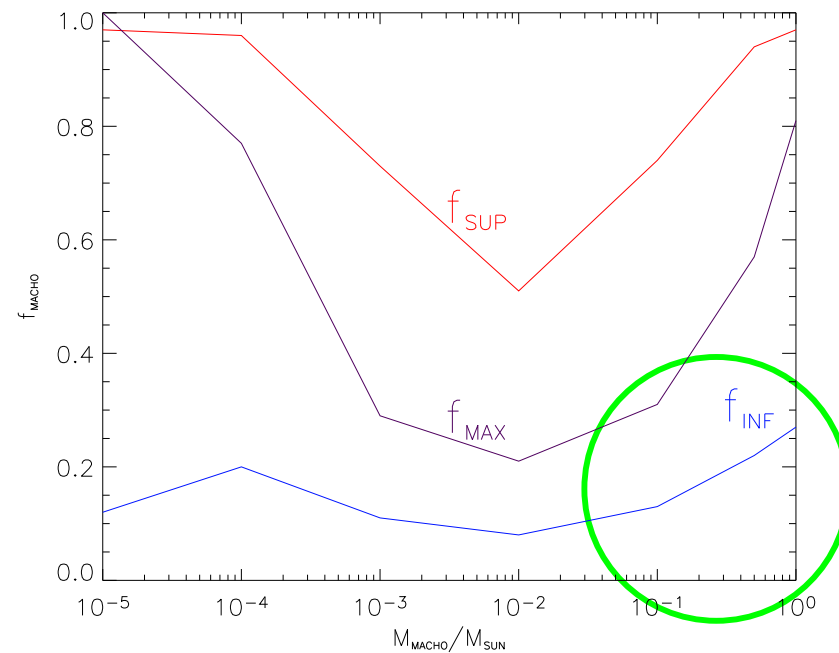
27 reported candidate events



Looking for MACHOs (versus self lensing): results

♣ **POINT-AGAPE**: *Evidence for a MACHO signal toward M31*

(SCN et al. A&A 2005)

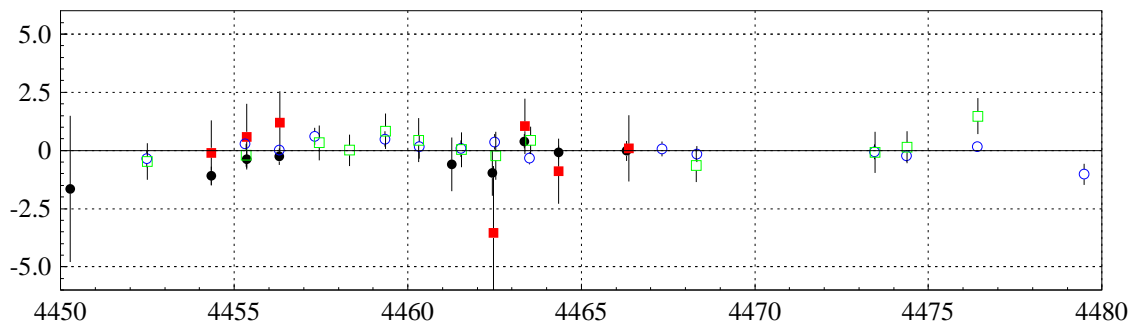
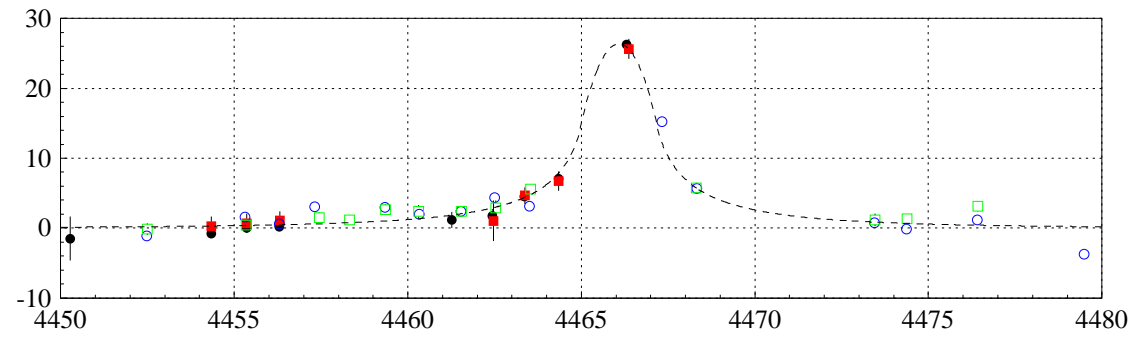
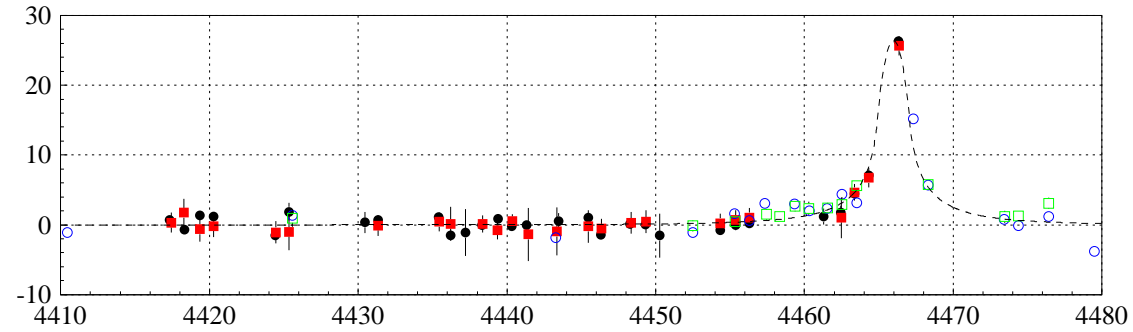


◇ **MEGA**: observed signal consistent with expected self-lensing rate

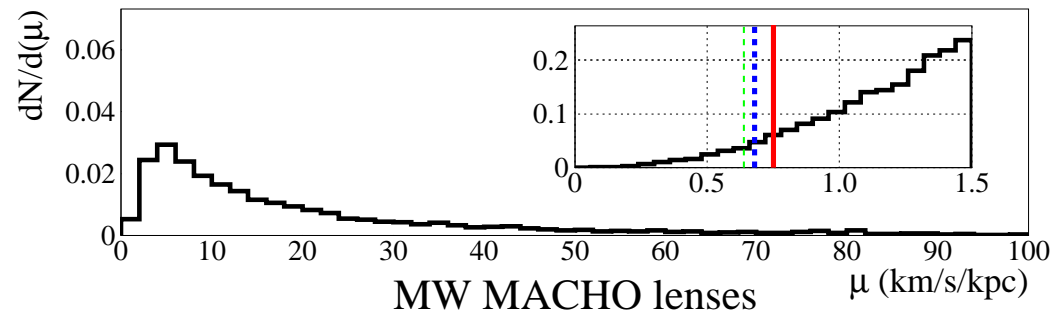
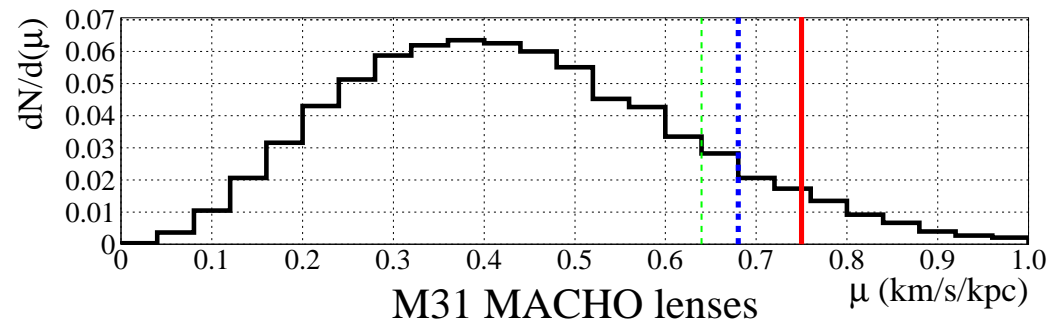
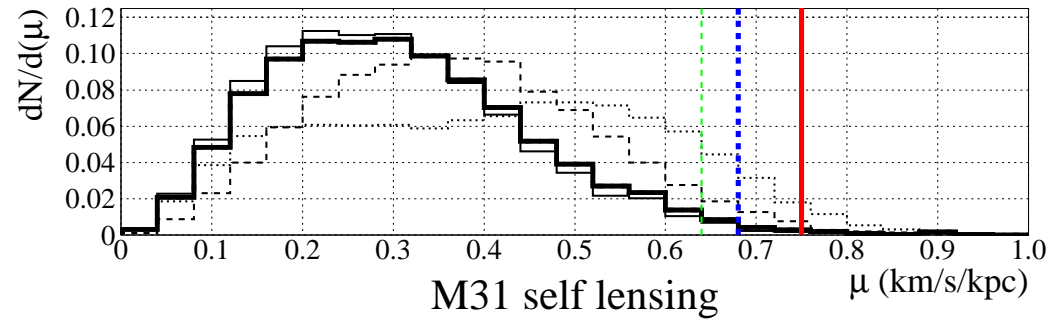
(De Jong et al. A&A 2006, an analysis challenged by Ingrassio, SCN et al A&A 2006, 2007)

‡ **single events**: PA-N1, PA-S3/GL1, OAB-N2 → MACHOs evidence ?

OAB-N2 *A study of the lens proper motion...*



... → μ lower limit vs Monte Carlo analysis: **MACHO** ?



The **P**ixel **L**ensing **A**ndromeda collaboration

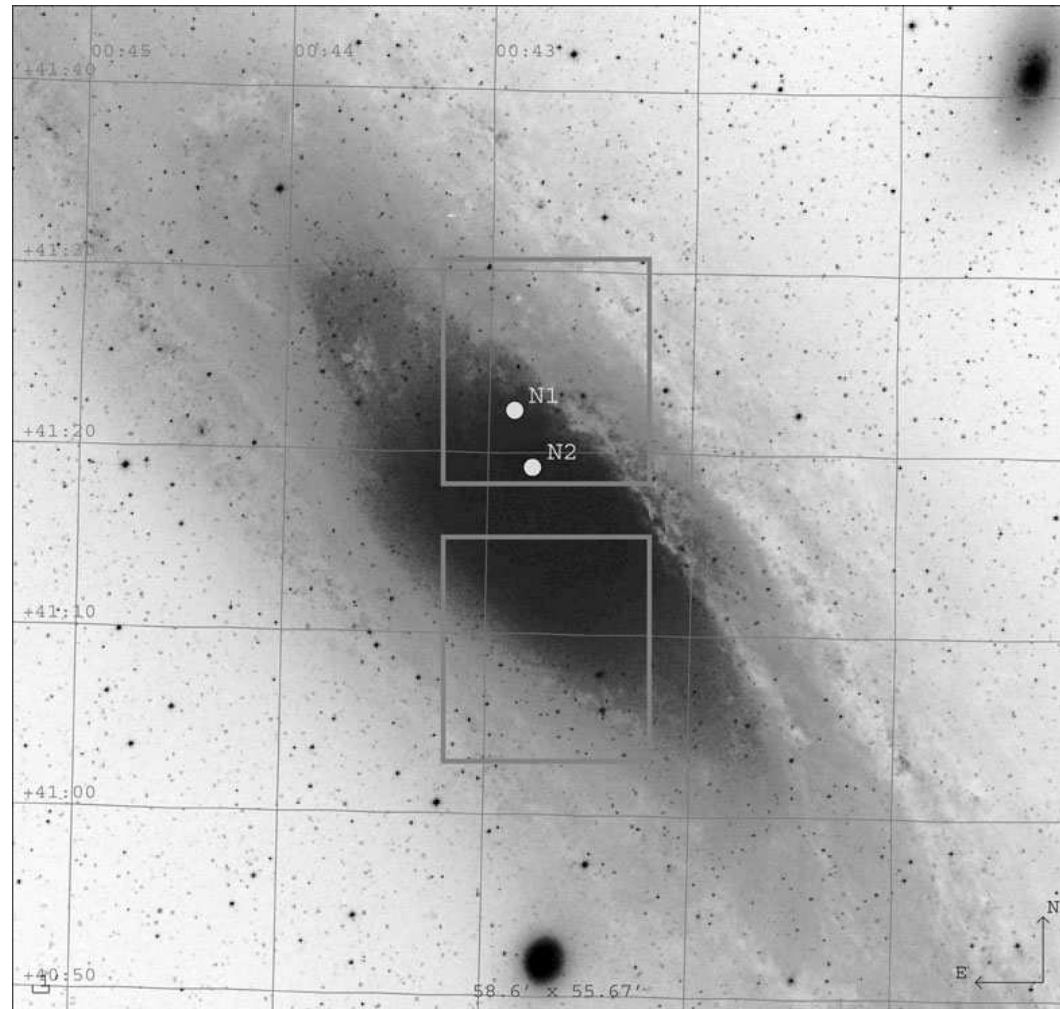
- V. Bozza, **SCN** (PI), L. Mancini, G. Scarpetta (Salerno U.)
- F. De Paolis, G. Ingrosso, A. Nucita, F. Strafella (Lecce U.)
- Ph. Jetzer, M. Sereno (ITP Zürich CH)
- I. Bruni & R. Gualandi (OAB), M. Dall'Ora (OAC)
- M. Dominik (SUPA, UK)
- A. Gould (OSU, US)
- A. Subramaniam, M. Sofonova (IIAP, India - new entries 2010)

<http://plan.physics.unisa.it>

PLAN@1.5m OAB: 2006-2010 (full consecutive nights campaigns)

PLAN@2m HCT : 2010 (10 consecutive nights, 2hr/night)

2007 analysis: two microlensing candidate events



SCN et al, ApJ 2009

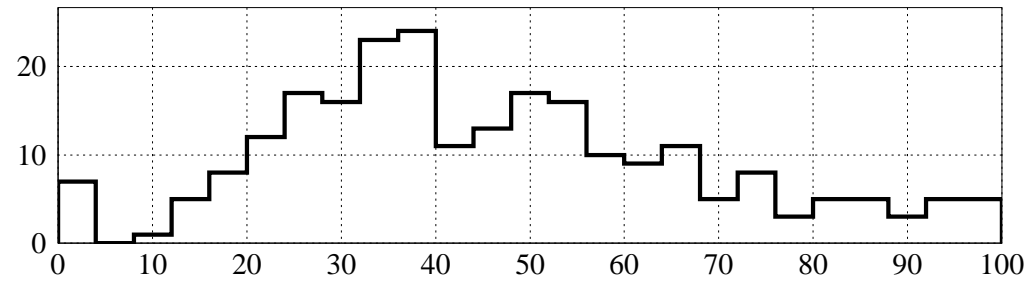
ANALYSIS: The (fully automated) pipeline
(the fewer the criteria ... the better!)

- select significant flux variations (no resolved objects!)
- (Paczinsky) shape: light curve analysis (χ^2 , t_{FWHM} ...)
- image shape analysis (is the bump real?)
- unicity: extension along 3 years of PA-INT data

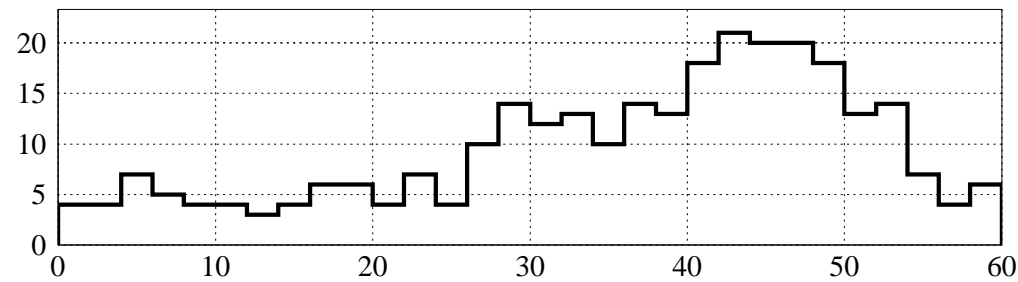
...RESULTS

- 2007 (50 nights) : $n_{\text{obs}} = 1 + 1$
 - OAB-N1 ? ($t_{\text{FWHM}} = 7$ days, $d_{\text{M31}} = 7.1'$)
 - **OAB-N2** ($t_{\text{FWHM}} = 3$ days, $d_{\text{M31}} = 2.8'$)
- 2008 (66 nights) : $n_{\text{obs}} = 0$
- 2009 (33 nights) : $n_{\text{obs}} = 0$ (?) *working on!*

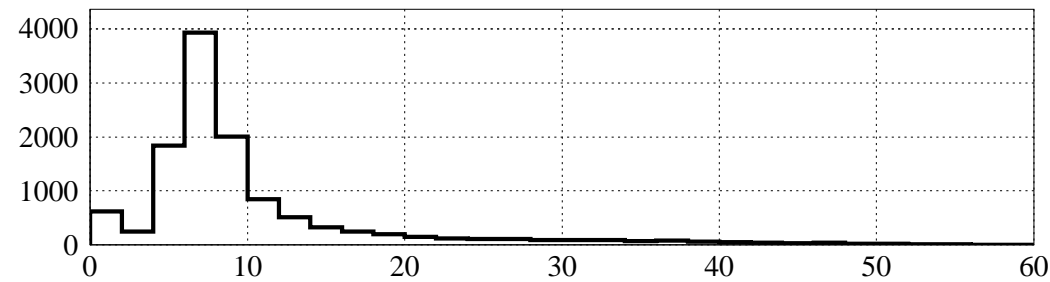
the pipeline: $t_{1/2}$ and the INT extension



OAB: $t_{1/2}$ (days) - OAB pipeline selected light curves

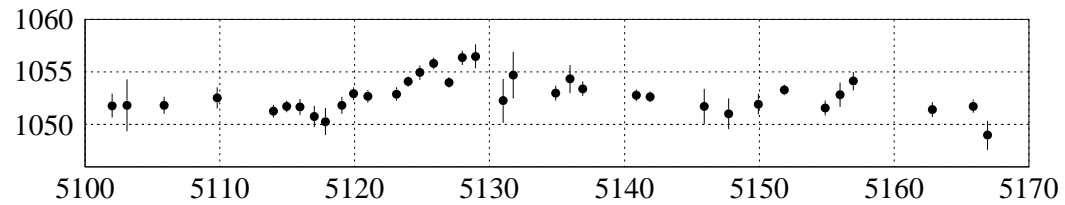


INT: $P_{lomb}(R)$ - OAB pipeline selected light curves

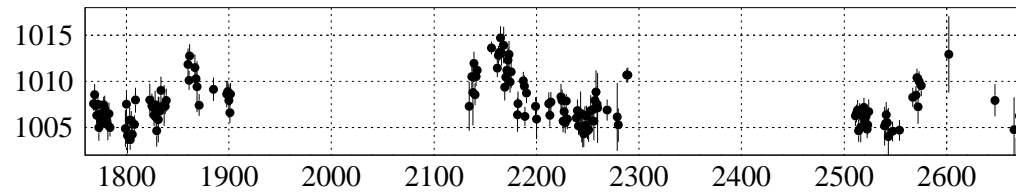


INT: $P_{lomb}(R)$ - random light curves

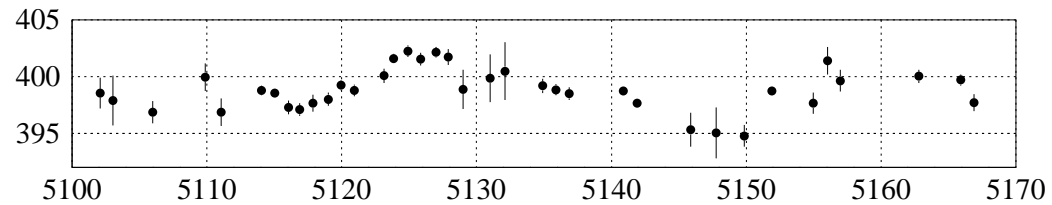
the pipeline: a few **rejected** light curves



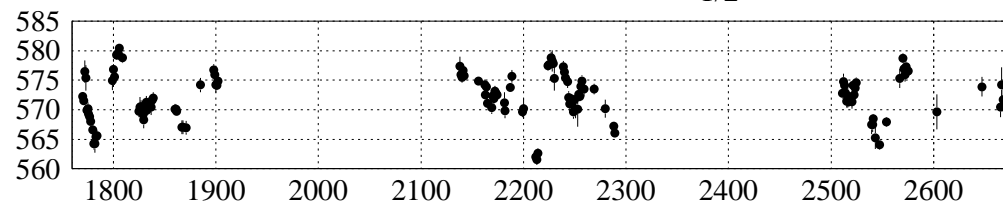
OAB selected light curve - $t_{1/2}=12$ days



INT extension - $P_{\text{lomb}}(R) = 31.8$



OAB selected light curve - $t_{1/2}=6$ days



INT extension - $P_{\text{lomb}}(R) = 43.4$

The expected signal: Monte Carlo simulation

- Astrophysical model (the M31 luminous components issues...?)
- Microlensing (amplification) model (Paczinsky + finite size)
- experimental setup (tuning is non trivial!)

$$N_{\text{exp}}^{(MC)} = \sum_i w_i \eta_i$$

$w_i \propto$ the microlensing rate

$\eta_i = 0, 1$ selection within the MC (light curve analysis only!!)

$$N_{\text{exp}} = \varepsilon N_{\text{exp}}^{(MC)} \quad \text{to be compared with } N_{\text{obs}}$$

ε : efficiency analysis on real data for events selected within the MC
(additional step beyond the MC to take into account *image* issues)

Monte Carlo efficiency corrected results: number of expected events

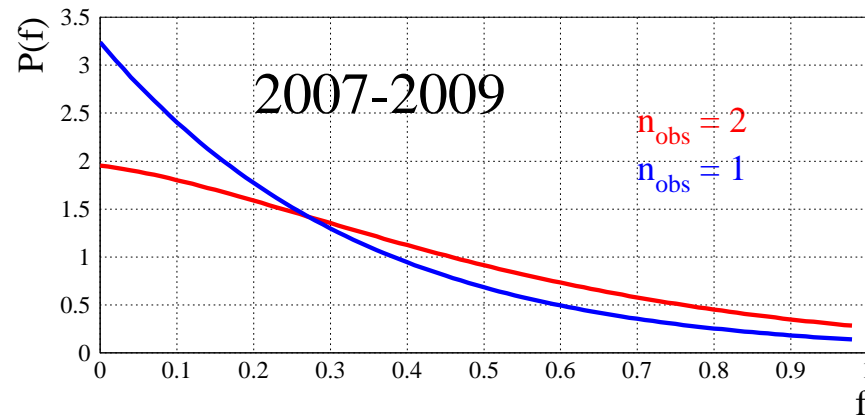
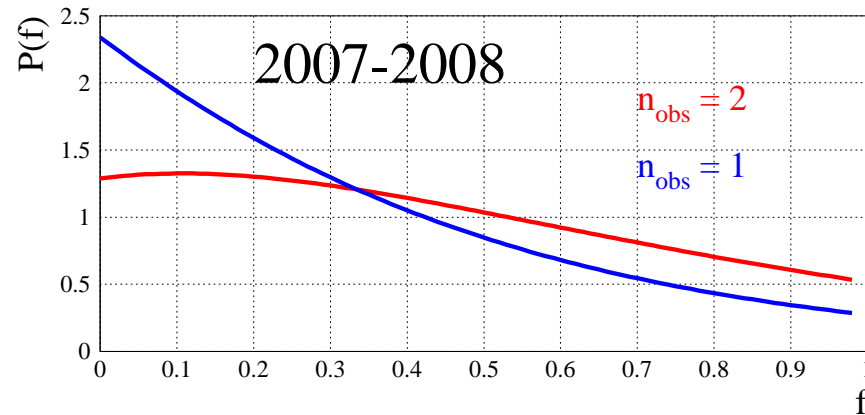
	$d < 4'$ OAB-N2	$d > 4'$ OAB-N1
2007-2008		
M31 SL	1.075	0.725
$f = 1, 0.5 M_{\odot}$ MACHOs	1.068	1.770
2007-2009		
M31 SL	1.532	0.996
$f = 1, 0.5 M_{\odot}$ MACHOs	1.476	2.417

♣ observed rate in agreement with **self lensing**

♠ **MACHO lensing**: statistics too small to draw firm conclusion

0.5 M_⊙ bounds on f through a likelihood analysis

$$L(f, \{m\}) = \prod_{\text{bin}, i} \exp(-n_{\text{exp}, i}) n_{\text{exp}, i}^{n_{\text{obs}, i}} / n_{\text{obs}, i}! \rightarrow P(f, \{m\})$$



SCN et al. 2011, in preparation

MACHOs: the hunt is still open ...