PAndromeda
- A dedicated M31 survey with Pan-STARRS 1 -

PIs: Stella Seitz, Ralf Bender

Team Members:
Arno Riffeser, Mihael Kodric, Johannes Koppenhoefer, Ulrich Hopp, Jan Snigula, Claus Goessl
& PS1 Science Consortium

Chien-Hsiu Lee 2015 January 21
19th Microlensing Conference
The PAAndromeda Team

PIs: Ralf Bender, Stella Seitz
Pan-STARRS 1

- Panoramic Survey Telescope And Rapid Response System (Pan-STARRS)

- Wide-field imager, 1.4 Giga pixel, ~7 deg$^2$ F.O.V with 0.25"/pixel

- 3Pi survey (Dec>-30 deg): 30,000 squared degrees in g, r, i, z, and y, about 1 mag deeper than SDSS

- Plus selected deep fields for SNe, planets, M31

Dupuy & Liu 2009
PAndromeda in a nutshell

- Observed M31 in 2010-2012, from July to Dec.
- 2% of the 3yrs PS1 observing time (including overheads)
- 1.8m PS1 telescope, ~7 deg2 F.O.V., 0.25″/pixel
- $r_{PS}$ and $i_{PS}$: up to 2 visits per night
- $g_{PS}$, $z_{PS}$, $y_{PS}$: sparse exposures in 3 yrs

Main goals:

- Constraining the compact matter fraction in the M31/MW halos
- Inventory of variables in M31, including Cepheids, binaries, long-period variables
PAndromeda footprint

WFC/INT \sim 0.3 \, \text{deg}^2, \quad \text{Calchi Novati+ (2005)}

MegaCAM/CFHT \quad 1 \, \text{deg}^2, \quad \text{Fliri+ (2012)}

PS1 \sim 7 \, \text{deg}^2, \quad \text{Lee+ (2012)}
Fig. 1.— The distribution of the observations of PS1 towards M31. We plot the monthly fraction of nights in the $r_{P1}$-filter during the 2010, 2011 and 2012 seasons. In general, the observations cover most of the time in the second half of each year.

Lee et al. (2014)
Data Analysis

Use our own image subtraction software *mupipe* (Goessl & Riffeser 2002) and *MDia* (Koppenhoefer 2013) to obtain high quality lightcurves in crowd fields.

- **warped images** delivered by IPP
  - **reference images** stack of the 70 best-seeing images
  - **visit stacks** stacks of all images taken in one visit

- **aligned visit stacks** matching zero points and background to reference image

- **difference images** visit stacks – PSF matched reference image

- **light curves**
  - a) light curves of each pixel
  - b) light curves of resolved sources

- **MACHO events** applying detection criteria to light curves of each pixel
- **variable stars** applying detection algorithms to light curves of resolved sources

Kodric et al. (2013)
Fig. 14.— Position of the six microlensing event candidates detected in the central $40' \times 40'$ region of M31 from PAndromeda. The coordinates, RA (J2000) in hour and Dec (J2000) in degree are also shown in the figure. The FOV of this image is $40' \times 40'$. Lee et al. (2012)
Microlensing – Lightcurve examples

6 short duration events, Lee et al. (2012)
2009 Cepheids
- Largest published sample to-date

Type I Cepheids trace the spiral arms  Type II Cepheids trace M31 halo

Kodric et al. (2013)
Cepheids
- Age distribution

Kodric et al. (2013)

Gordon et al. 2006

\[ t > 70 \text{ Myr} \]

\[ 70 > t > 40 \text{ Myr} \]

\[ t < 40 \text{ Myr} \]

Star formation ring at 10 kpc

Kodric et al. (2013)
Cepheids – PL relation

PS1 optical photometry

Pan-chromatic Hubble Andromeda Treasury (PHAT)

Kodric et al. (2013)

Dalcanton et al. (2012)
Cepheids - PL relation

PS1 optical photometry

HST IR photometry

Kodric et al. (2013)

Kodric et al. (2014)
Eclipsing binary
- M31 as a distance anchor

Three steps to the Hubble Constant

Credit: NASA, ESA, and A. Feild (STScI)
298 Eclipsing binaries

- Classification (Rucinski 93, Pojmanski 02):

\[ f(\phi) = \sum_{i=1}^{4} a_i \cos(2\pi i \phi) + b_i \sin(2\pi i \phi) \]

- Select bright detached systems for spec. follow-up:

Lee et al. 2014
Long-period variables

We found 5900 LPVs, among them 3800 with P>100d (mainly Miras)

600 semi-regular variables (SRVs)

Snigula et al. (in prep.)
Long-period variables
- IR P-L relation

M31 3.6 um – log P

LMC K – log P
Summary

- PAndromeda provides a wide, high-cadence view of M31.

- With image subtraction method, we are able to detect microlensing events and identify different classes of variables.

- The 3-year light curves, as well as classification of variables, will be released to the public.