New Dwarf Galaxies in the Nearby NGC 2784 Galaxy Group Discovered in KMTNet Supernova Program (KSP)

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KMTNet Supernova Program (KSP)

- N2784 group
- 10Mpc, \((m-M)=30\)
- BVI color image
- \textbf{400x60sec stack}
- 2015.2.~7.
- 9x7arcmin/2x2deg
- NGC 2784 galaxy
  + 2 dwarfs
Dwarf Galaxies in the Local Group

- Dwarf galaxy: $M_V > -17$ mag & $R_{eff} > 40$pc (GCs)
- The LG dwarf galaxies: Tolstoy+2009, McConnachie2012 ($N=105$, +SDSS)
- Missing satellite problem: Klypin+1999 (Moore+1999)
Dwarf Galaxies in Nearby Galaxy Groups

- Previous study: faint ($M_v > -10$ mag) & nearby ($D < 10$ Mpc) groups:
  - M81 group: Chiboucas+2009, $N=22$, 65 $d^2$, resolved, CFHT/MegaCam
  - M83 group: Muller+2015, 16 dwarfs, 60 deg$^2$, unresolved, CTIO/DECam
  - NGC 5128 group: Crnojevic+2016, Magellan/Megacam
  - M106 group: Kim+2011, CFHT/MegaCam
  - M101 group: Merritt+2014, Dragonfly Telephoto Array

- Finding new dwarf galaxy candidates &
  - Slope of LFs: much flatter (-1.2) than the slope (-1.8) of ΛCMD model.
  - We need new discovery of the faint dwarf galaxy in the nearby galaxy groups:
    (1) missing satellite problem
    (2) structure formation of galaxy groups in various environments
Observation

- KMTNet Supernova Program:
  - CTIO, SAAO, SSO
- N2784 fields: Feb.-Jul. 2015
  - N2784-3,4,5,6,7 (400x60 sec)
  - N2784-1,2,8 (6x100 sec)
- FOV of 4 chips: 2x2deg²
  - Total: 60 deg²
- $B(1.5'')$, $V(1.4'')$, $I(1.3'')$
Data Reduction

- Pre-processing: KMNet pipeline crosstalk, overscan, bias, flat fielding
- Astrometric calibration: SCAMP
- Combine: SWarp (median, BS 512 pix)

- STD magnitude: APASS (BV,gri)
  \[ B = b + c(B-V) + \text{zero} \]
  \[ V = v + \text{zero} \]
  \[ I = i + \text{zero} \]
- photometry: SExtractor
Searching for Dwarf Galaxy Candidates

- Visual inspection technique
- Selection criteria:
  1. with diffuse stellar light (>10")
  2. without a spiral structure
  3. not steep surface brightness
- Finding $\rightarrow$ V (B) check using zscale of DS9
- H.S.P. & M.P.
- 30 new dwarf galaxy candidates
  +7 previous known dwarfs
- Naming: KSP-DW???
Surface Photometry

- IRAF/ELLIPSE: 30+7 dwarfs (B, V, I)
- Limiting surface brightness:
  \[ \mu_V = 28.5 \text{mag}/''^2 \] (3sig, 27.0 shallow)
- Sersic fit: \[ \mu_0 + 1.0857(r/r_0)^n \]
  1. Central surface brightness:
     \[ \mu_{0,I} < 25.1, \mu_{0,V} < 26.1, \mu_{0,B} < 26.9 \text{ mag}/''^2 \]
  2. Sersic scale length: \[ 2'' < r_{0,I} < 23'' \]
  3. Sersic curvature index: \[ <n>_{med} = 1.2 \]
     \[ (n=1, \text{exponential surface profile}) \]
- Effective radius (r_{eff}) > 170 pc (3.5'')
- Total mag (I < 20.5, V < 20.6, B < 21.7)
Color-Magnitude Diagrams

- **Color:**
  
  \[ \langle \mu_{(B-V)} \rangle = (B-V), \quad \langle \mu_{(V-I)} \rangle = (V-I) \]
  
  \[ \langle (B-V)_0 \rangle \sim 0.7, \quad \langle (V-I)_0 \rangle \sim 0.4 \]

- \( \langle (B-V)_0 \rangle \) color is similar to
  
  those of M83 and M106 group.
The radial density is decreasing when the galactocentric distance from N2784 is increasing.

The outermost candidate is ~0.7 Mpc away from NGC 2784 galaxy.

Most of the dwarf candidates detected in the N2784 field are members of the NGC 2784 group.
N2784 dwarf candidates are well located in the area of the central surface brightnesses and effective radii of the dwarf galaxies in the M83 group and the Local Group: the $\mu_{0,V}$ and $r_{\text{eff}}$ brightens/increases when the dwarfs get brighter.

Sersic-$n$ curvature indices are also roughly consistent.

The dwarf galaxy candidates in the N2784 field may be genuine dwarf galaxies bound to the NGC 2784 group.

Within detection completeness boundary for a galaxy survey: assuming exponential surface profile, $r_{\text{lim}}=10''$, $\mu_{\text{lim}}=28$ mag/$''^2$
Luminosity Function

- Cumulative galaxy LF
- Cumulative Schechter function fit:
  - fit range: \(-18 < M_V < -8\) mag
- Faint-end slope (alpha):
  - N2784: \(\alpha = -1.2\)
  - others: \(-1.4 (M83) < \alpha < -1.0 (LG)\)
- But much flatter than the slope (\(\alpha = -1.8\)) expected by \(\Lambda CDM\)
We newly discovered 30 dwarf galaxy candidates around NGC 2784 galaxy using KMTNet Supernova Program (KSP) images:

- surface brightness: $\mu_V < 28.5$ mag/$''^2$
- central surface brightness: $\mu_0,V < 26.1$ mag/$''^2$
- total absolute magnitude: $M_V < -9.5$ mag
- effective radius: $r_{\text{eff}} > 170$ pc

The color and Sersic structure parameters of N2784 dwarf candidates are well consistent with those in other galaxy groups. The dwarf candidates show radial concentration toward N2784 galaxy center. Most of the candidates may be members of the NGC 2784 galaxy group.

The faint-end slope of the LF of the NGC 2784 group galaxies is $\alpha = -1.2$, which is much flatter than that of the LF expected from the $\Lambda$CDM model.