Chemistry of Ultra-Faint Dwarf Galaxies in the Dark Energy Survey

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and the DES Milky Way Working Group
20+ satellites discovered by DES

Stellar density field from SDSS and DES

Blue = Known prior to 2015
Red triangles = DES Y2Q1 candidates
Red circles = DES Y1A1 candidates
Green = Other new candidates

DES footprint in Galactic coordinates (~5000 deg²)

Bechtol+2015
Drlica-Wagner+2015
20+ satellites discovered by DES

- DES satellites have lower masses than previously-known dwarfs
- Potential for single nucleosynthetic event to influence all stars in galaxy
- Physical isolation (and reionization) preserves “fossil record” until today

Drlica-Wagner+2015
• Hor I has solar-type abundances, very unusual for a metal-poor stellar population

Red points: Hor I stars; colored points: stars in other UFDs; grey points: MW halo stars

Nagasawa+2018
Tucana II chemistry

• Tuc II has chemical diversity
• May be a surviving “first galaxy”
  – But for one rogue star

Ji+2016a;
Chiti+2018
Detailed chemical abundance patterns of stars in Ret II show high levels of rapid neutron-capture element enhancement ($r$-II).

Suggested explanation is a binary neutron star merger early in this small galaxy polluted the entire population of stars.
• Brightest star studied by Hansen+2017 shown to be mildly \( r \)-process enhanced (\( r-I \))

• Four more stars observed in core+tails, Li+2018

Grey lines define \( r-I \) stars; red squares are Ret-II stars

Marshall, Hansen+ \textit{in prep}
All five stars in Tuc III are $r$-I stars
- One star has some $s$-process as well

Grey lines define $r$-I stars; red squares are Ret-II stars

Solid: scaled solar $r$-process; dashed: scaled solar $s$-process

Marshall, Hansen+ in prep
The Origin of the Solar System Elements

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Graphic created by Jennifer Johnson

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ESA/NASA/AASNova
Cartoon of the theoretical phases of a binary neutron star merger event

Image credit: “Enrichment history of r-process elements shaped by a merger of neutron star pairs” Tsujimoto & Shigeyama 2014

Theoretical models make specific predictions of how these events should evolve with time.
Image credit: Las Cumbres Observatory
LIGO announces first GW signature of a binary NS merger

“Multi-messenger Observations of a Binary Neutron Star Merger”, LIGO scientific collaboration, VIRGO collaboration, and partner astronomy groups (including 3600+ authors!), 2017

Electromagnetic counterpart imaging followup
DECam is a great instrument for LIGO followup

Even with Virgo, LIGO’s localization of GW events was not very precise

DECam’s large FOV covered the region in only 10 pointings; Soares-Santos+2017
The future

- We will soon have observed every DES satellite star that can be studied at high resolution with today’s telescopes

DES Y1 candidates; Bechtol+2015
The future

• We will soon have observed every DES satellite star that can be studied at high resolution with today’s telescopes

• LSST should find ~100 more ultra-faint dwarfs
  – But only after several years

• Next generation telescopes will be essential in studying additional stars in the DES dwarfs as well as new objects discovered by LSST and others
GMT first light instruments

GMACS: the wide-field, moderate resolution multiobject spectrograph

The Giant Magellan Telescope

G-CLEF: an extreme precision radial velocity spectrograph
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• Next generation telescopes will be essential in studying additional stars in the DES dwarfs as well as new objects discovered by LSST and others

• By studying chemistry of satellites and halo stars, we will likely know the production sites of all elements on the Periodic Table in the next few years