Ultracompact binaries

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Overview

Astronomy, not physics with gravitational waves for these objects

Classes of double compact objects

- Evolutionary scenarios
- Strategies for finding them
- What we know about populations
- Key open questions

What we can hope for in the LISA era and what we need to do to get ready to exploit the LISA data

Classes of double compact objects

Red: not yet seen

Green: seen

Blue: remnant of process

Roman: no mass transfer

Italic: mass transferring

	WD	NS	BH
WD	*AM CVn* He WD-WD binaries Double CO WD binaries *R Cor Bor stars* *Type Ia?*		
NS	*UCXBs* Millisecond pulsars with He WD	Binary pulsars *Short GRBs* ALIGO	
BH	Fast WD orbits *XMMU J122949.7+075333* *47 Tuc X9*	ALIGO *Short GRBs?* Pulsar binaries	LIGO microlensing

Ingredients & tests of binary population synthesis

Initial mass function

Initial mass ratio distribution

Initial period distribution

Common envelope evolution

Stellar winds

Supernova kicks

Angular momentum transport in binaries (GWR, circumbinary disks, magnetic braking)

Disk winds

Tides

Accretion disk stability

Spectral energy distribution

Observational selection biases

Triples and other multiples

Dynamical formation

Expected numbers of source classes: accretors

BHXBs - typically few thousand in Galaxy, but see also B. Tetarenko et al. 2016 -- maybe hundred thousand, number with WD secondaries wildly uncertain

NSXBs - typically ~ 10^4 in Galaxy, with ~ half being UCXBs (e.g. van Haaften et al. 2013)

CVs - space density of ~10^-5 pc^-3 (Pretorius et al. 2007), so few million total, few hundred within 1 kpc - only this number is reasonably constrained from observations

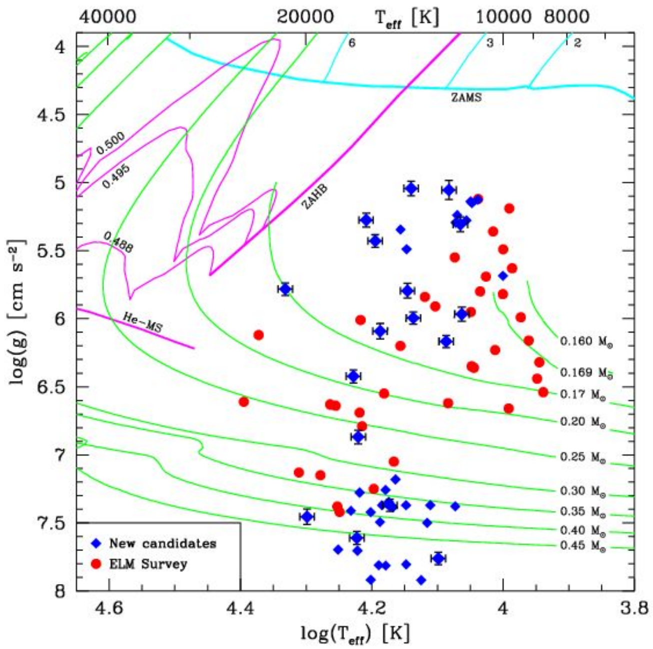
AM CVn - ~0.1 times the number of CVs (Roelofs et al. 2007), so few hundred thousand, total, few hundred within 1 kpc

Detached double white dwarfs

Present sample based on searching for He WDs and doing follow-up after

Could easily be double CO WDs, just not easy to find

These would be more likely to be Type Ia progenitors



Brown et al. (2013)

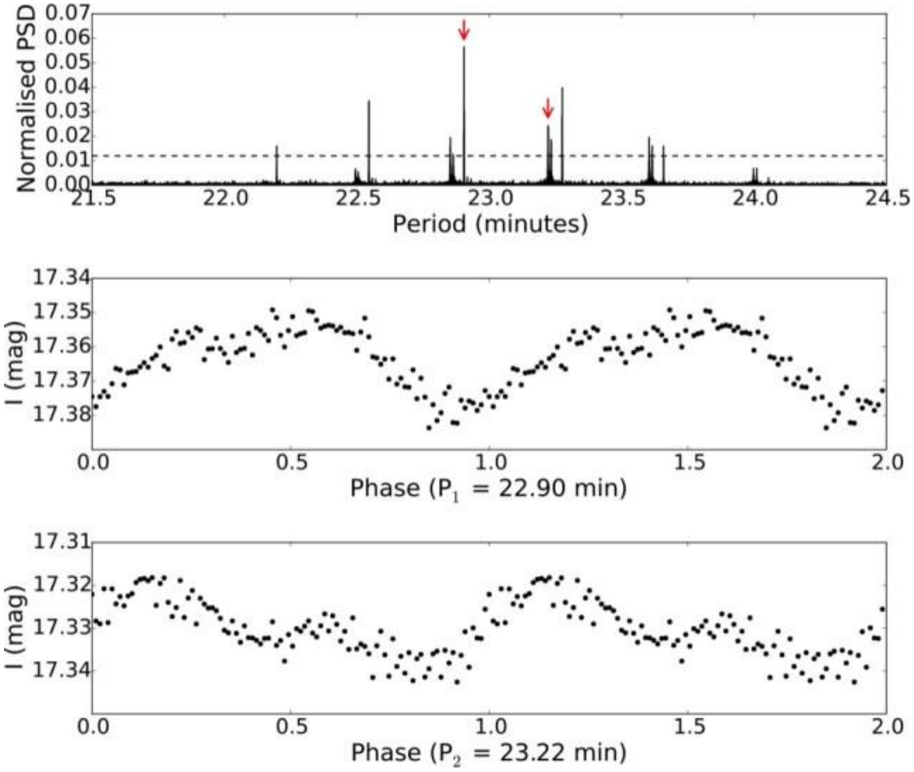
AM CVn stars

He WD-CO WD binaries with mass transfer

About 40 known members of class (Levitan et al 2013), mostly from SDSS, or from short PTF outbursts

Outbursters easiest class to grow, but necessarily will be longer orbital period systems

Newest short period system was X-ray selected from Chandra Galactic Bulge Survey (Wevers et al. 2016)



Wevers et al. 2016

White dwarf-neutron star binaries with mass transfer

Ultracompact X-ray binaries (UCXBs)

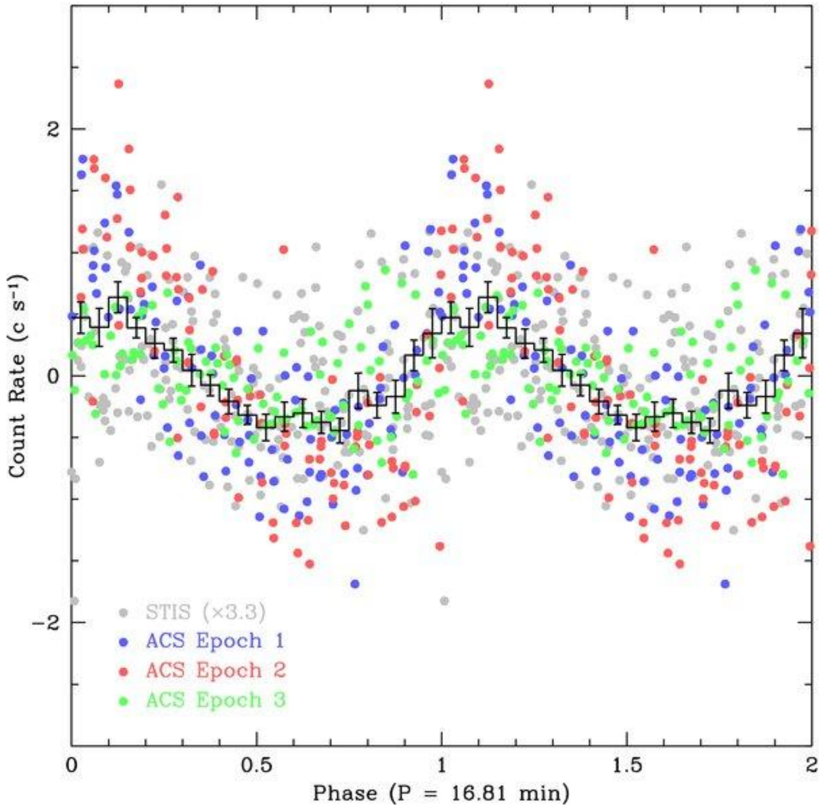
11 clear examples, some additional candidates

Most of the fastest ones are in globular clusters

Makes it harder to assess whether Pdot,orb “behaves”

Mixture of He, CO WD donors

UV period searches very effective!



Zurek et al. 2009

White dwarf-neutron star binaries without mass transfer

Pulsar timing has found many

These are generally wide binaries, unlikely to be LISA sources

May have other cases of WD-NS binaries without mass transfer that open up with LISA (e.g. pre-ultracompact X-ray binaries)

Either we find many of these or we learn about the initial periods of UCXBs

Double neutron star binaries

J0737 is a marginal test case, others probably too wide, 14 total objects

Key goals here:

Better statistics on populations, compare with ALIGO

Understand pulsar beaming better (O'Shaughnessy & Kim 2010)

Compare radio, X-ray beams (it's very hard to X-ray-select pulsars), requires X-ray timing capability!

Neutron star-black hole binaries

None yet known

Unclear if they're rare

Pulsars in these binaries could be highly accelerated, so even pulsar binaries might be more easily detected with LISA first, then electromagnetically

1 degree error boxes line up well with FOV of radio telescopes at low frequency, STROBE-X collimator

Searches for steep spectrum radio sources without timing signals may be valuable in the meantime (Bhakta et al. 2017; Chris Britt et al, in prep)

BH-WD binaries: extragalactic

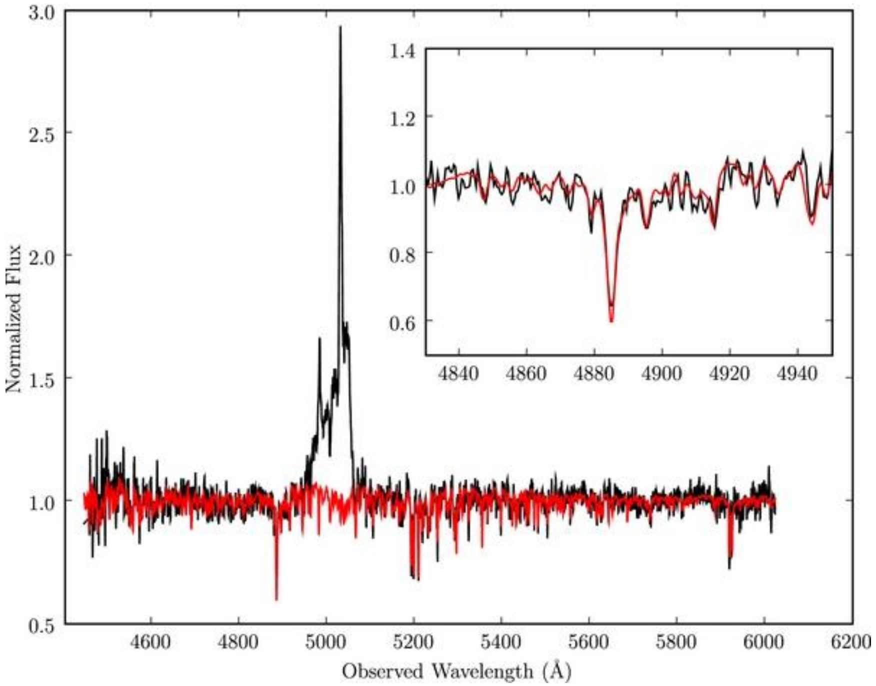
Strongest case, XMMU J122939.7+075333 in NGC 4472

Globular cluster persistent ULX (Maccarone et al. 2007)

Strong [O III] (Zepf et al. 2008), no other lines in optical

Tentative evidence for [OVII] in X-rays (Tana Joseph thesis, 2013)

Variability consistent with just changing absorption



Steele et al. 2014

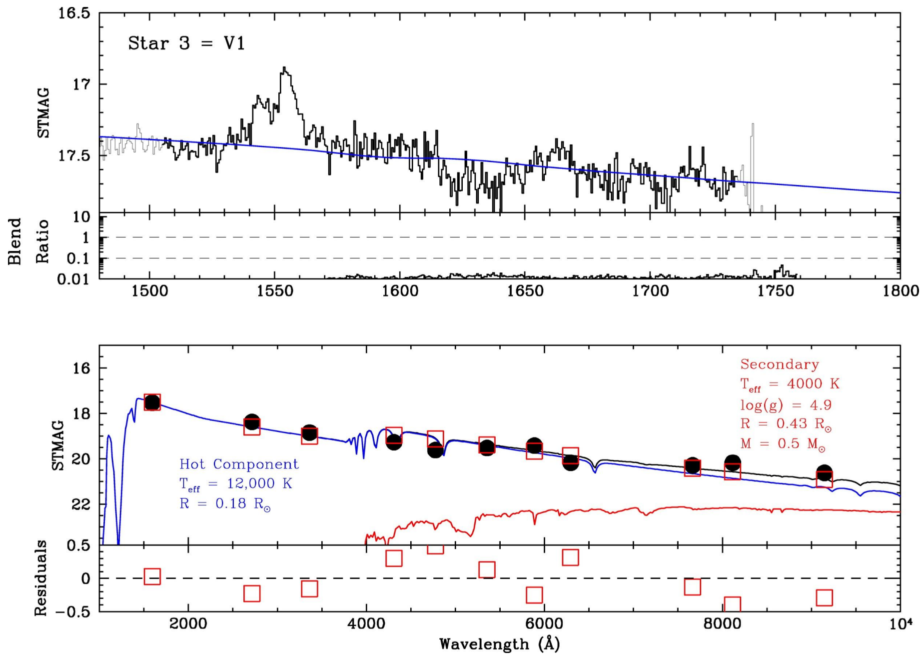
Black hole-white dwarf binaries: Galactic

One strong case, 47 Tuc X-9 (Miller-Jones et al. 2014; Bahramian et al. 2016)

Radio was key identifier, then showed 28 minute period, ***no H nor He***

Hard (Gamma~1) X-ray spectrum: bremsstrahlung emission due to higher <Z> of accreted gas?

Expect ~1 per cluster based on the discoveries to date, going to ~1 hr periods



Spectrum from Knigge et al. (2008);
re-interpreted in Miller-Jones, Bahramian

Double black holes

Right now, serious constraints only from LIGO

Microlensing may allow detections (Eilbott et al. 2016)

Rapid sweep-through LISA band allowing aLIGO follow-up (Sesana 2017)

Would be detectable out to Virgo Cluster distances (Kremer et al. 2018; Benacquista Amaro-Seoane, TJM, in prep)

- Standard siren distances
- Proper motions from NGVLA
- 6D probes of dark matter potentials!

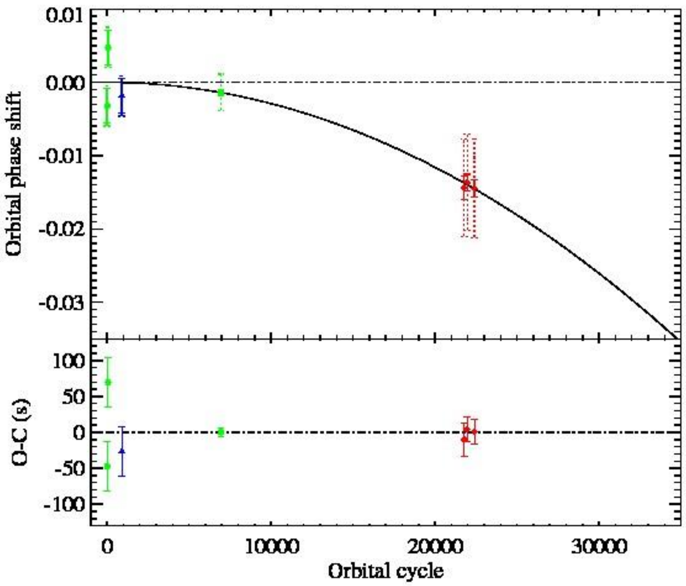
Learning from LISA I: Do we understand period derivatives?

Some short period XRBs have Pdot,orb orders of magnitude larger than expected from GWR

Tidal effects, especially in eccentric binaries, even when detached (e.g. Stroer et al. 2005; Valsecchi et al. 2012)

Disk instabilities and wind mass loss variations

Circumbinary disks (see also Muno & Mauerhan 2006)



Gonzalez-Hernandez et al. 2012, XTEJ118+480

Getting ready for LISA

X-ray surveys

Radial velocity curves/photometric orbital modulation curves: understand stability of periods for AM CVn systems

High cadence LSST data!

Accelerations within globular clusters, and progress toward testing IMBH models -- presumes we have GAIA distances ahead of time

Should be able to separate the GWR acceleration from the cluster acceleration

JWST -- look for mid-IR circumbinary disks around test binaries

Conclusions

Studies of double compact objects are in their infancy

LISA discoveries of compact binaries will be evolving slowly enough for electromagnetic follow-up

These will be useful more for doing astronomy with gravitational waves than for doing general relativity with compact binaries

- Binary evolution, common envelopes, kicks, etc.

- Probing mass distributions in globular clusters and galaxy clusters