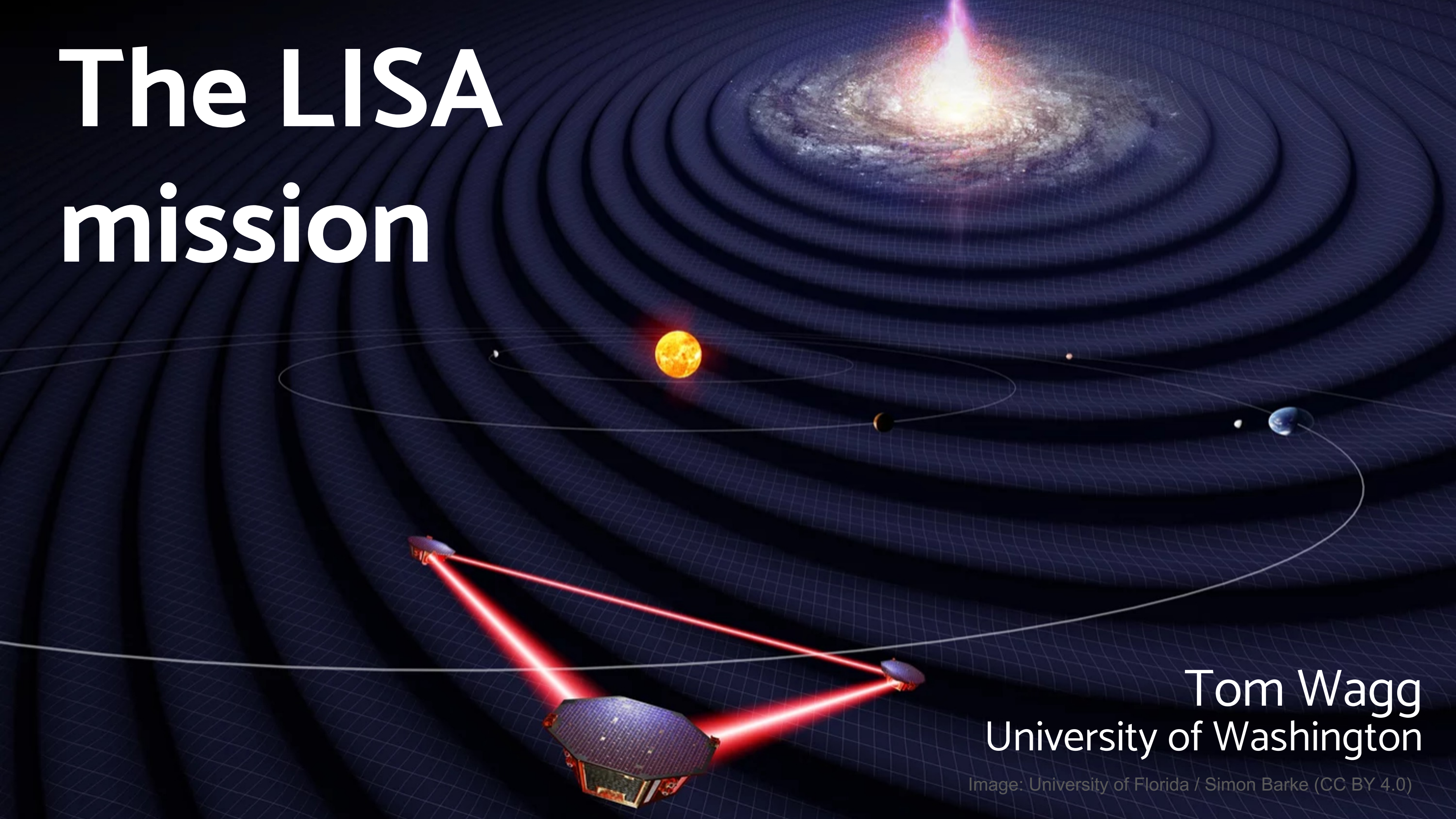
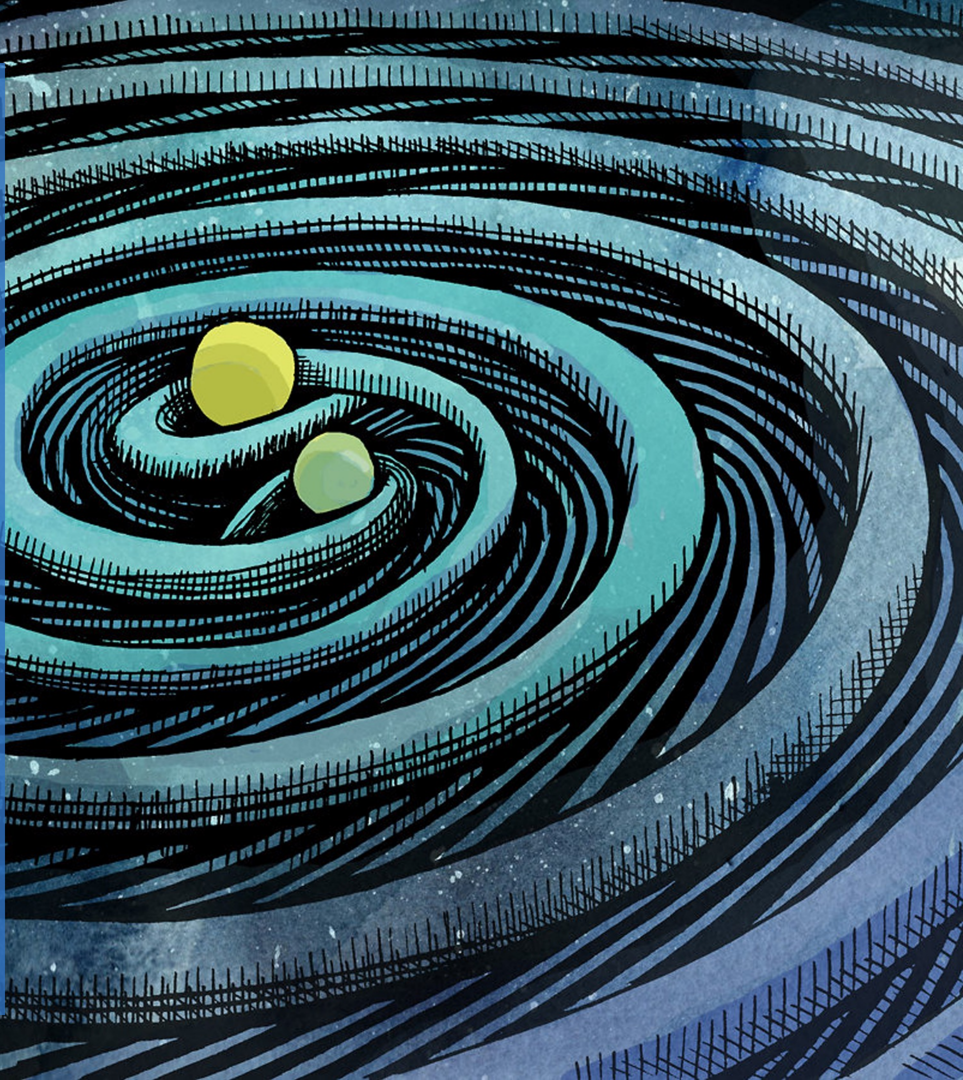


The LISA mission

Tom Wagg
University of Washington

LISA overview

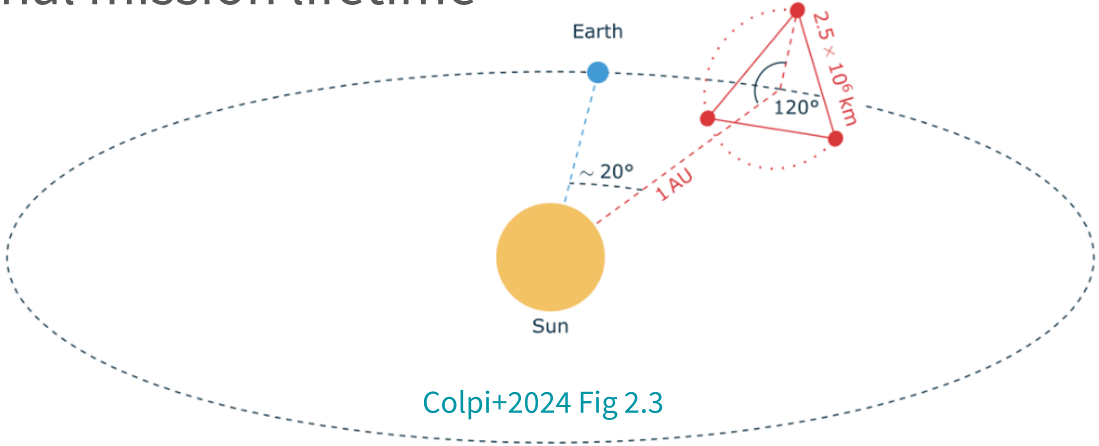
What is LISA?
Differences from other detectors?



LISA mission design

Laser **I**nterferometer **S**pace **A**ntenna consists of 3 spacecraft in equilateral triangle constellation, orbiting 20° behind Earth

4.5 year nominal mission lifetime



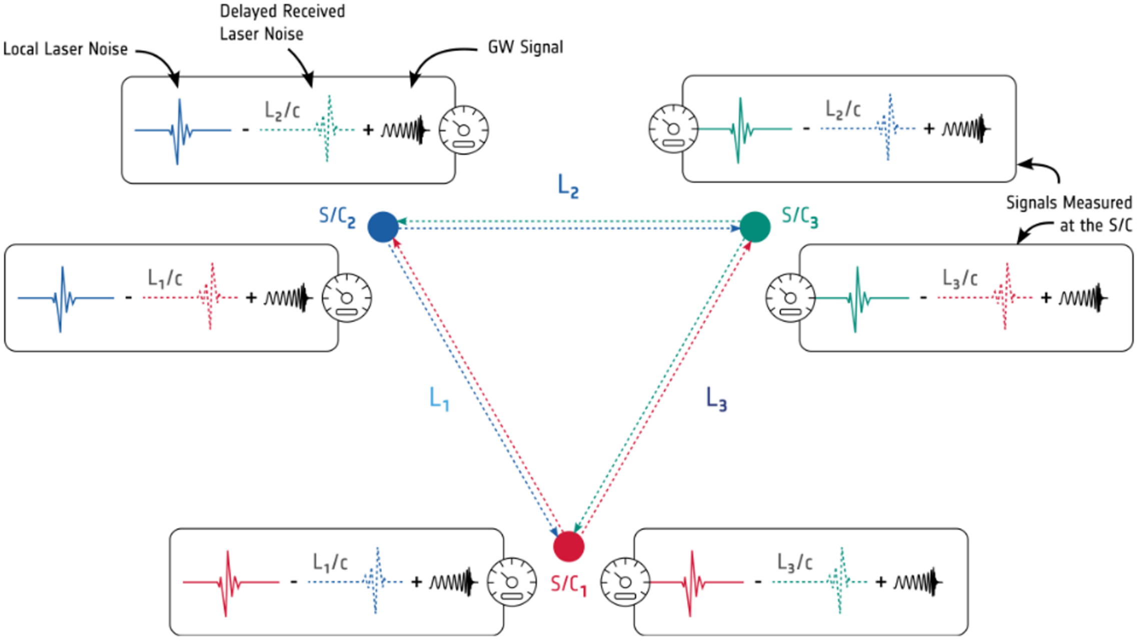
Colpi+2024 Fig 2.3

Time-Delay Interferometry setup

Each spacecraft emits and receives a beam

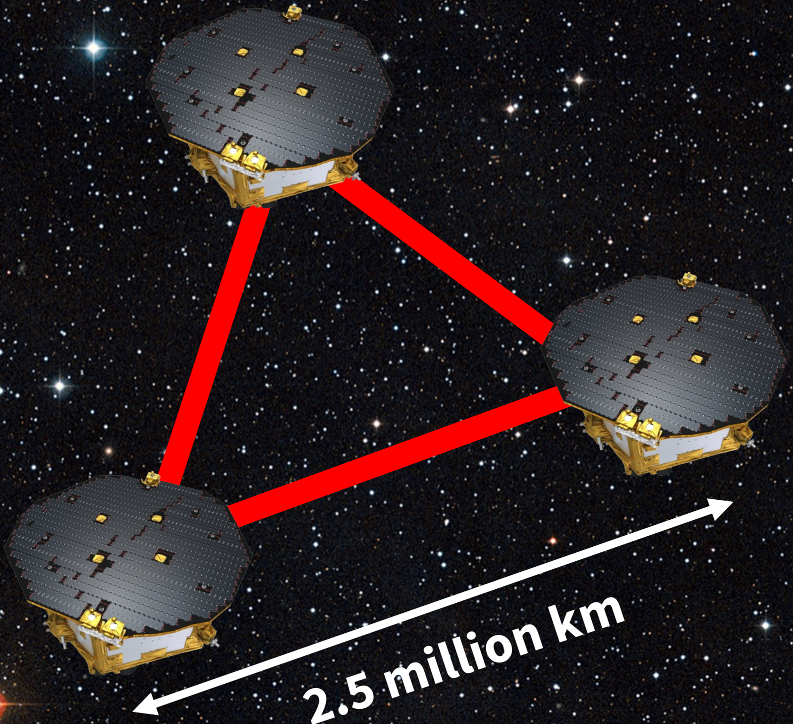
Pairs of lasers compared at end of each arm, can remove frequency noise

GW signals retained as different correlations between one-way measurements



Colpi+2024 Fig 2.5

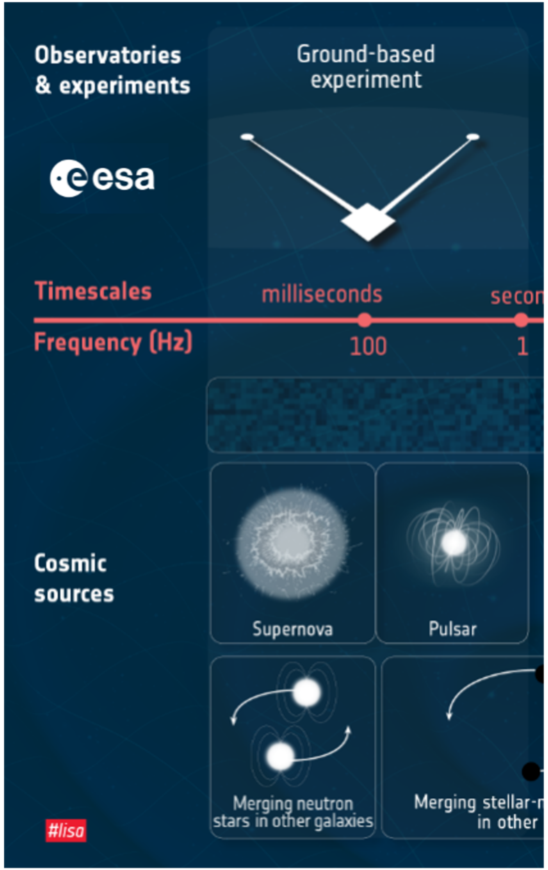
LISA is *extremely* sensitive



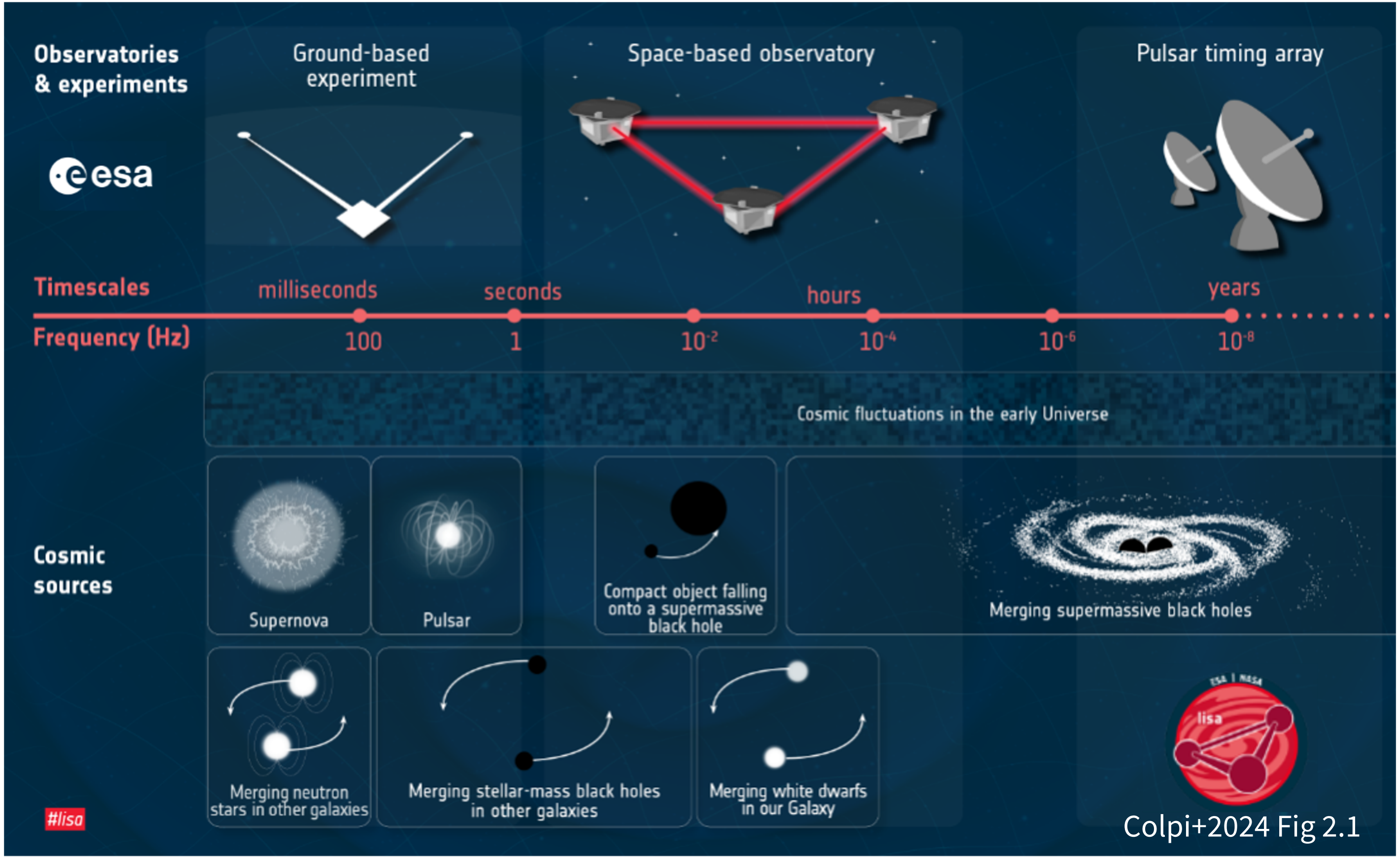
~62.5 times around the Earth

Detects shifts in separation **less than the width of a human hair**

LISA focuses on millihertz gravitational waves



LISA focuses on millihertz gravitational waves



Colpi+2024 Fig 2.1

LISA detects complementary sources

Different evolutionary stages

Stellar-mass binaries can be detected prior to merger

Multiband detections

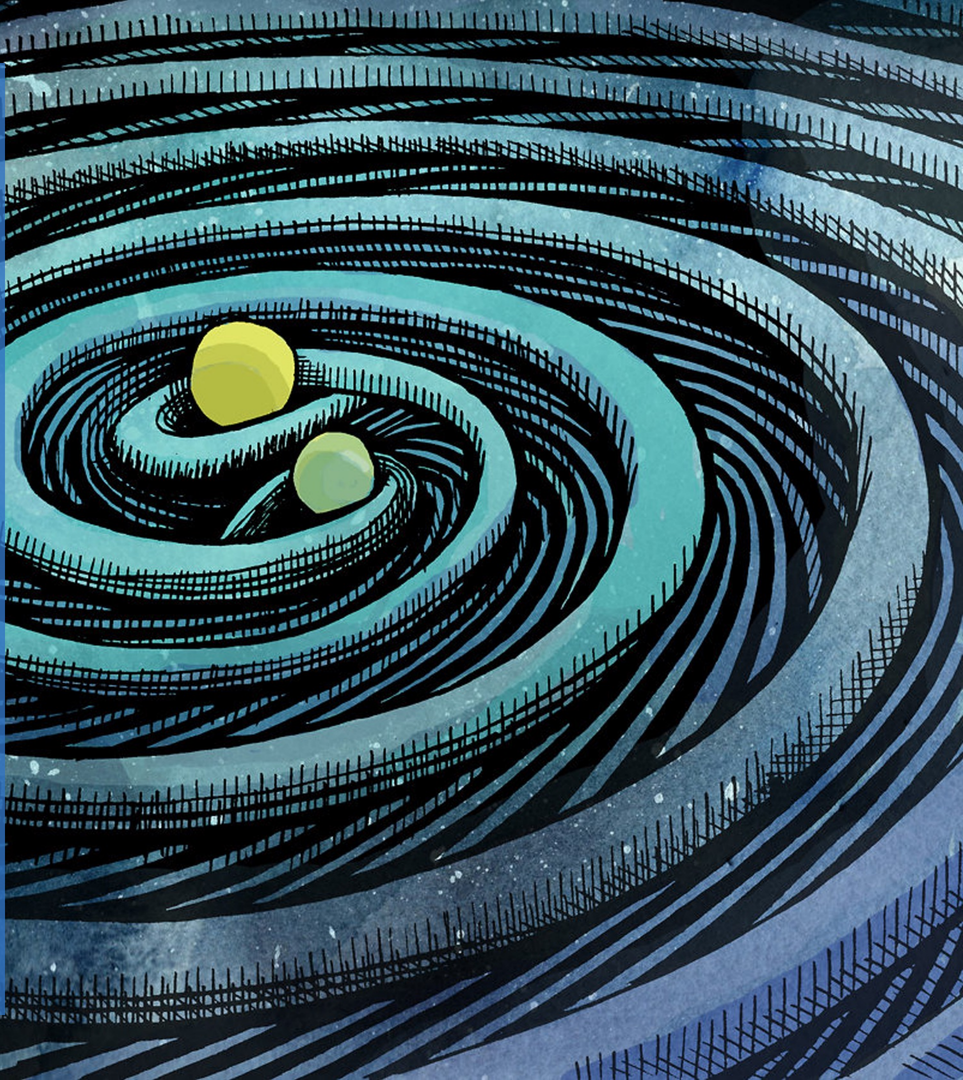
Some sources could be detected by LISA *and* other GW detectors

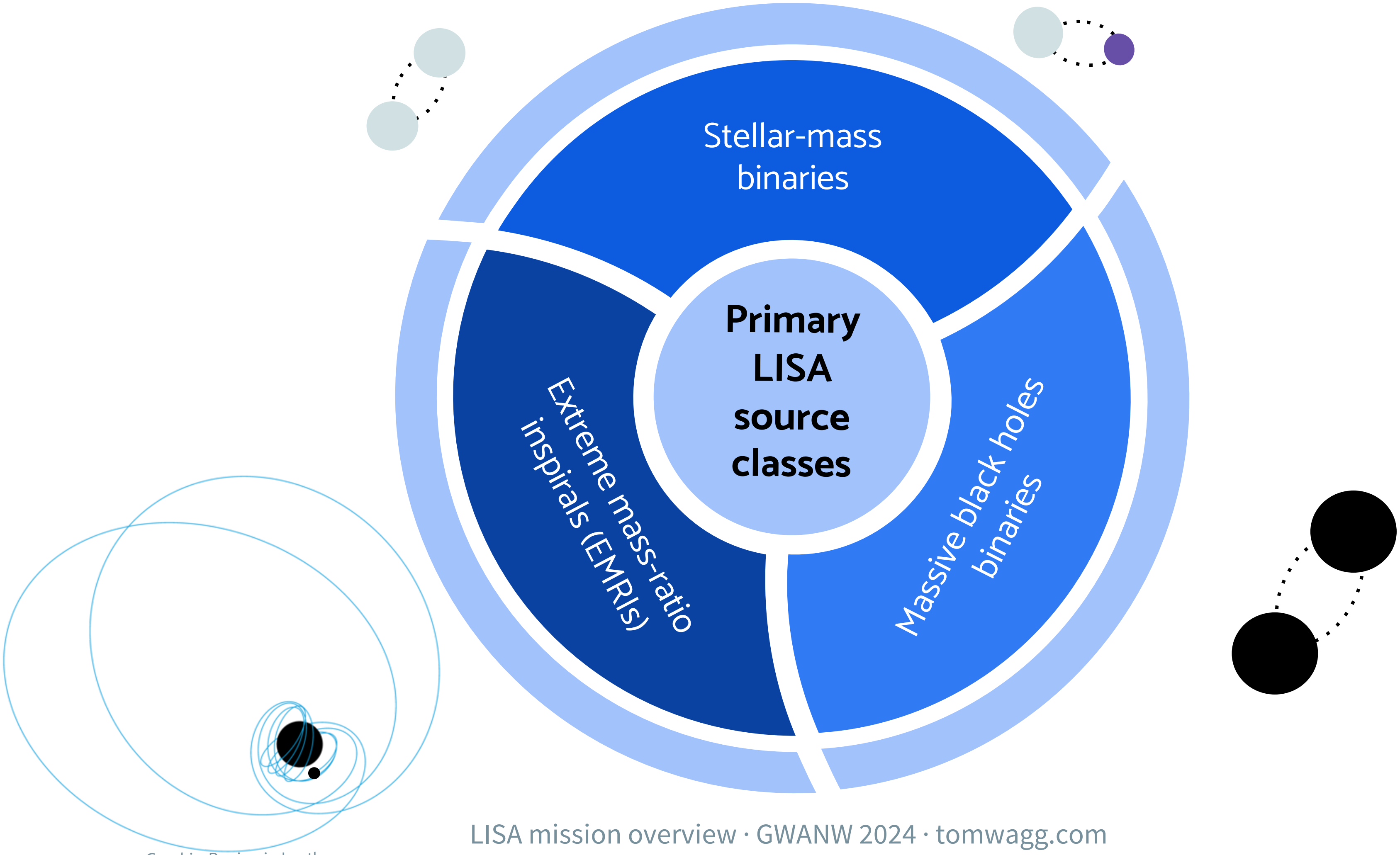
New sources

LISA can detect GWs from massive black hole binaries

Science Goals

(A subset of the) science enabled by LISA



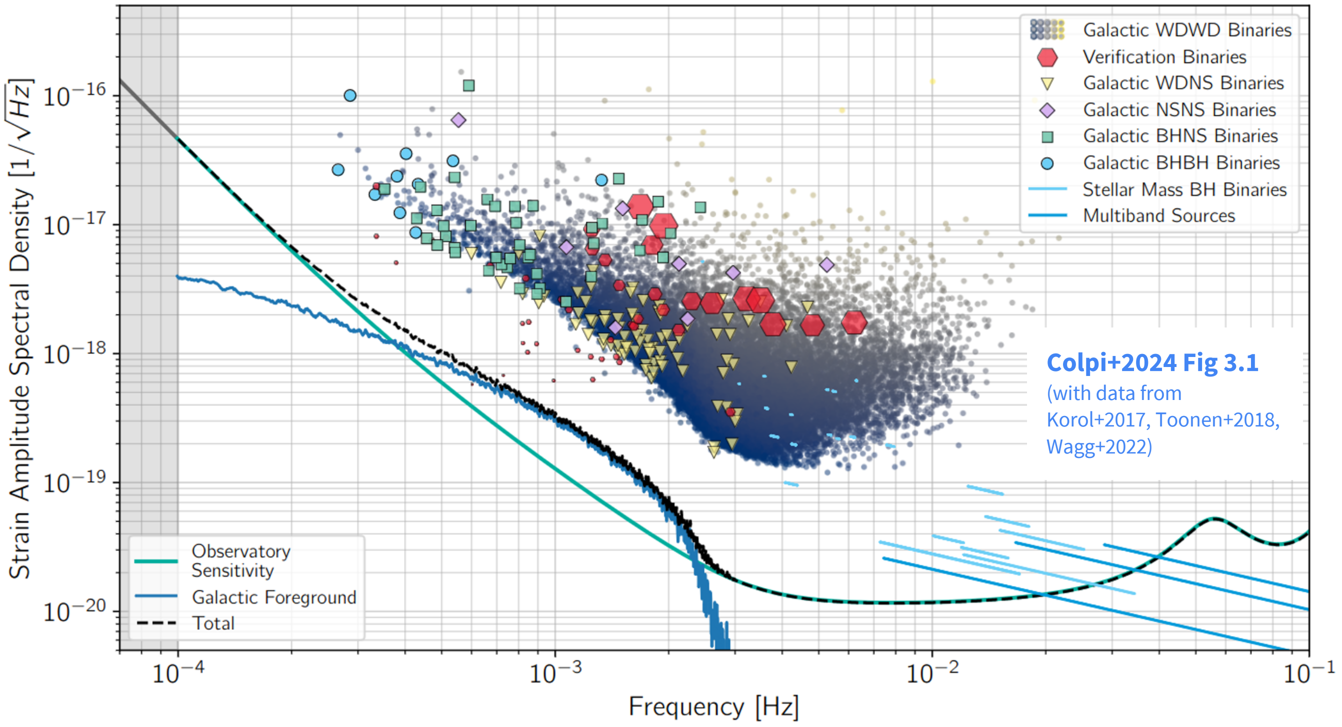


Graphic: Benjamin Leather

Stellar-mass binaries landscape

Unresolvable sources contribute to galactic confusion noise

~25,000 WDWDs (Korol+2017) and 10-100s more massive binaries (Toonen+2018, Wagg+2022) detected

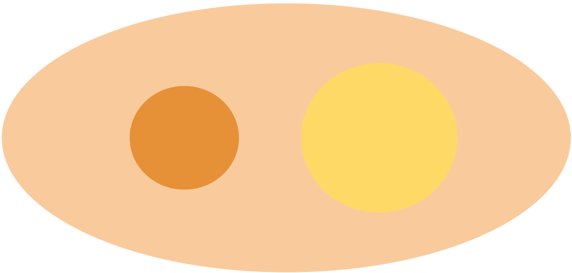


Colpi+2024 Fig 3.1
(with data from Korol+2017, Toonen+2018, Wagg+2022)

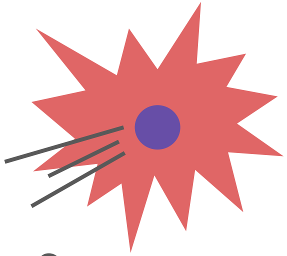
Stellar-mass binaries: Understanding binary evolution

Rate and distributions of close LISA binaries constrain aspects of binary evolution (e.g. Nelemans+01, Ruiter+10, Breivik+18, Lamberts+18, Wagg+22)

Mass transfer



Common-envelope

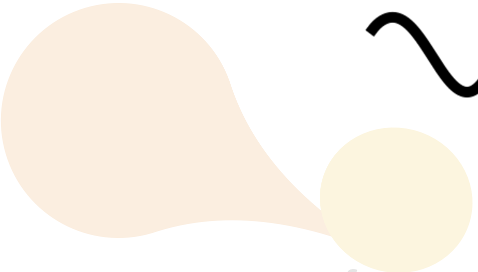


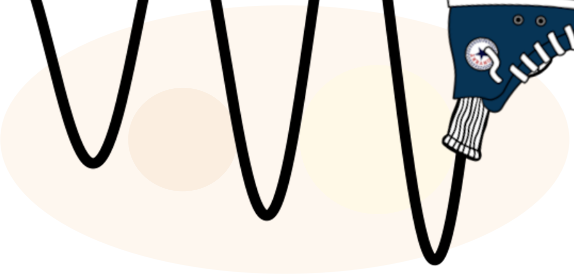
Supernova natal kicks

Sources otherwise likely *invisible* to EM - can measure MW mass distribution (e.g. Korol+21, Georgousi+23)

Stellar-mass binaries: Understanding binary evolution

Rate and distributions of close LISA binaries constrain aspects of binary evolution (e.g. Nelemans+01, Ruiter+10, Breivik+18, Lamberts+18, Wagg+22)





LEGWORK

More to come in my talk about `LEGWORK` tomorrow!

Sources otherwise likely *invisible* to EM – can measure MW mass distribution (e.g. Korol+21, Georgousi+23)

Stellar-mass binaries: Black hole formation

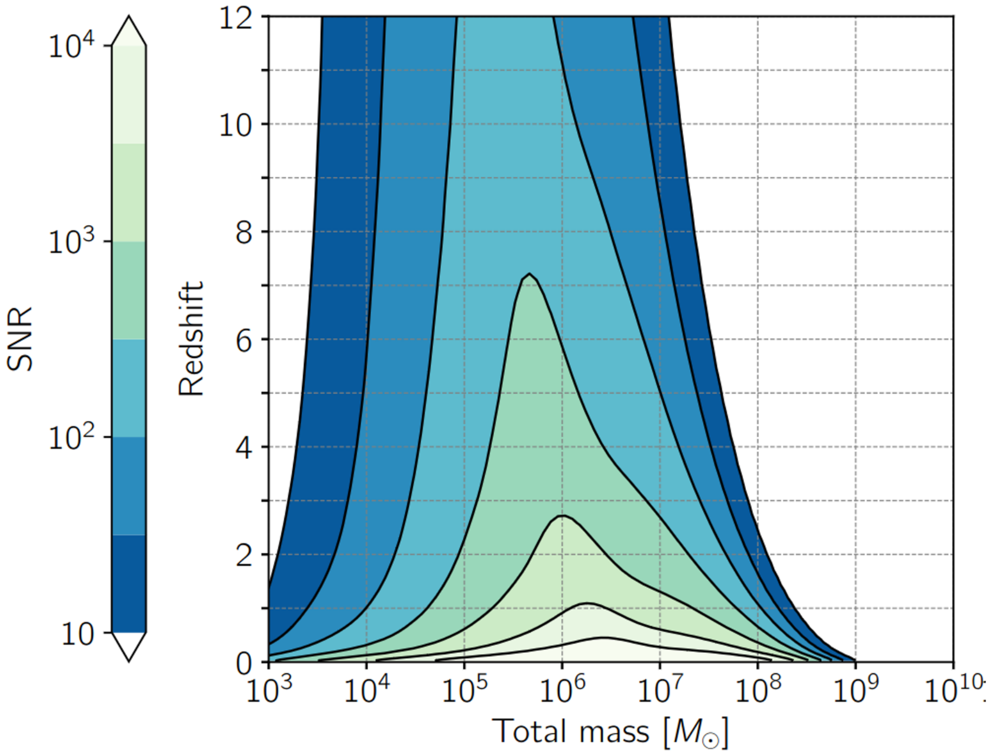
LISA advantage: measures **eccentricity** to precision of ~10^{-3} for SNR > 8 (Nishizawa+16)

Distinguish dynamical vs. isolated binary formation with 99% confidence (Nishizawa+17)

LISA will identify handful of multiband sources - can predict merger location to ~few deg^2 and time to ~several hours (Sesana+16)

Potential EM counterparts (Perna+16, de Mink+17, Tagawa+21) and cosmological probes (Muttoni+22, Baker+23)

Massive black holes: Origins of SMBHs



LISA is sensitive to SMBH and IMBH binaries at high redshifts with high SNRs

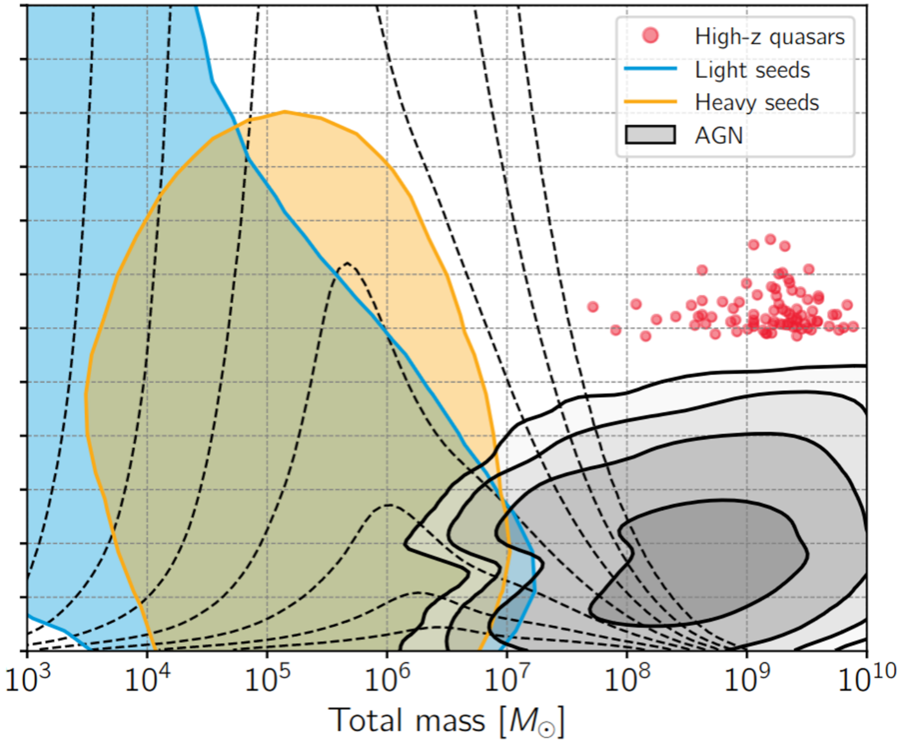
Massive black holes: Origins of SMBHs

Light seeds: formed from many metal-free stars (~10-100s Msol)

Heavy seeds: formed from single supermassive star (1e4-1e5 Msol)

Seed populations can be identified by LISA

Bonetti+19 (seeds), Wu+2022 (AGN), Yang+21 (quasars)



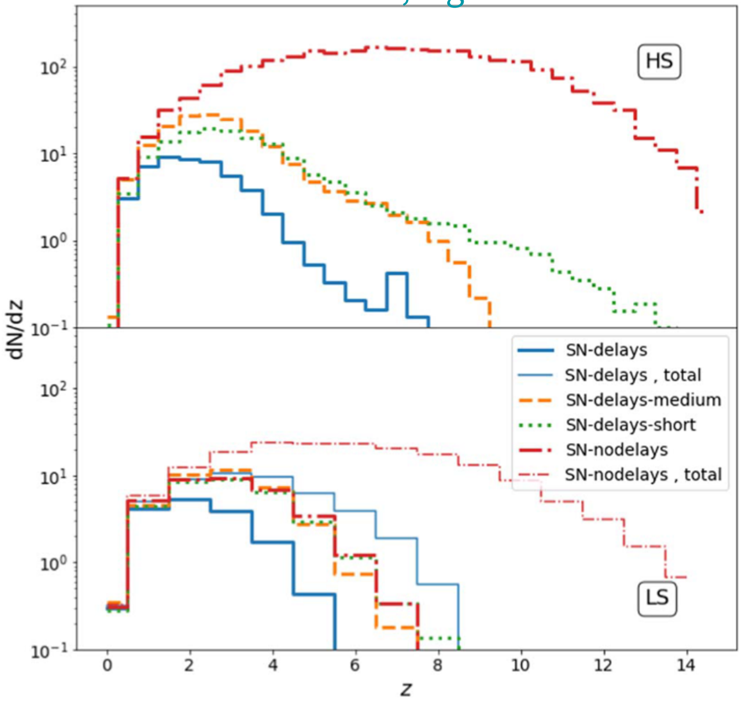
Massive black holes: Evolution

Dual AGN discovered…but only *candidate* MBHBs (de Rosa+19, Bogdanović+22)

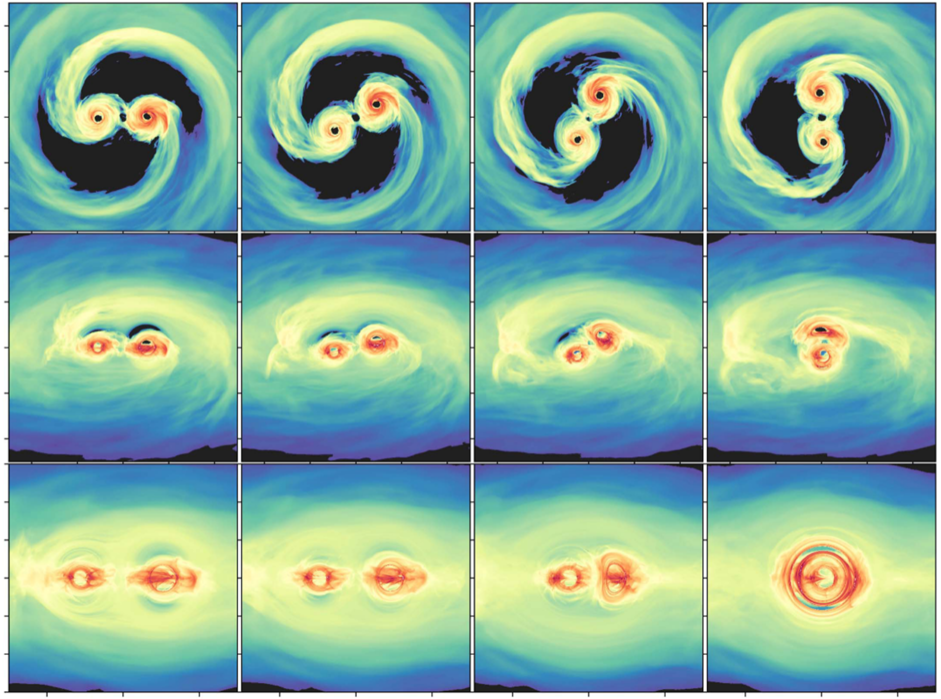
Rates + distributions inform merger histories of MBHBs *and their hosts* (e.g. Dayal+19)

Expect ~few-100 per year (e.g. Barausse+20)

Barausse+20, Fig 1



Massive black holes: Environment


d'Ascoli+19, Fig 9

EM counterparts = perfect lab for accretion & jet-launching in time-varying spacetime (e.g. d'Ascoli+19)

Consequences of merger on disc? Turn on of AGN? Multiwavelength collimated jet? Observe with multimessenger! (e.g. Corrales+10, Rossi+10, Yuan+21)

EMRIs (+IMRIs & XMRIs) landscape

IMRI

1e-3 < q < 1e-4

IMBH + something

EMRI

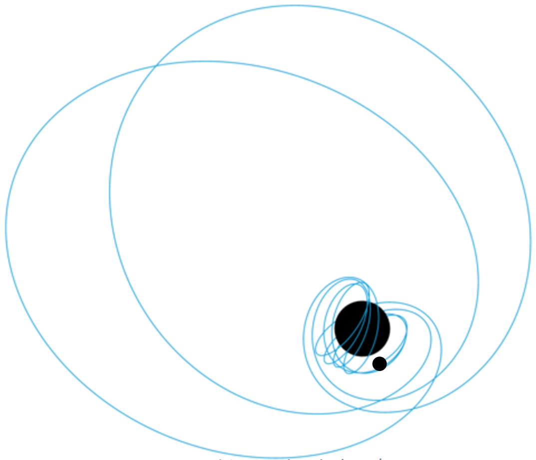
1e-6 < q < 1e-4

MBH + stellar mass object

XMRI

1e-6 < q

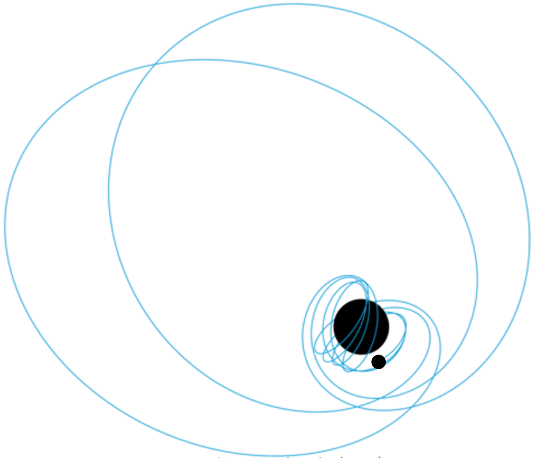
Something + brown dwarf



Graphic: Benjamin Leather

IMRIs up to ~few hundred (Arca Sedda+21), EMRIs ~few-several thousands (Babak+17), and ~10s of XMRIs (Berry+13)

EMRIs (+IMRIs & XMRIs) landscape



Graphic: Benjamin Leather

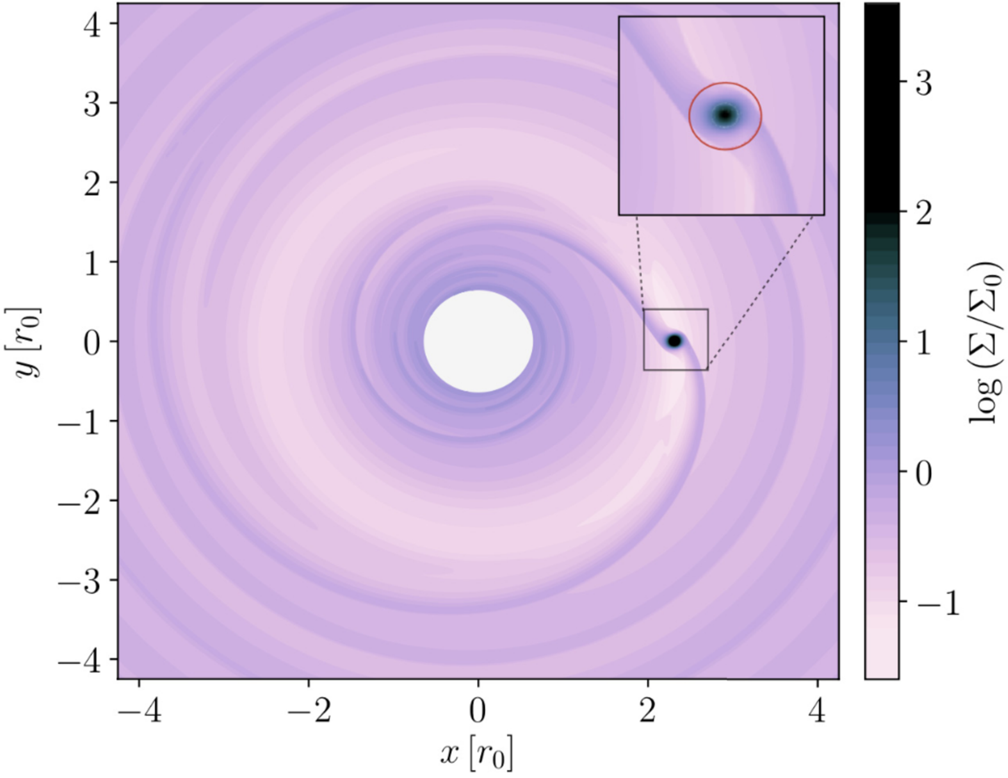
IMRI	EMRI	XMRI
1e-3 < q < 1e-4	**1e-6 < q < 1e-4**	**1e-6 < q**
IMBH + something	MBH + stellar mass object	Something + brown dwarf

IMRIs up to ~few hundred (Arca Sedda+21), EMRIs ~few-several thousands (Babak+17), and ~10s of XMRIs (Berry+13)

EMRIs: MBHs in quiescence

Unique probes of MBHs in quiescent state (no merger or accretion) and their environment (e.g. Derdzinski+21, Zwick+22)

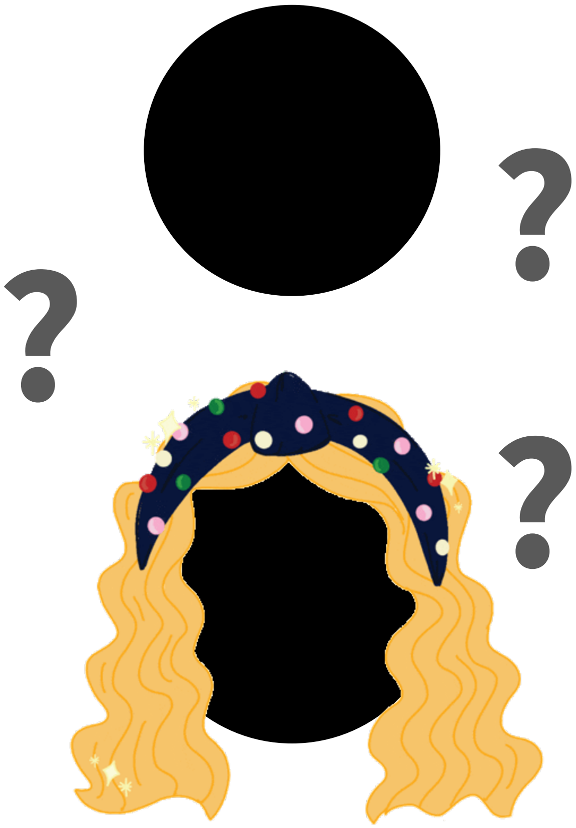
Derdzinski+21, Fig 1



EMRIs: Tests of gravity

EMRIs encode detailed information about the central object's geometry (Babak+17)

Provide constraints for deviations from Kerr and test the "no hair theorem" (Herdeiro+15)



And so much more!

Probe expansion rate of universe with bright/dark sirens

IMBH populations with IMRIs

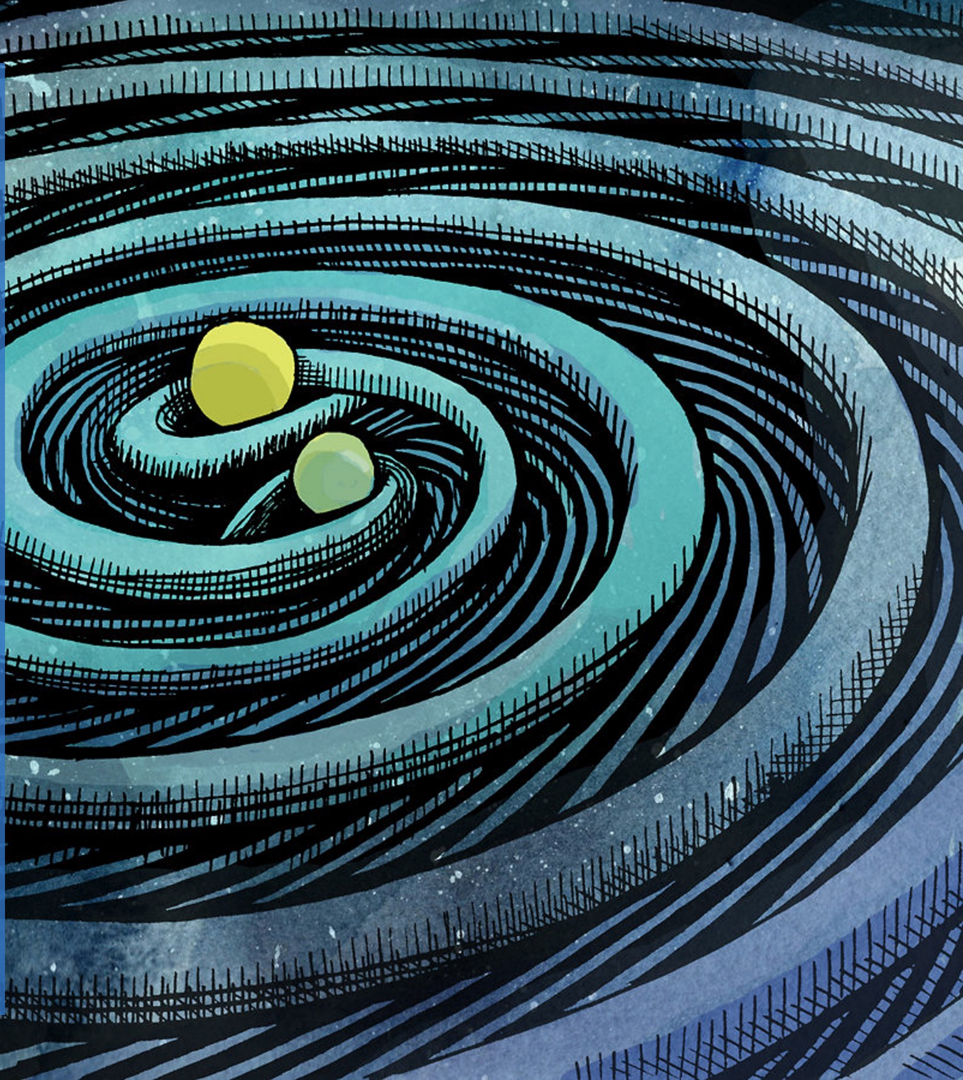
Stochastic GW backgrounds

GW bursts? Unforeseen sources?

Cosmic strings??

Mission Status

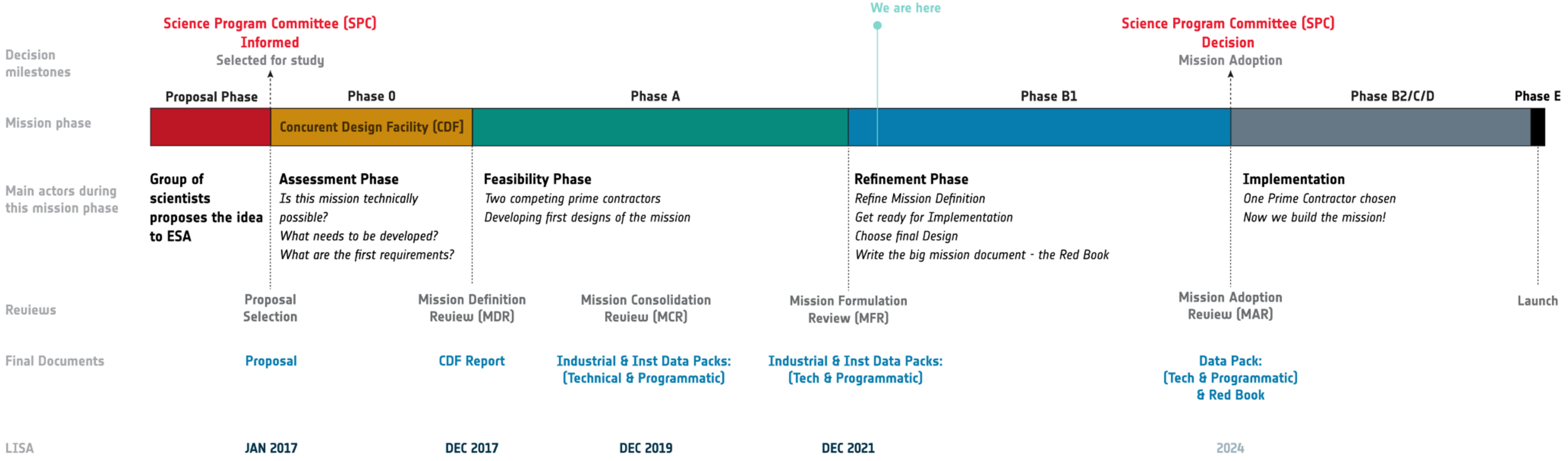
What is LISA ✅
Why is LISA ✅
When is LISA ?



LISA has been adopted!

As of January 25th 2024 LISA has been officially adopted 🎉🎉🎉

Entered Phase B2 (beginning hardware implementation!!)



Launch aimed for 2035 on an Ariane 6

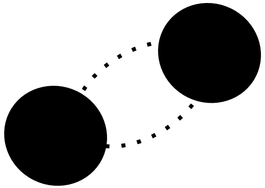
These are ESA timelines so error bars are fairly small on this date :D

There's a stable design for the technology that's robustly tested

Noise isolation and micronewton thrusters by LISA pathfinder - ground-based tests on the laser receiver/emitter - laser ranging with Grace Follow-On mission

LISA Takeaways

LISA will open an entirely **new window into gravitational waves**



We'll be inundated by **a host of new sources** (inspiralling sBHs, MBHBs, EMRIs and more!)

LISA will help us **constrain our understanding** of multitude of topics - binary stellar evolution to testing GR

🤓 Set your alarms for ~10 years and get excited! 🤓