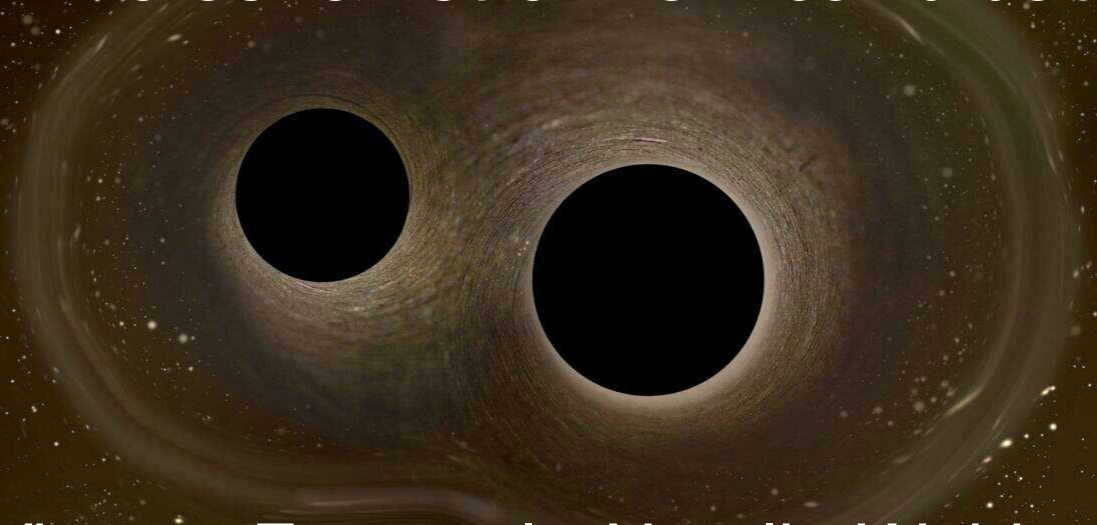
# Update in the search for close massive binary black holes: a list of new candidates



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Journées SF2A

irap
astrophysique & planétologie

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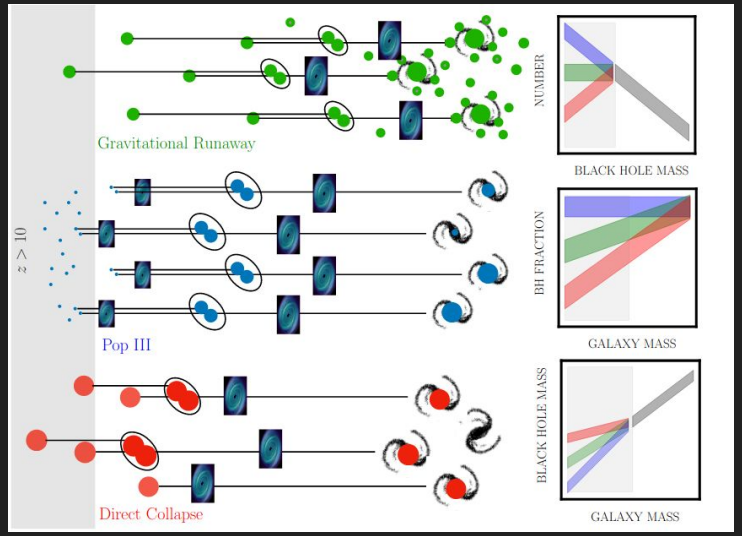
# Supermassive Black holes (SMBHs)

- Stellar mass black holes :
  - Mass : 5-60 $M_\odot$
  - End of life of massive stars

- SMBHs :
  - Mass : $10^5$ - $10^{10}$ $M_\odot$
  - Located in the center of galaxies

*Sagittarius A* : SMBH in the center of the Milky Way (credit: EHT)*

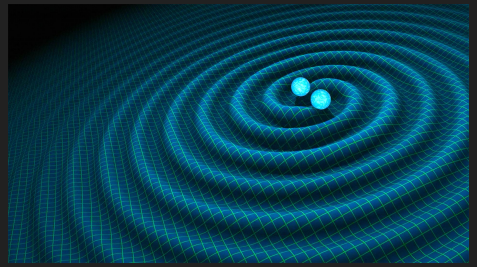
# Supermassive Black holes (SMBHs)




*Formation and evolution scenarios leading to SMBHs (Greene, Strader and Ho, 2020)*

Three different formation and evolutionary paths leading to SMBHs : which one?

# LISA

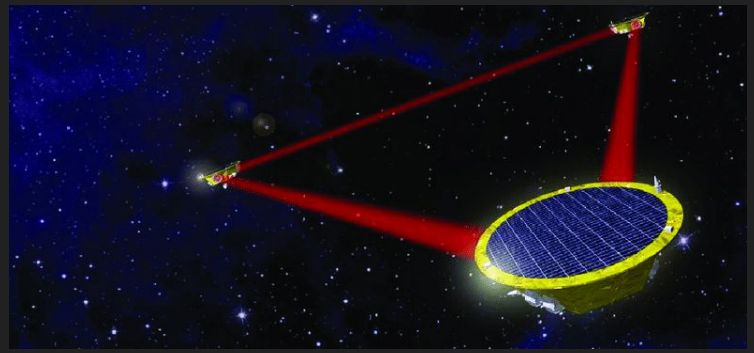


*Gravitational wave emission (Credit: NASA)*

- Compact objects binary produce gravitational waves

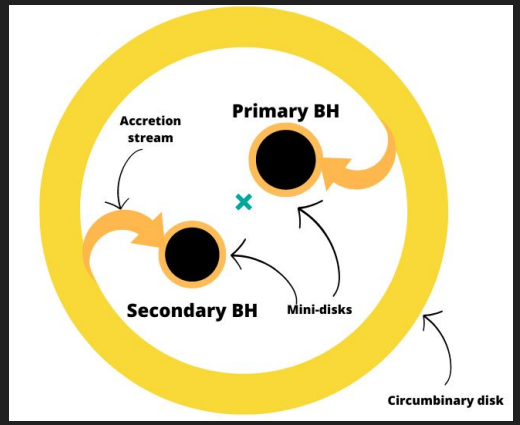
- First space-based gravitational waves observatory
- Frequency : 0.1 mHz to 1 Hz
- Range of detected binaries by LISA
  - $M \approx 10^{4\text{-}7}\ M_{\odot}$ to redshift $z \approx 15$

⇒ Creation of a LISA sources catalog



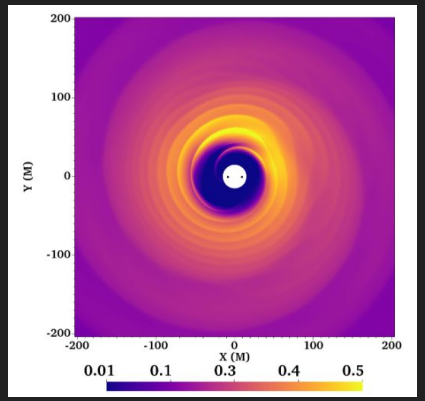
*Artist view of LISA observatory (Credit: ESA)*

# Massive Binary Black Holes (MBBHs)




*MBH Binary system*

- System separated in three parts :
  - Circumbinary disk
  - Accretion streams
  - Mini-disks




*Density map after 63 orbits in an equal mass MBBH (Mignon-Risse, Varniere, Casse, 2023)*

- Periodic optical variability :
  - Blob of gas in the circumbinary disk
  - Periodic accretion flow
  - Doppler boosting emission
- Double peaked emission line

# Optical catalogs

*Catalina Sky Survey (Credit: University of Arizona)*

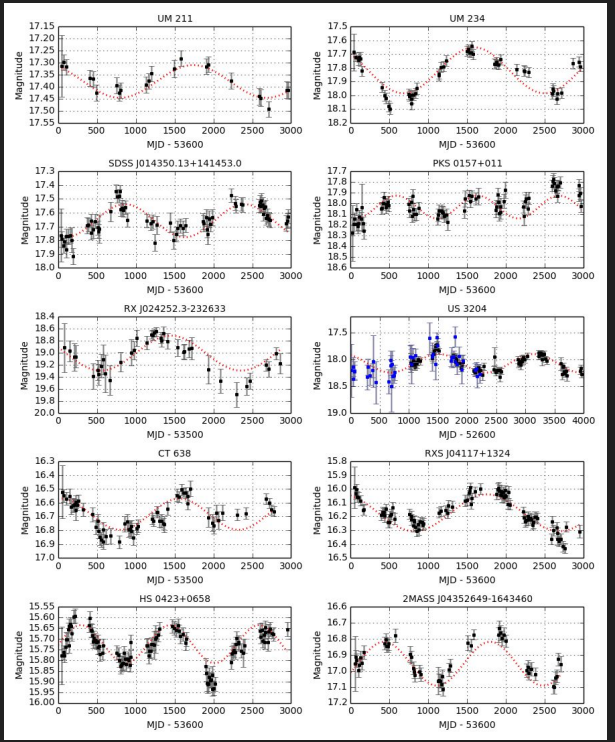
- Catalina Real-Time Transient Survey (CRTS) optical catalog :
  - Mt Lemmon Survey
  - Catalina Sky Survey
  - Siding Spring Survey
- Observations : ~2005-2015 in V band
- ~ 500 million objects

- Zwicky Transient Facility (ZTF) :
  - Palomar observatory
- Observations : ~2017 - ongoing in r, g and i filters
- ~ 7 billion sources

*Palomar observatory (Credit: Caltech)*

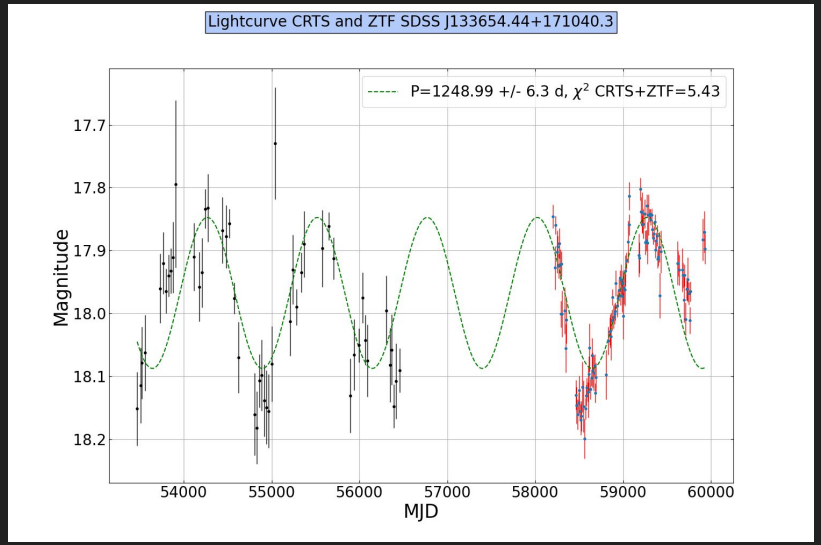
# Known possible candidates

- Many dual-MBBHs at kpc scale already discovered
- few mpc MBBH candidates
  - OJ 287
  - 111 identified in Graham et al, 2015
- Intrinsic quasar variability due to the accretion process (red noise)




*Periodic variabilities identified in quasars from CRTS survey (Graham et al, 2015)*

# Lightcurves

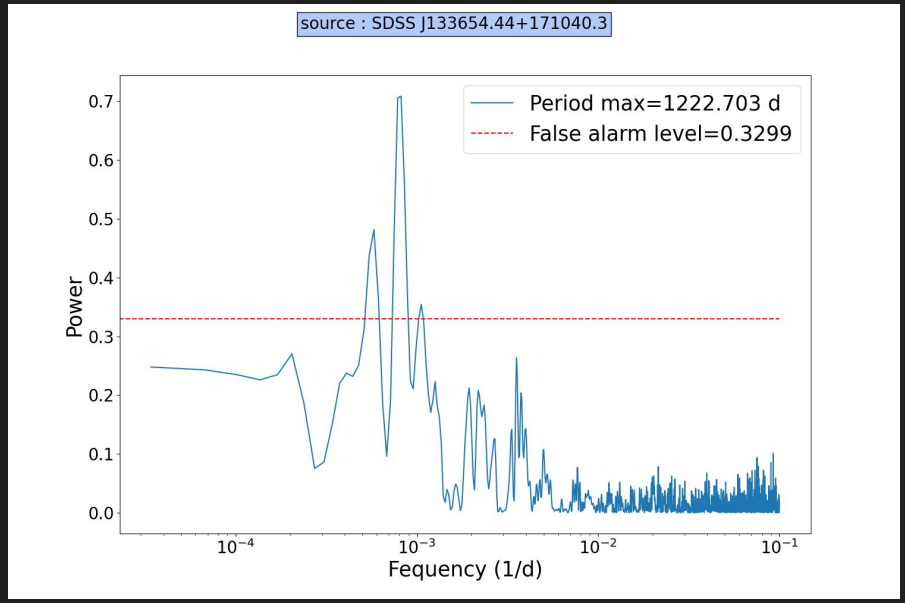



*SDSS J133654.44+171040.3 CRTS (black) and ZTF (red) optical lightcurve*

- Confirmed 24 out of 111 graham candidates thanks to ZTF observations
- Identified ZTF variable sources in the center of galaxies
- Searched for periodicities
- Included CRTS observations to increase the number of periods
- Identified 10 strong candidates and created a catalog of more possible MBBHs

# Lightcurves

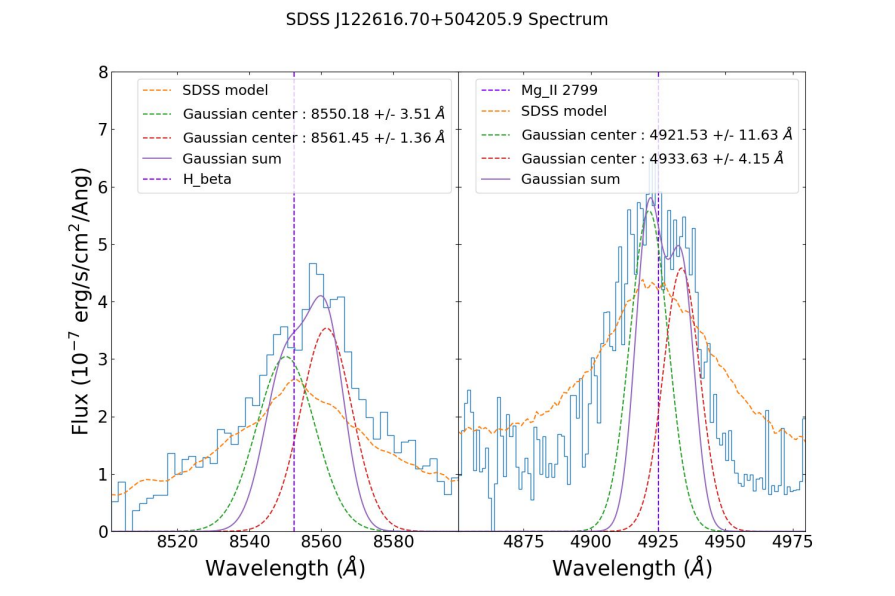
- Sample of 34 strong MBBHs candidates
- Validated found periodicities with Lomb-Scargle periodogram




*SDSS J133654.44+171040.3*
*Lomb-Scargle periodogram*

# Results

- Searched for confirmation of found candidates in SDSS spectra
- 2 out of the 34 candidates exhibit double-peaked emission line
- Submitted an ESO proposal to observe optical spectrum of found candidates
- Started a multi-messenger search in PTA data
- Foustoul et al, in prep




*J122616.70+504205.9 SDSS $H_\beta$ (left) and $Mg_{II}$ (right) double peaked emission lines*

# Conclusion and future work

- Created a catalog of possible merger candidates
- Found merger are important at cosmological distances but still today
- Multi-messenger follow up to validate the identified variabilities and constrain the origin of the observed variations.
- Vera C. Rubin first light planned for december 2023, will be useful to find binaries with closer separation

*Thank you*