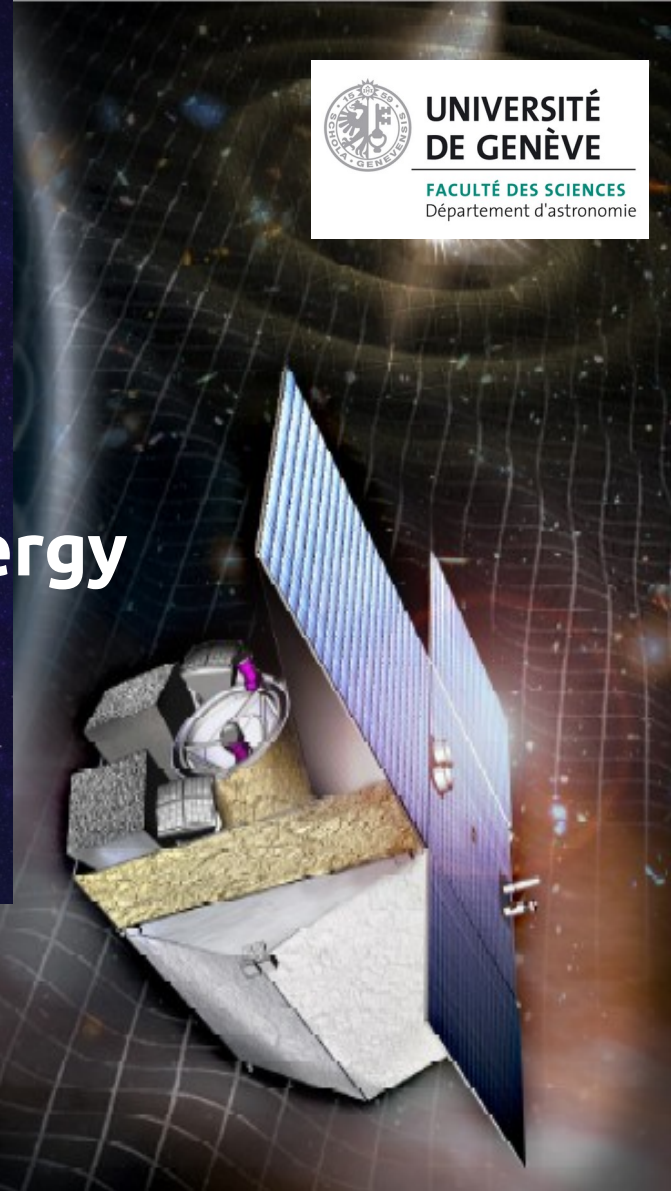
LISA and its possible synergy with THESEUS



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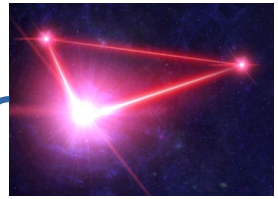
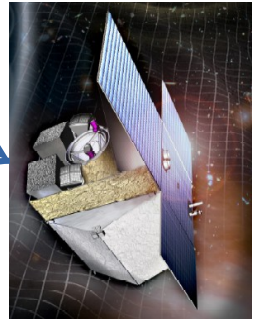
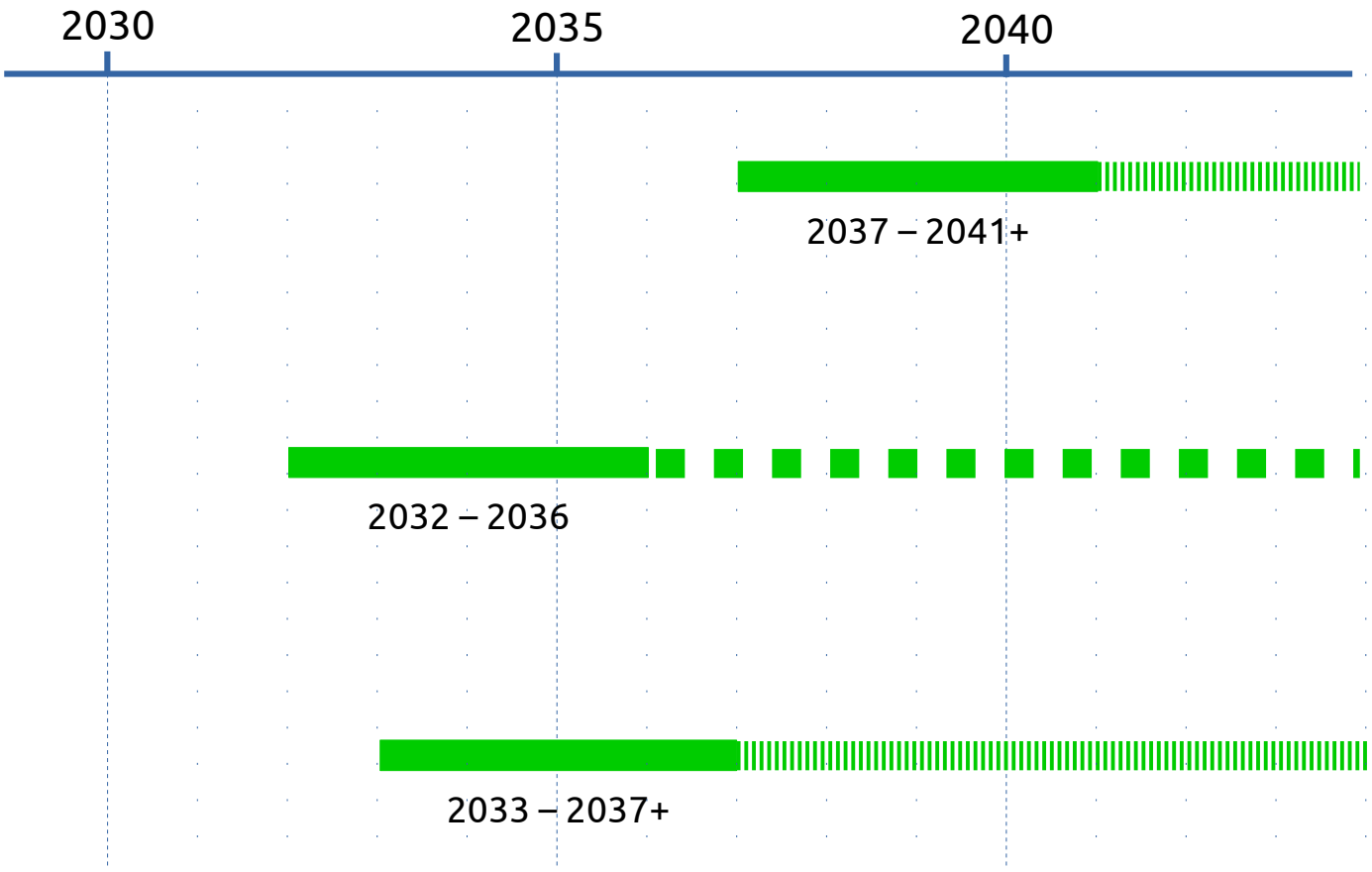
Caveat 1






Credit: MPE, ESA and Athena Team


2030
2035
2040
2037 – 2041+
2032 – 2036
2033 – 2037+

Caveat 2

White Paper: Athena-LISA Synergies

Athena-LISA Synergy Working Group:

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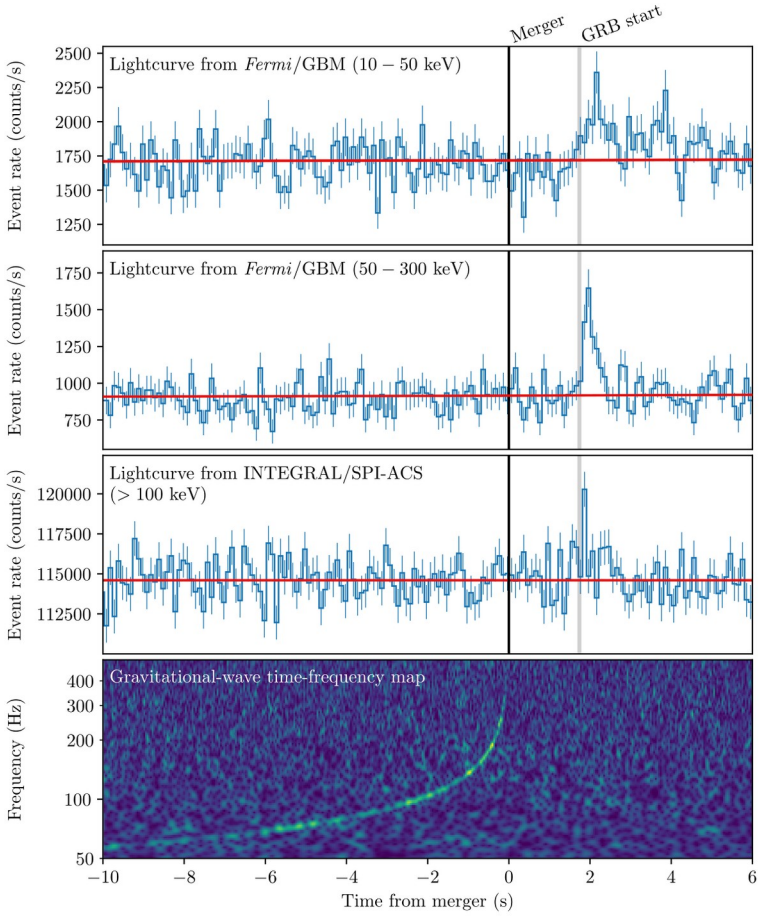
(with contributions by J.Aird, A.Klein, A.Mangiagli, E.M.Rossi, A.Sesana)

https://www.cosmos.esa.int/documents/678316/1700384/Athena_LISA_Whitepaper_Iss1.0.pdf

Caveat 2a

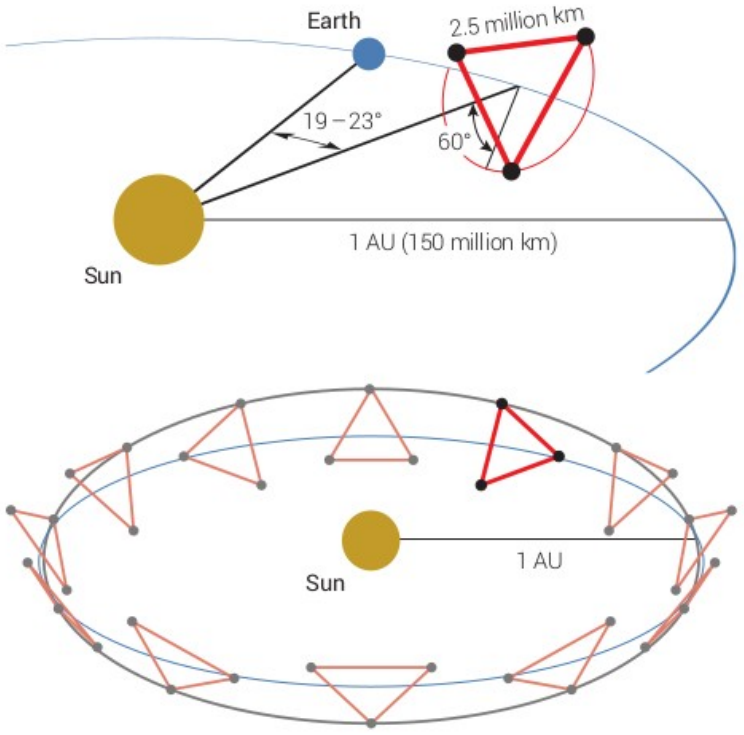
- X-ray fluxes of GW event counterparts are very uncertain
  - Only one detection, for the kilonova GW170817
- Rates of relevant GW events are also very uncertain
- Hard to make realistic quantitative predictions

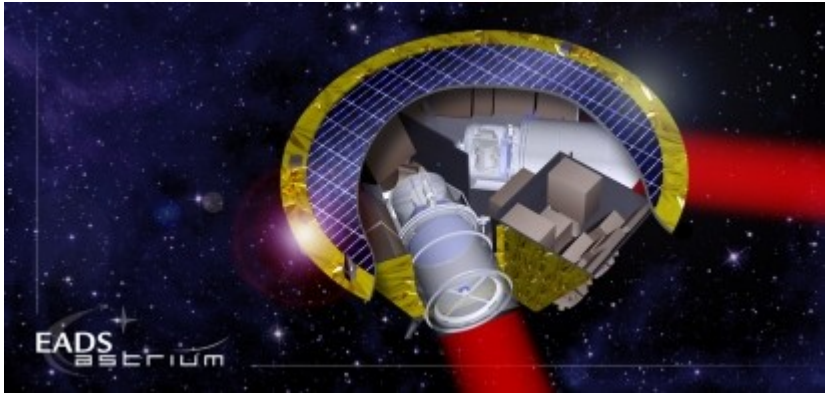


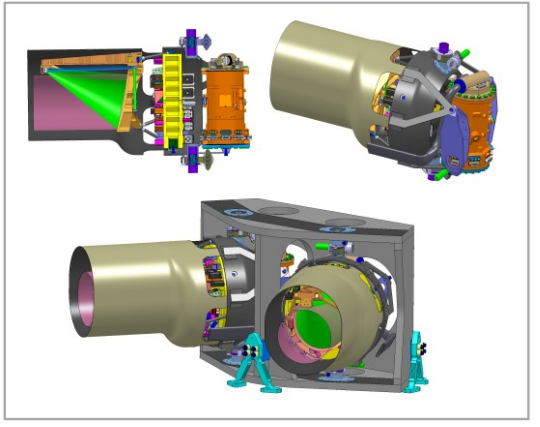
Caveat 2b

- Some goals are only attainable with Athena
  - e.g., those requiring good spectral resolution at the Fe Kα line energy
  - Sensitivity
- If a position is determined to the arcminute, the work of THESEUS is done, as Athena will follow up
  - We focus here on the capability of THESEUS to efficiently provide precise positions for subsequent follow-up by Athena (needed for further follow-up, e.g. *z* determination)

The LISA Mission



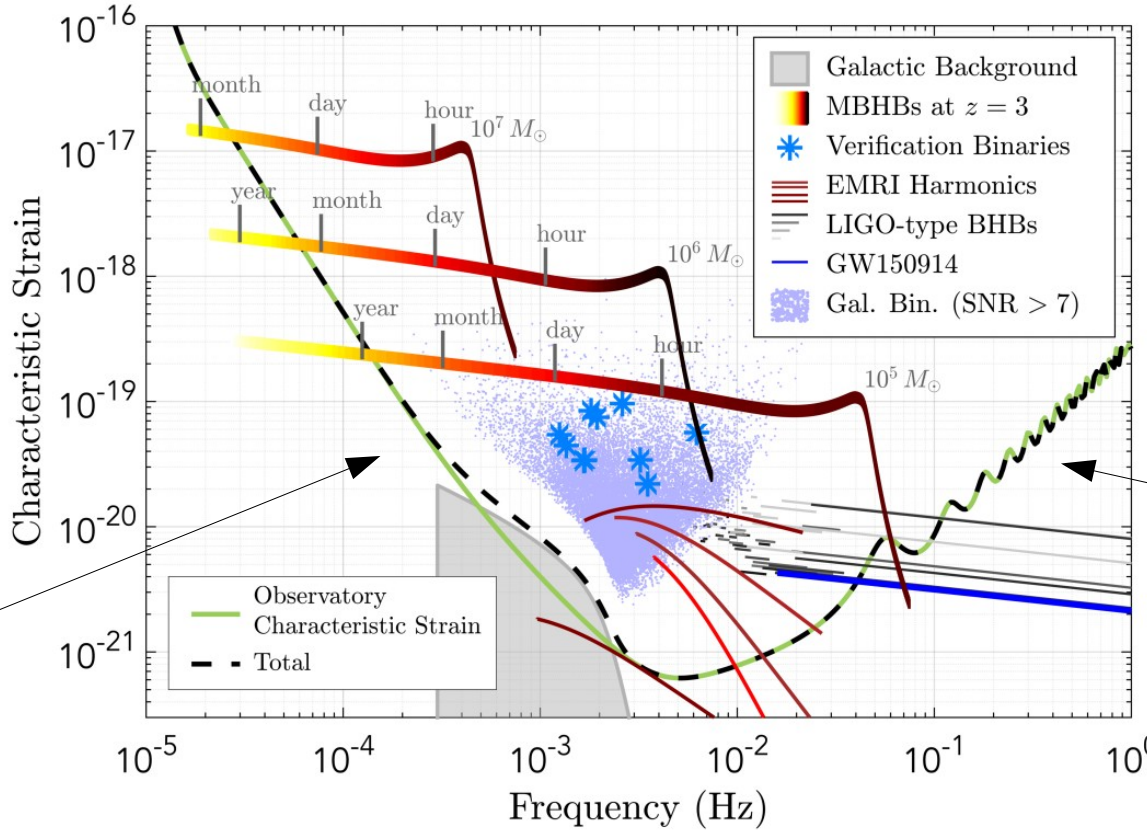




Metrology systems

- 30 cm telescopes
- 2W lasers

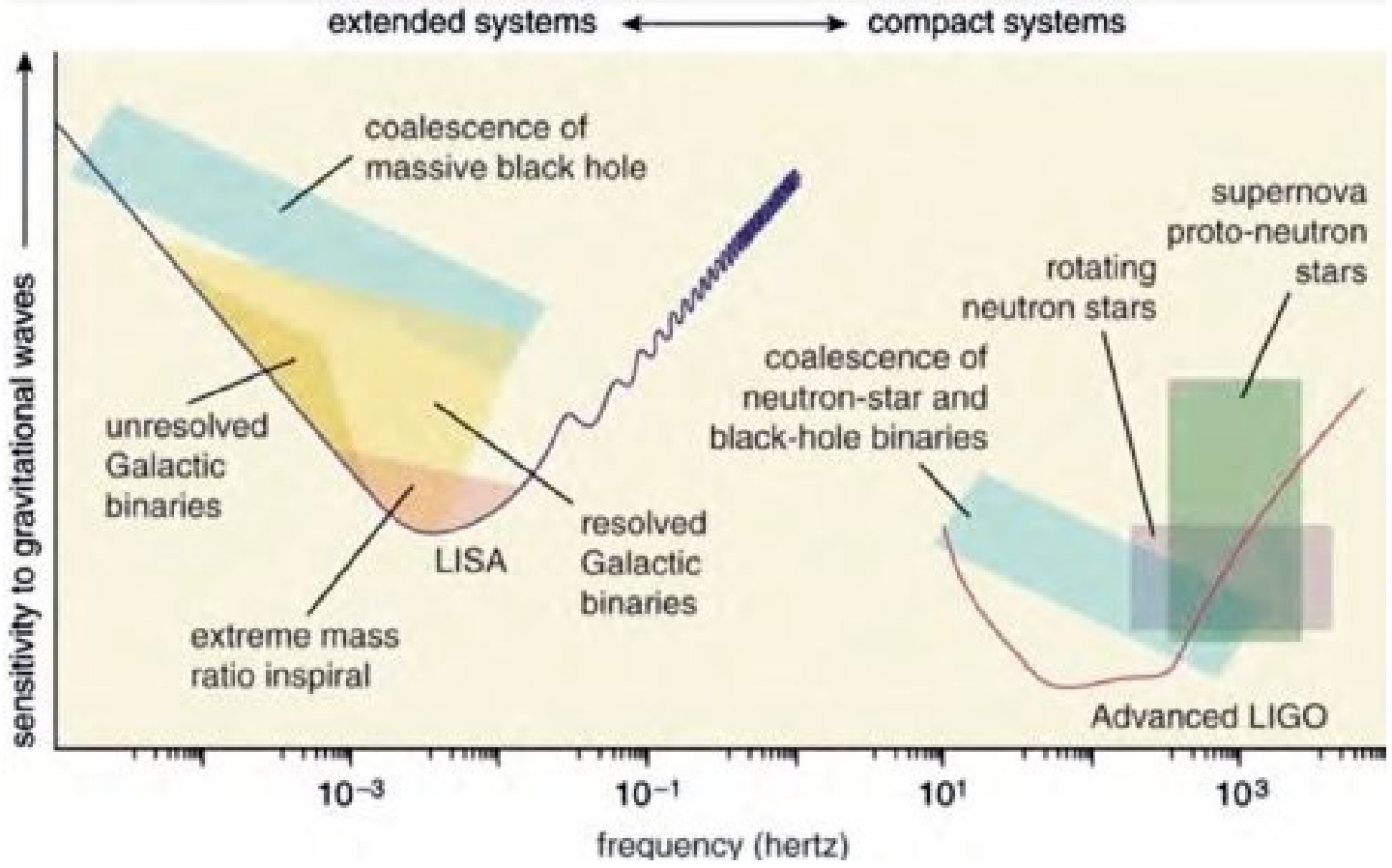
LISA Sensitivity



Acceleration noise

Photon noise
+ other sources

LISA vs LIGO/VIRGO Sensitivity



LISA Sources

- Extended systems
  - Massive black-hole binary (BHB) systems in accreting systems
    - Cosmic distance scale (standard sirens)
    - AGN physics (accretion physics; GW fixes BH mass, spin)
    - Fundamental physics (e.g., speed of gravity)
  - Extreme mass ratio inspirals
    - Any counterpart in X-rays? Broad X-ray lines in AGN?
  - Stellar-mass BHB, years before the merger
    - Not really expected to have any EM counterparts

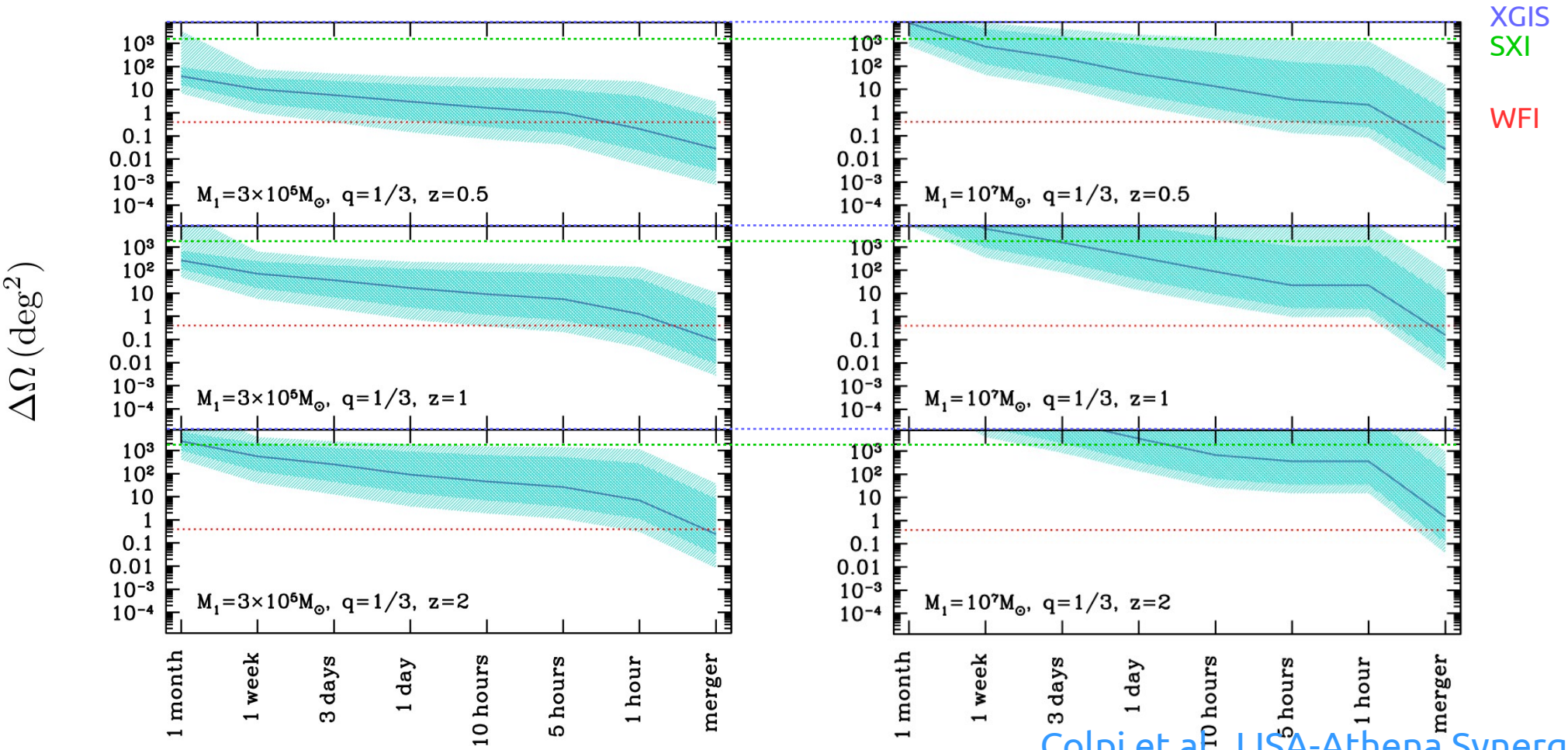
Colpi et al., LISA-Athena Synergy

Multi-messenger Science with MBHB

- LISA will detect MBHB mergers over the full Universe (z~20)
  - 10 – 300 events per year, most of them at z>5 and low SNR
- SNR is crucial in determining source position
  - Increases with time until merger → position improves
  - Few events will have SNR high enough for precise localization

Colpi et al., LISA-Athena Synergy

Localization Accuracy of LISA BHB Mergers



Colpi et al., LISA-Athena Synergy

Localization of MBHB Mergers in X-rays

- A few objects expected to have < 1deg² error box at the time of merger (up to z~2)
  - Post-merger phase only is accessible to Athena
- Very rare objects expected to have < 10 deg² error box a few days before the merger (up to z~1)
  - Merger phase is accessible to Athena, with significant effort (mapping 10 deg² in a few days)

Colpi et al., LISA-Athena Synergy

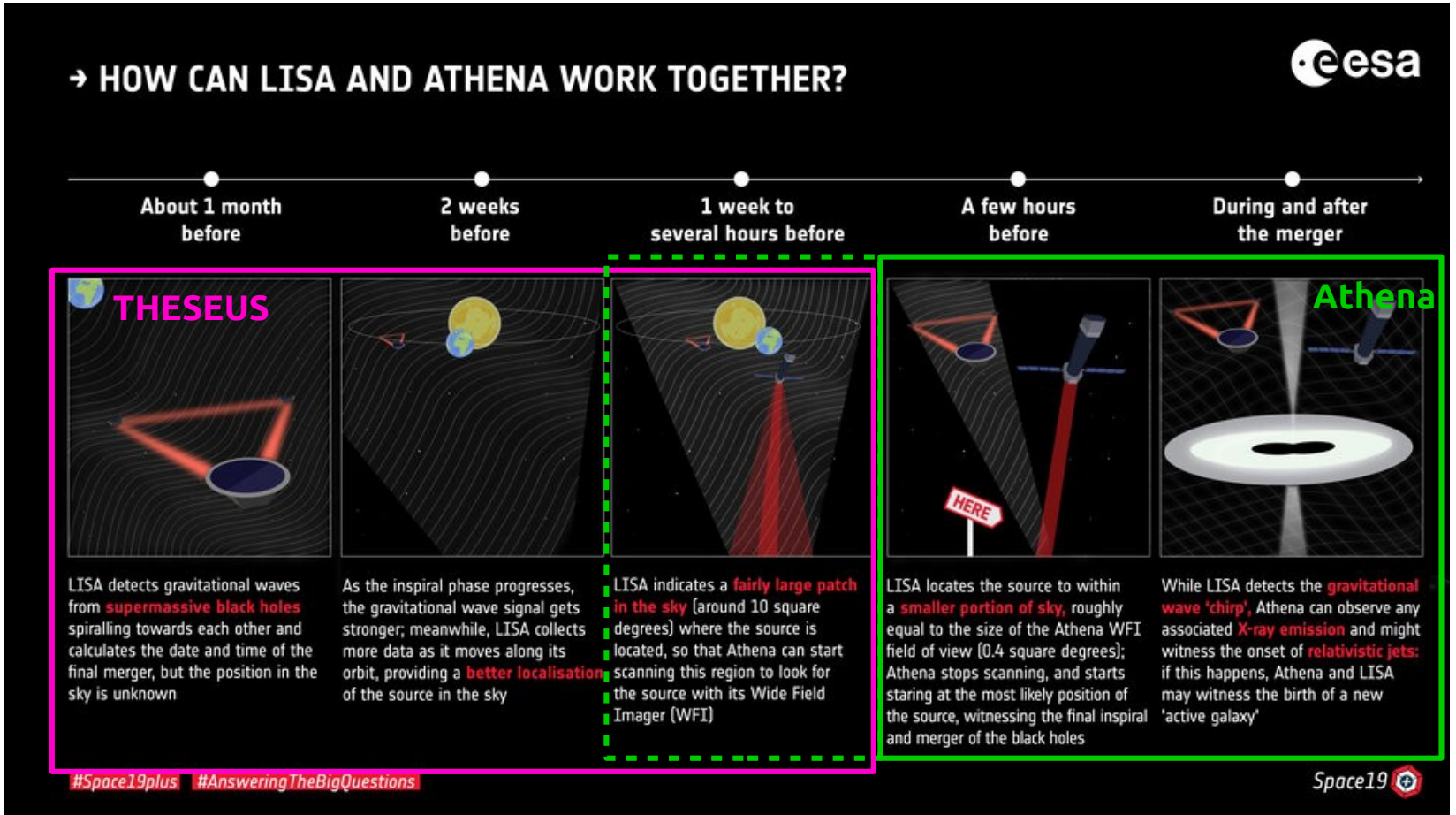
Athena Strategy for the loudest BHB Merger Events

- MBH binaries with a position uncertainty of 10 deg² 3 days before merging
- 23x9 ks WFI pointings can be used to map the whole area in 3 days
  - Can be reduced by targeting the maximum-likelihood area
- But observing the area is not be sufficient!
  - 100s of sources in the WFI pointing
  - Time signature of the signal, ~10^{-2} – 10^{-3} Hz, necessary to provide unambiguous identification

THESEUS Identification of MBH Binaries EM Counterparts

- For 10^7 $M_\odot$ BHB mergers:
  - XGIS observation for 1 day (z~2) to 1 month (z~0.5)
  - SXI observation for ½ (z~2) to 10 days (z~0.5)
- For $3 \cdot 10^5$ $M_\odot$ BHB mergers:
  - SXI (and XGIS) observation for a month, possibly much more
- Confusion limited regime to be expected, but time signature might provide unambiguous identification

How can LISA and THESEUS (and Athena) work together?



Conclusion

- LISA – X-ray synergy presents significant unknowns
  - GW event rate
  - X-ray luminosity
- BHB mergers are the most promising candidates
  - But it is challenging for Athena as well
    - Tedious observing campaign
    - Proper identification of the counterpart
  - THESEUS might be the best way to provide accurate localizations to Athena through time signatures