

# Panel discussion

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# Source detections

- Compact binary coalescences in LIGO/Virgo bands
  - BH-BH, NS-NS, BH-NS(?)
  - Population of detections; what science can we get from many detections?
- Continuous waves (Accreting binaries,...)?
- Supernovae?
- Astrophysical background (eg. Unresolved population of BBH)?
- Cosmological background?
- Unexpected; what?

# Fundamental physics, Astronomy, & Cosmology

- Astronomy
  - stellar evolution & environment, galaxy formation & evolution, etc
  - binary dynamics, triple dynamics,  $N$ -body dynamics
  - Input from last night's discussion....
- Testing gravity
  - was Einstein right? Exotic compact objects?
- Cosmology
  - Looking beyond the EM (CMB) horizon
  - what do GWs tell us about early Universe?
- Neutron star EOS
- Two-body problem in GR and waveform modeling
- Dark matter

# Upcoming detectors

- KAGRA, IndiGO
  - localization; additional science?
- the science case for HF and deciHz detectors: the technology challenges for HF detectors and deciHz detectors, international collaboration opportunities
  - Postmerger and neutron star astrophysics
- Space-based detectors
  - Common science targets for ground-based & space-based detectors?
  - A single decihertz detector can provide  $\sim 1 \text{ deg}^2$  sky localization for EM bright binary coalescence sources (long signal duration  $\rightarrow$  aperture synthesis)

# Pulsar timing

- PTA benefits greatly from SMBH candidate identification (eg. From optical approach)
- What parameters do astronomers want to know if PTA detects a SMBH point source
  - EM-PTA synergy in determining relevant parameters such as chirp mass
- Common science targets for space-based and PTA detectors?

# EM counterparts of GWs

## Phenomena & Theory

- NS-NS
  - SGRB, Kilo-nova, Afterglow; FRB? Anything new?
  - Merger product: BH (HMNS-NS) vs long-lived NS; NS EoS
  - Jet physics: When formed? How propagate? What structure?
  - Ejecta: Geometry?  $M$  and  $v$ ?  $Y_e \rightarrow \chi_{lan} \rightarrow \kappa$ ? Heavy elements origin?
- Other sources (NS-BH, BH-BH, GWBs)
  - Exist?
  - What kind?

# EM counterparts of GWs

## Current optical observation of GW – EM counterpart in China

- Wide-field telescopes

- 1.0/1.2m Near Earth Object Survey Telescope @Xuyi, PMO
- 1.0m Nanshan Telescope @ Urumqi, XAO
- 0.6/0.9m Schmidt Telescope @ Xinglong, NAOC
- 3 x 0.8m Telescopes @ Yaoan, PMO
- 3 x 0.5m AST3 @ Dome A, PMO & NIAOT & NAOC & PRIC
- 0.5m Telescope @ Dabancheng, NAOC
- 12 x 28cm CHES array @ Yaoan, PMO

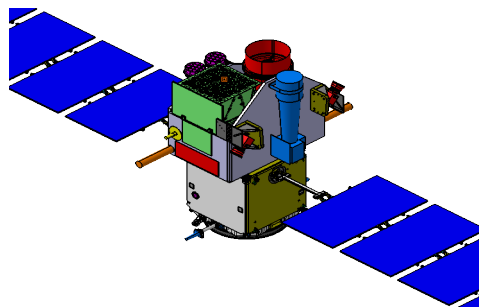
- Spectroscopic telescopes

- 2.16m @ Xinglong, NAOC
- 2.4m @Lijiang, YNAO

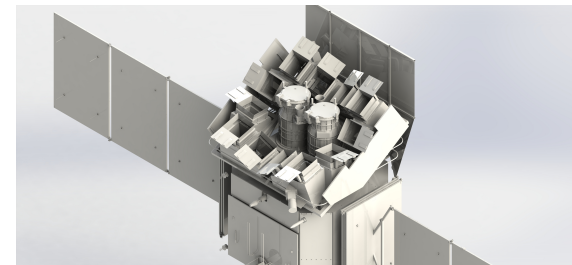
# Synergy in the GW-EM era in China



GECAM, 2020-



SVOM, 2021-



Einstein Probe, 2022-

## Photometric Survey Telescopes



60/90cm



1.0/1.2m



1.0m

2021-2025

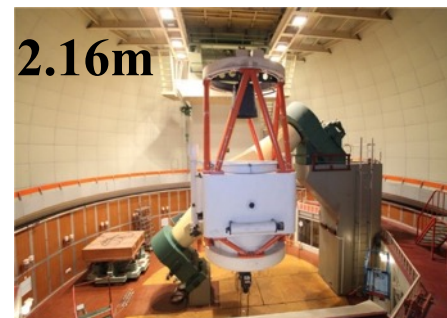
USTC-PMO 2.5m WFST @ Lenghu  
YNU 1.6m Mephisto @ Lijiang  
BNU 1.9m @ Muztagh

2025-2035

Sitian Project  
(proposed)

## Spectroscopic Telescopes

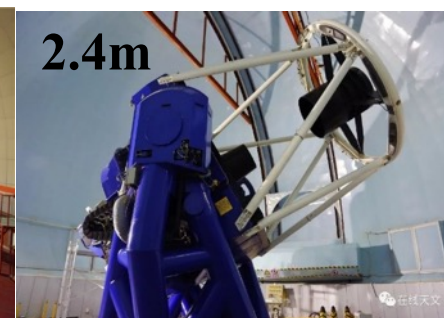
2m  
class



2.16m

4m  
class

2.4m



Sitian Project  
(proposed, 2025-2035)

10m  
class



12m LOT (2025)

# GW - EM Counterpart Research Consortium in China

- Strategic plan
- Operation & Observation
- Data: storage, transfer, analysis
- Theory: modelling
- Publication

# Challenges of finding EM counterparts of GW sources at high energies – technology viewpoint

- Conventional GRB monitors (Fermi/GBM, Swift/BAT, SVOM/GRM, HXMT, GECAM):
- Pro:
  - can detect short GRB easily, large/full sky coverage
  - Broad band
  - Matured technology; Relatively cheap
- Con:
  - Short GRBs are mostly detected beyond the LIGO/VIRGO horizon (i.e.  $> \sim 300\text{Mpc}$ ) (except for GW170817)  $\rightarrow$  no GW synergy
  - Relatively poor localization precision for multi-wavelength follow-up observations ( order of degrees or worse)
  - Sensitivity too low or bandpass too high to detect predicted X-ray isotropic emission

# Challenges of finding EM counterparts of GW sources at high energies

- Novel X-ray wide-field monitor (Lobster-eye MPO telescope)
- Pro:
  - high sensitivity (for longer bursts and extended emission)
  - Good for the detection of any extended emission
  - good localization precision ( $\sim 1$  arcmin or better)
  - Light weight
- Con:
  - Not good for short-duration transients (e.g. sGRB) (due to small effective area)
  - Narrow bandwidth
  - New technology & expensive

# Challenges of finding EM counterparts of GW sources at high energies

- Solutions:
  - Combine the two (e.g. Theseus): system complexity and budget increased
  - Or other new detection technology required: need R&D
- Future: in view of the synergy with the next generation of GW detectors (e.g. ET), to detect BNS at higher redshifts (e.g.  $>2$ )
  - Are the current high-energy ASM sufficient?
  - Or need to go deeper (higher sensitivity)
  - If yes, what technology? Something new?

# Comments from the community are welcome regarding the observing strategy of EP

- Q: what is the best survey/observational strategy for EP, in order to maximise the probability of detecting GW EM counterparts?
- Shall we do tiling observations on individual galaxies using the EP-FXT telescope? (note that the FXT FoV is largely mis-aligned to the centre of WXT FoV centre)

# Synergy between...

- GW observations & EM follow-ups
  - already great achievements; how to *further* improve?
- Theorists and experimentalists
  - Are there places to focus our efforts?
- multi-bands
  - which bands? for what science?

The Gravitational Wave Spectrum

Sources

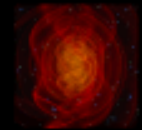
Detectors



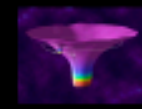
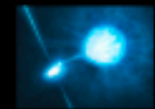
Big Bang



Supermassive Black Hole Binary Merger



Compact Binary Inspiral & Merger



Extreme Mass-Ratio Inspirals



Pulsars, Supernovae



age of the universe

Wave Period

hours

seconds

milliseconds

$10^{-16}$

$10^{-14}$

$10^{-12}$

$10^{-10}$

$10^{-8}$

$10^{-6}$

$10^{-4}$

$10^{-2}$

1

$10^2$

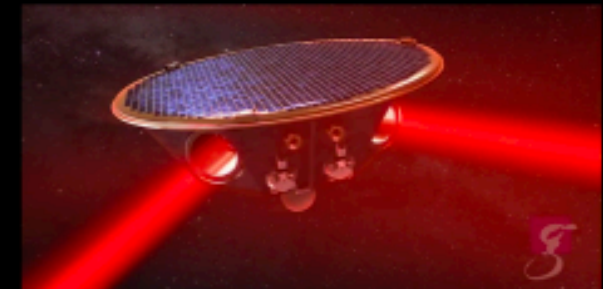
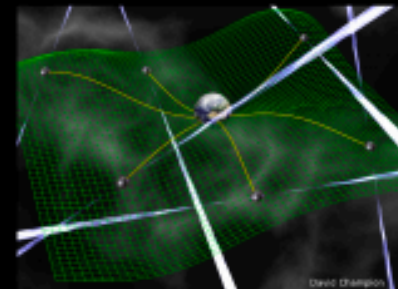
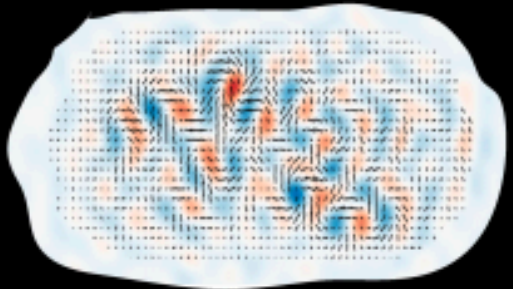
Wave Frequency

CMB Polarization

Radio Pulsar Timing Arrays

Space-based interferometers

Terrestrial interferometers



Thanks!