Aspen Winter Conference on Gravitational Waves, February 2003

Gravitational Wave Space Antennas

beyond LISA . . .

from LISA follow-ons to ASTROD

. . .

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March 17, 2003

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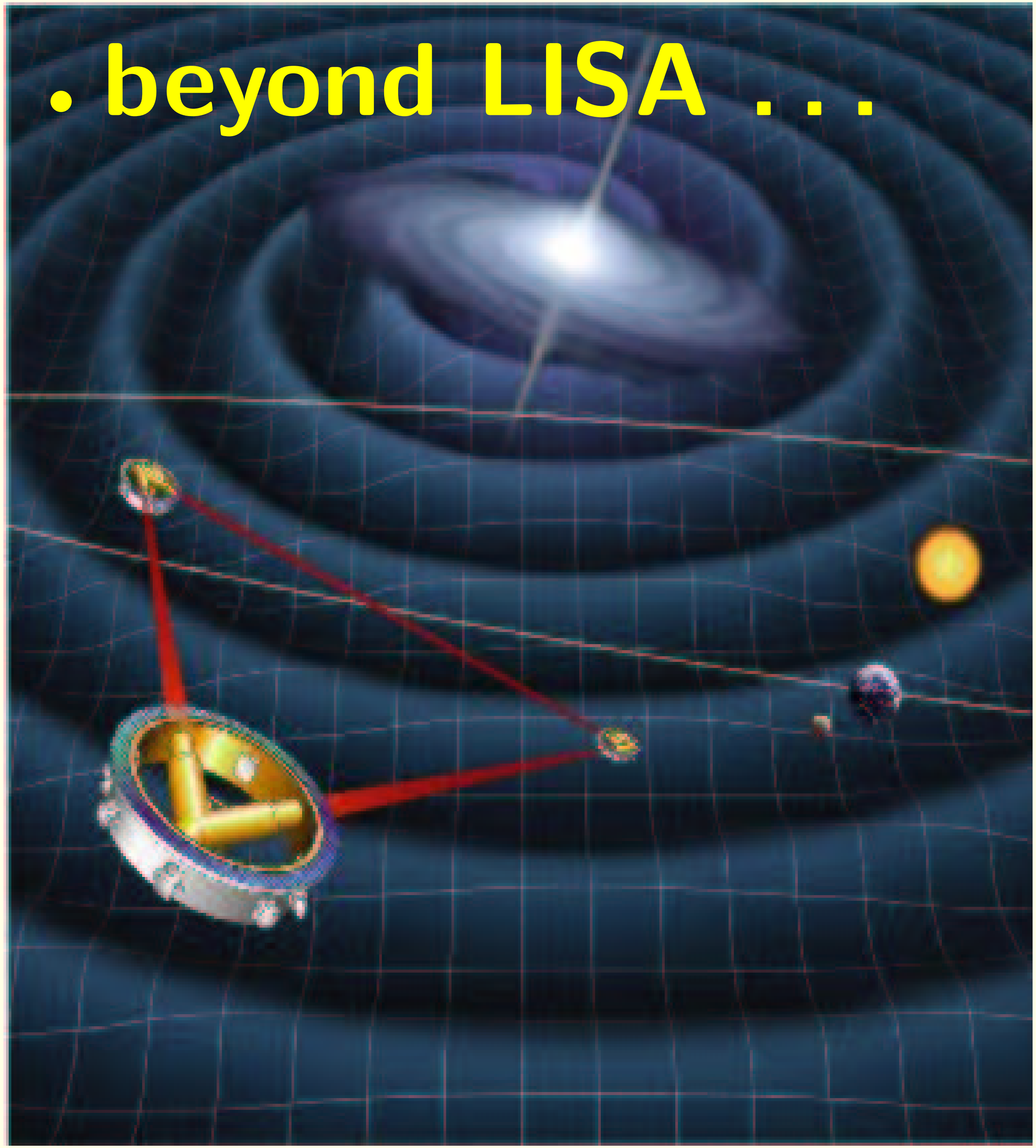
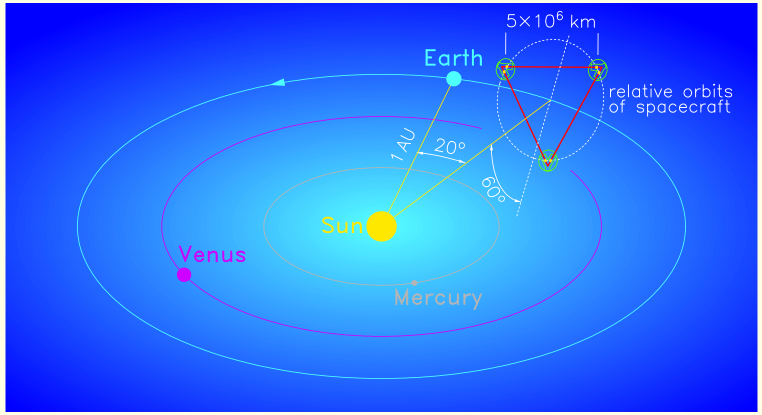
Talks on Gravitational Wave Space Antennas

at Aspen Winter Conference 2003

			Beyond LISA:
Mon	18:20	A. Rüdiger	LISA follow-ons + ASTROD
Mon	18:55	N. Seto	DECIGO
			LISA:
Thu	16:30	M. Tinto	Time Delay Interferometry for LISA
Thu	17:00	A. Krolak	On LISA Signal Resolution
Thu	18:00	J. Camp	LISA R&D
Thu	18:30	M. te Plate	LISA Technology Package (LTP)
Thu	19:00	A. Kuhnert	Disturbance Reduction System on ST7

. beyond LISA . . .

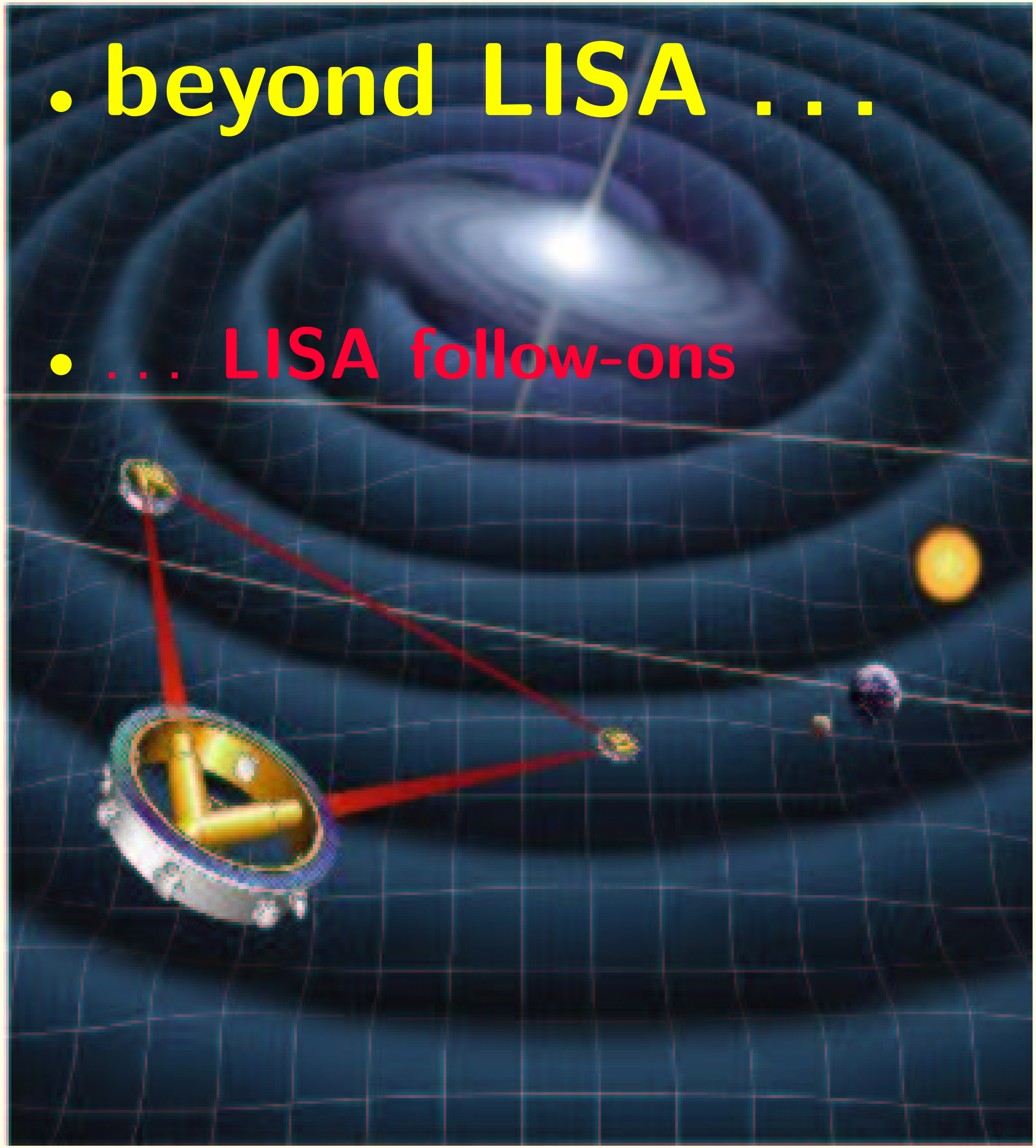


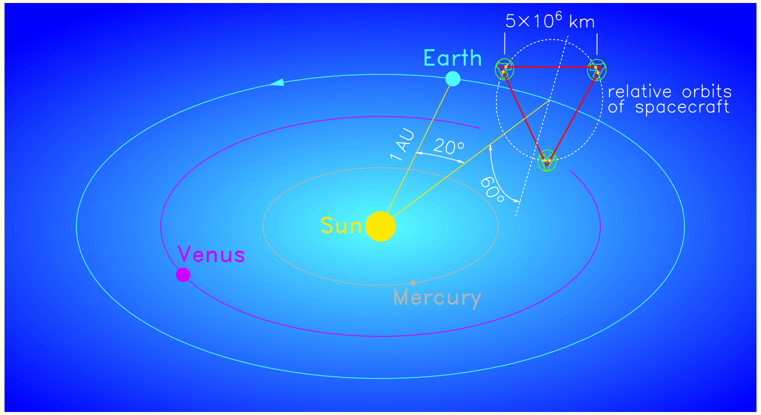


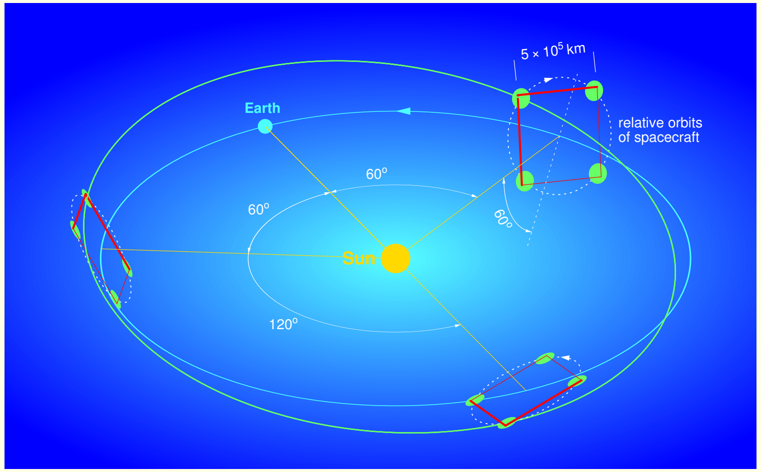
5×10^6 km
Earth
relative orbits
of spacecraft
1 AU
20°
60°
Sun
Venus
Mercury

- beyond LISA . . .

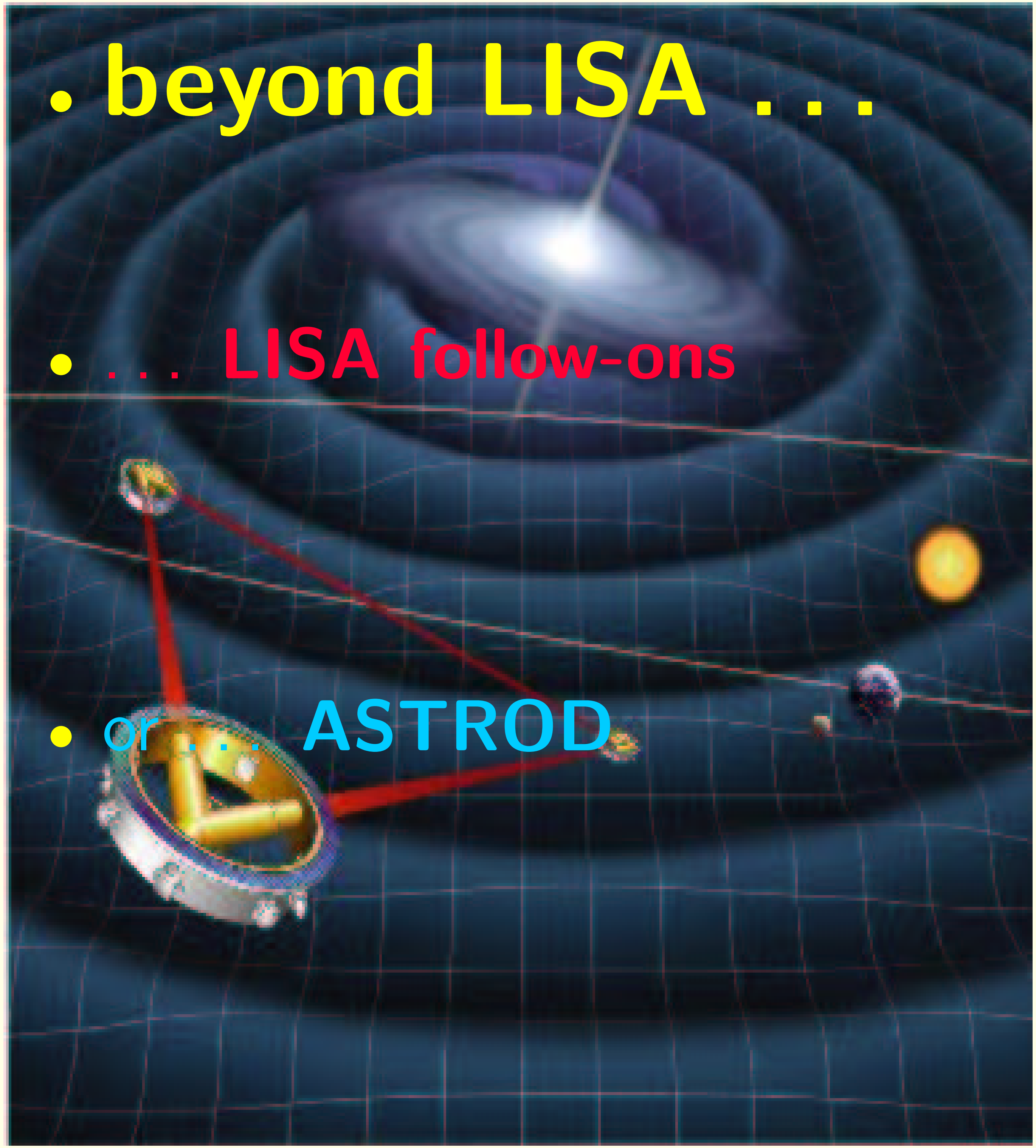
- . . . LISA follow-ons

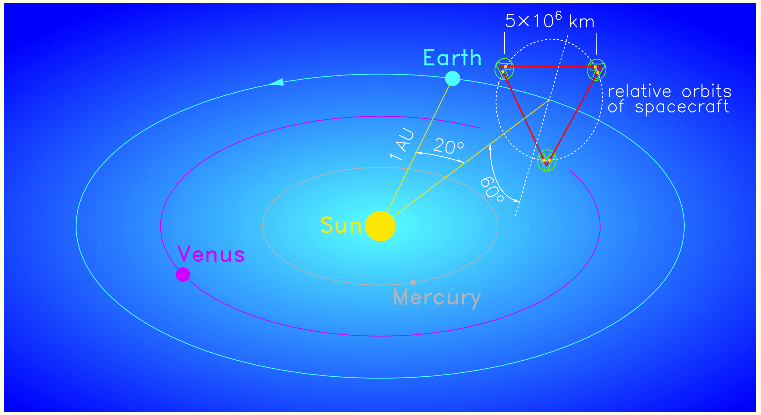


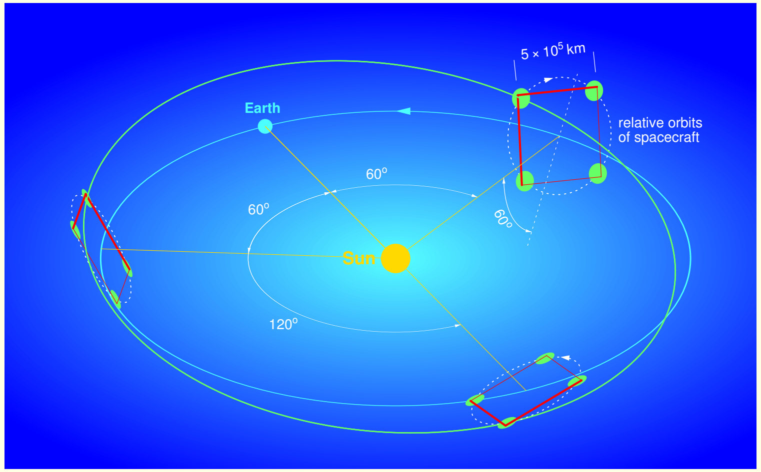


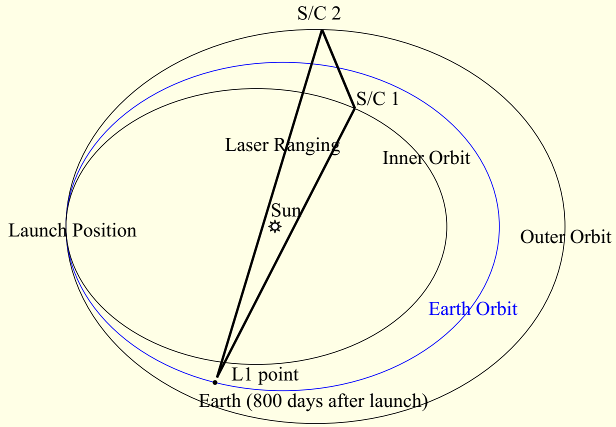


- **beyond LISA . . .**
- . . . **LISA follow-ons**
- or . . . **ASTROD**









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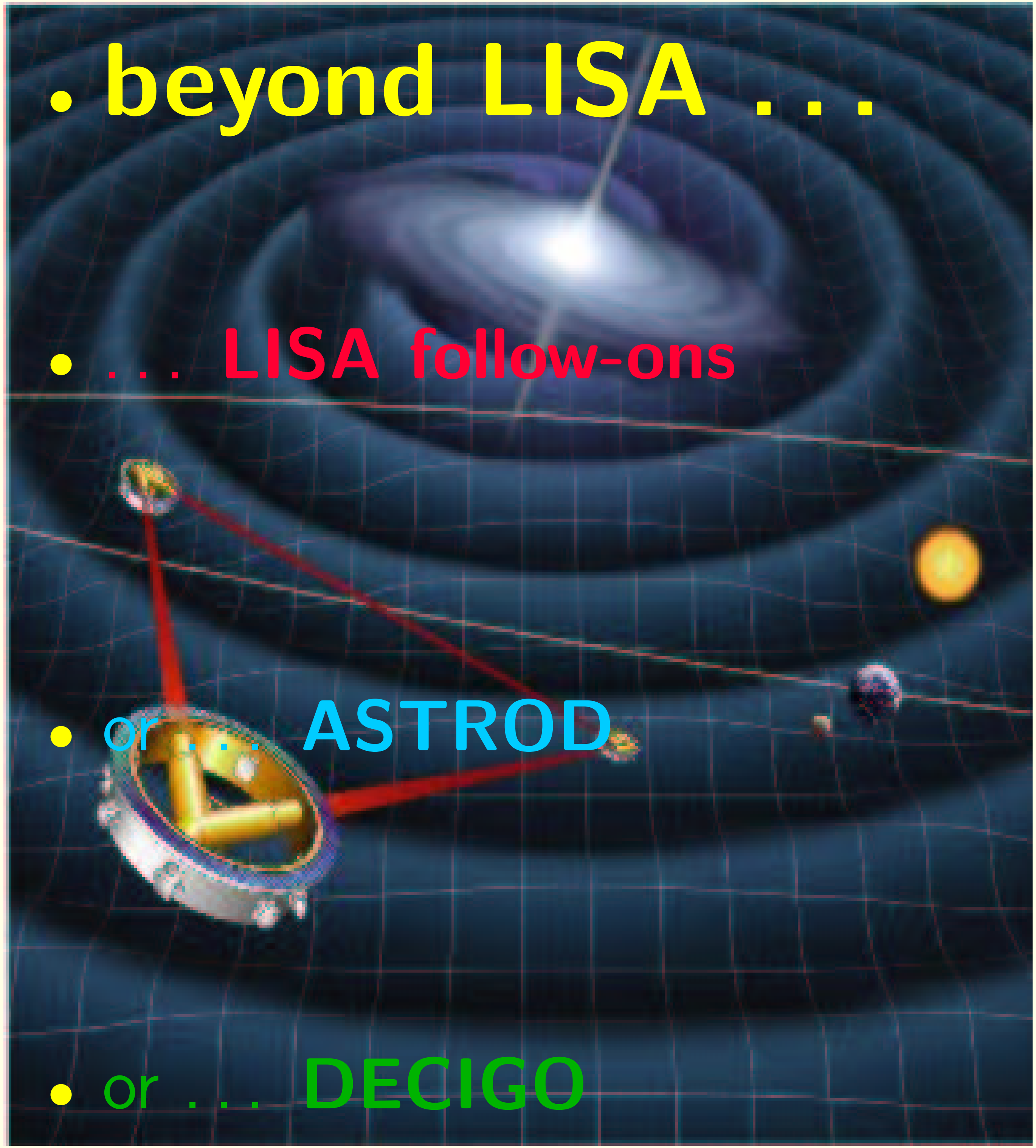
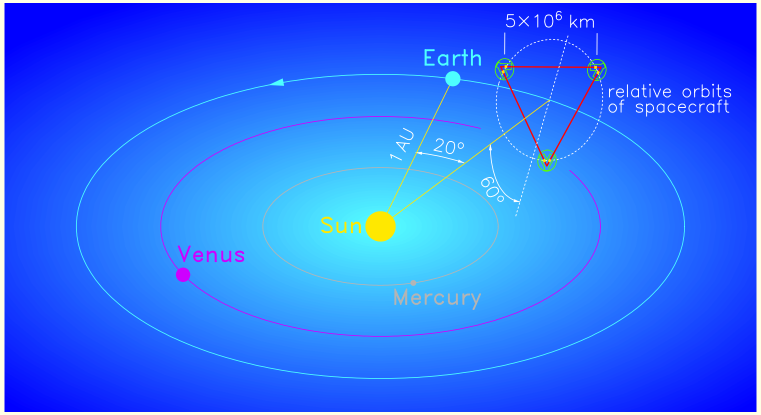
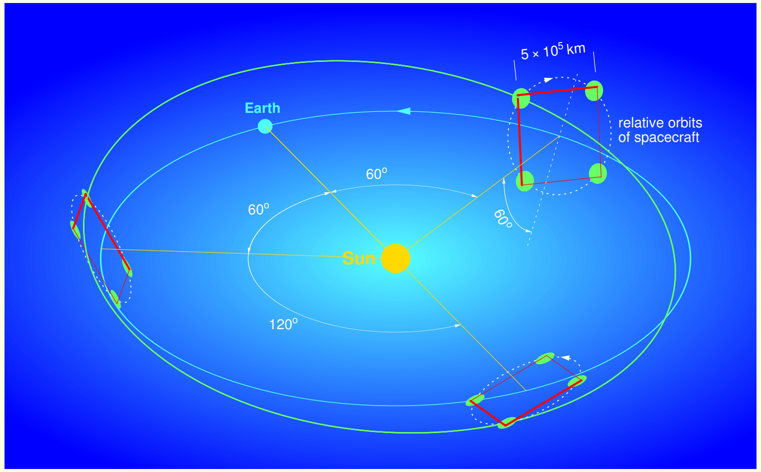
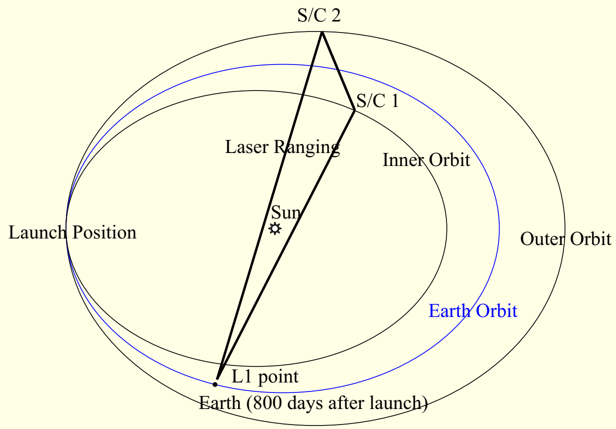
- or . . . ASTROD
- or . . . DECIGO





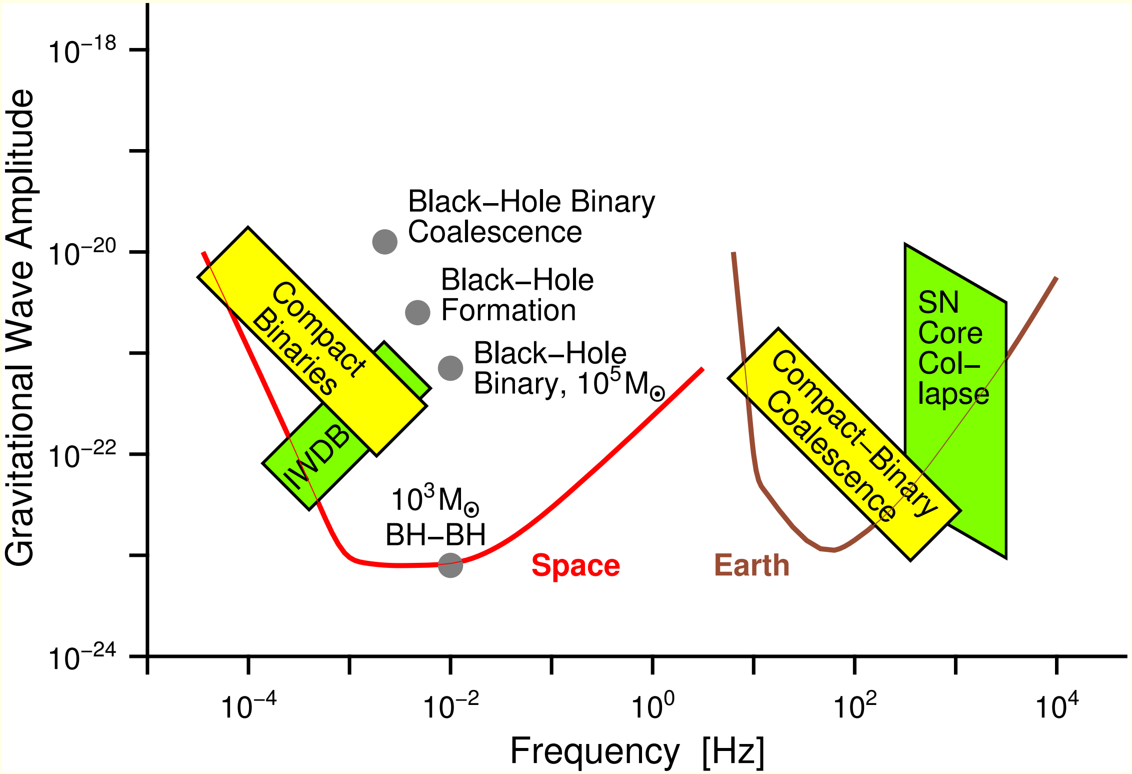




next talk, **N. Seto**

Sensitivities of Gravitational Wave Antennas

two separate frequency ranges:

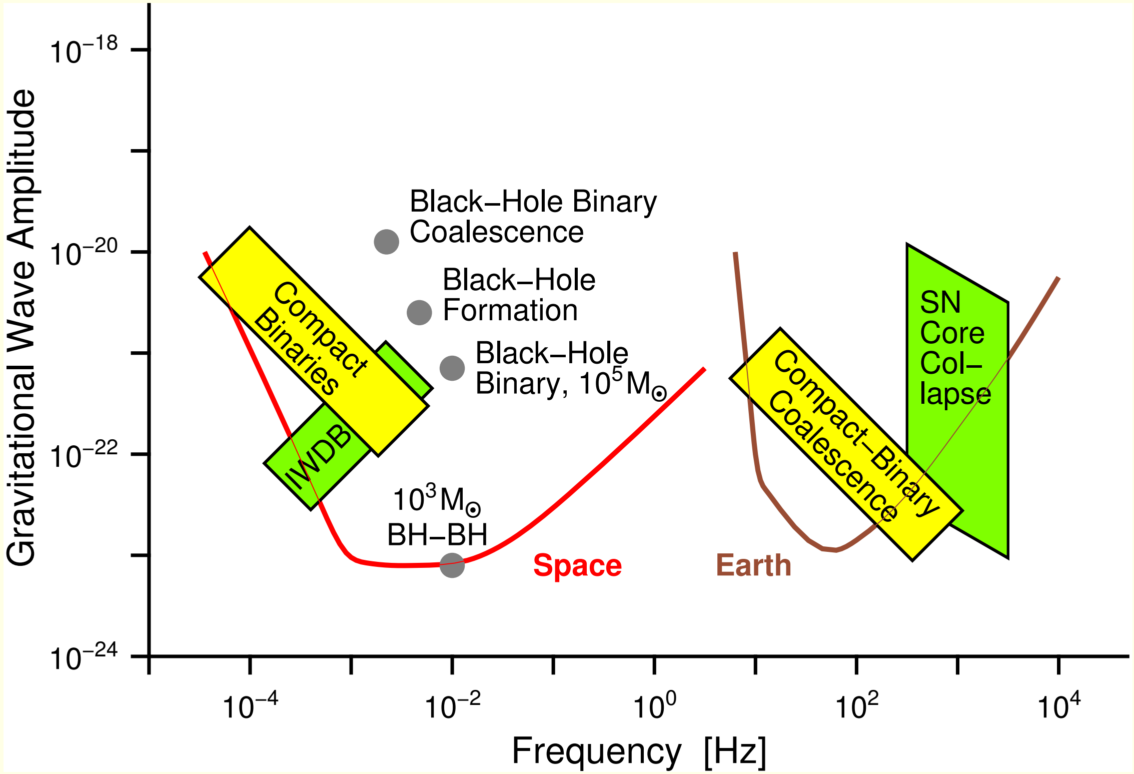


Sensitivities of Gravitational Wave Antennas

two separate frequency ranges:

Earth-based antennas

typically > 1 Hz to 10 kHz



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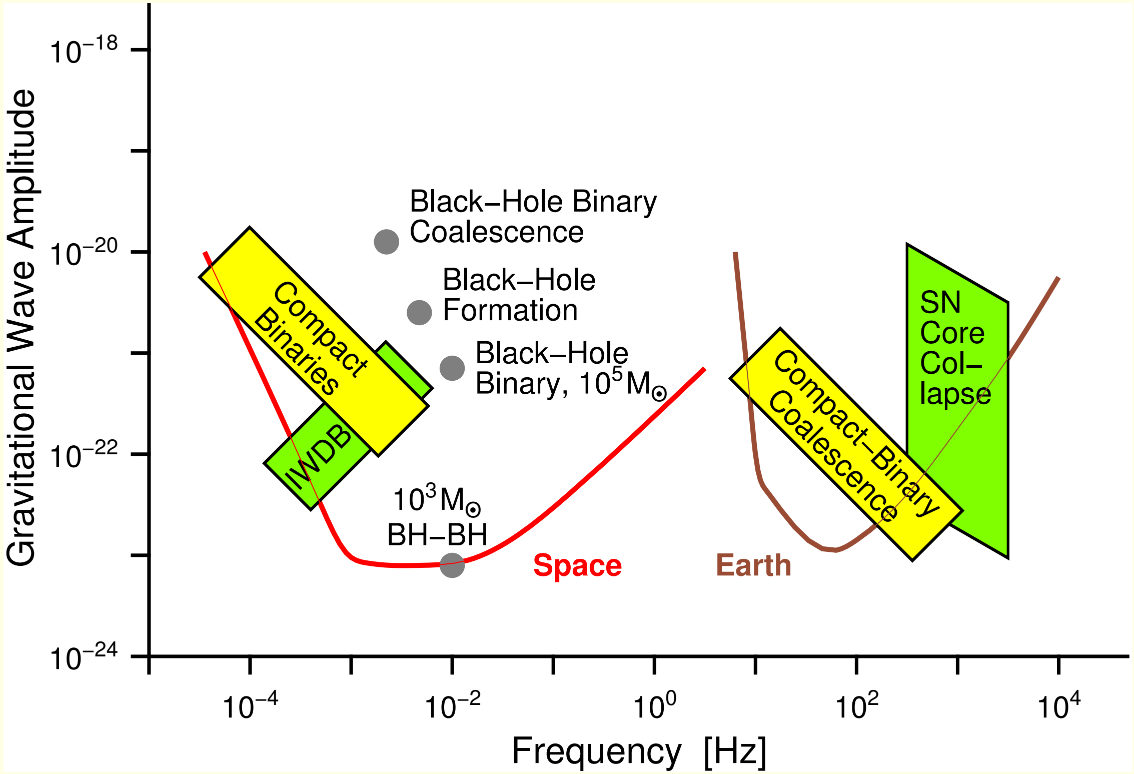

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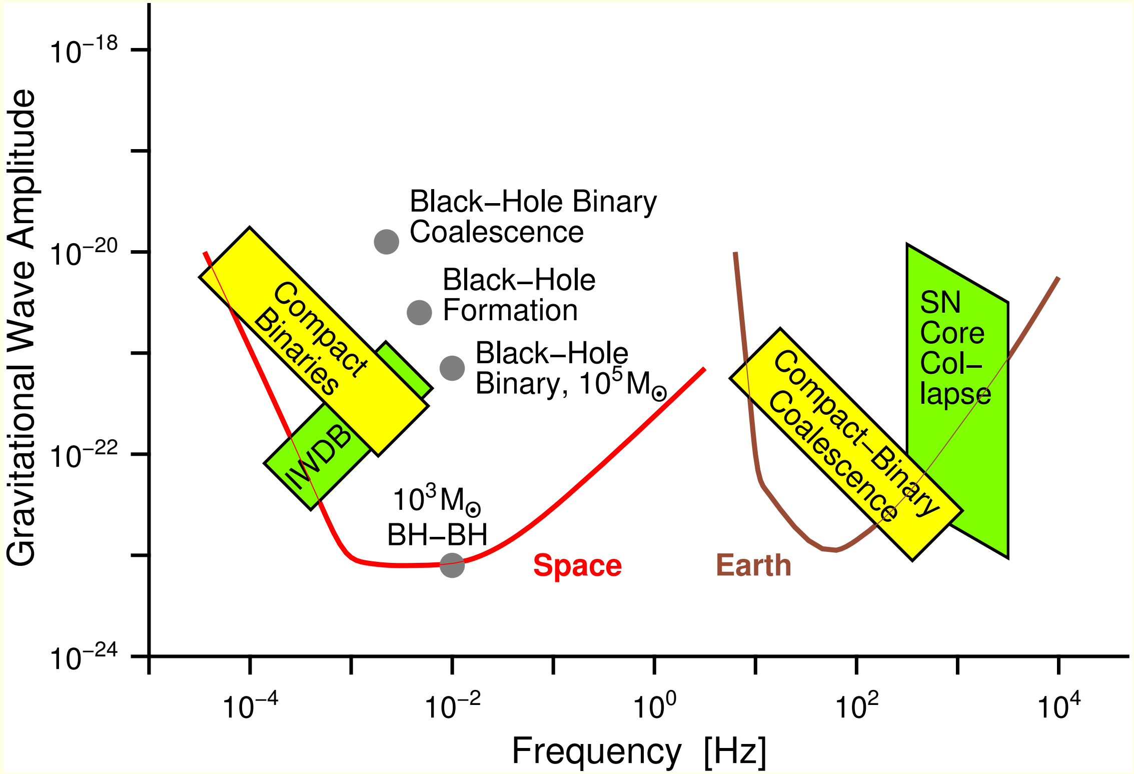

Schemes to move optimal frequencies for Space antennas:

$\leftarrow$ ASTROD	$\rightarrow$ LISA follow-ons	$\rightarrow$ DECIGO
10^{-4} Hz $\leftarrow$	$\rightarrow$ 10^{-2} Hz	$\rightarrow$ 10^{-1} Hz

Object(ive)s of Gravitational Wave Search

aside from **distinct events**:

also try to measure **stochastic background**

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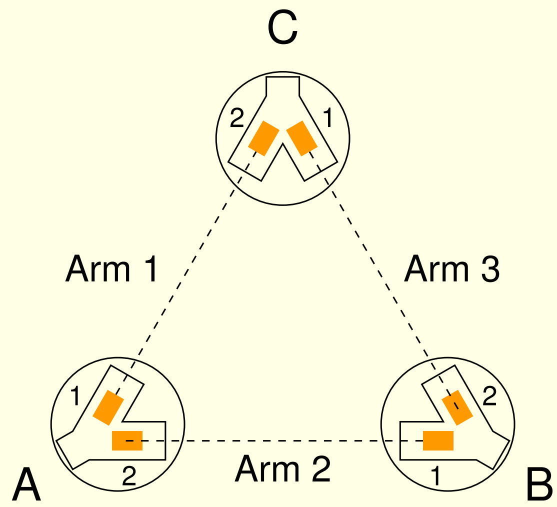
triangular configuration

with 3 s/c does not allow

independent measurements



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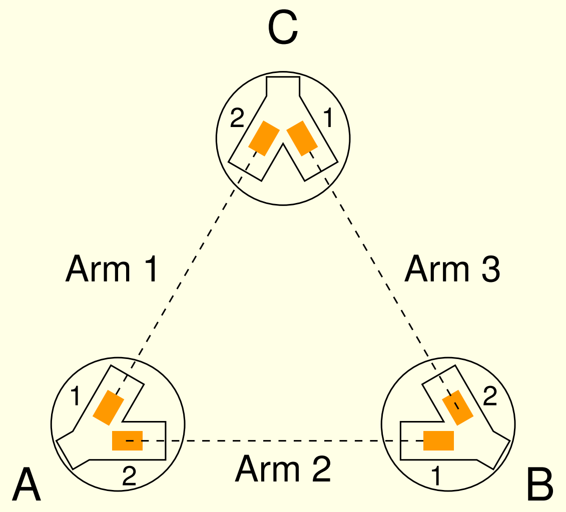
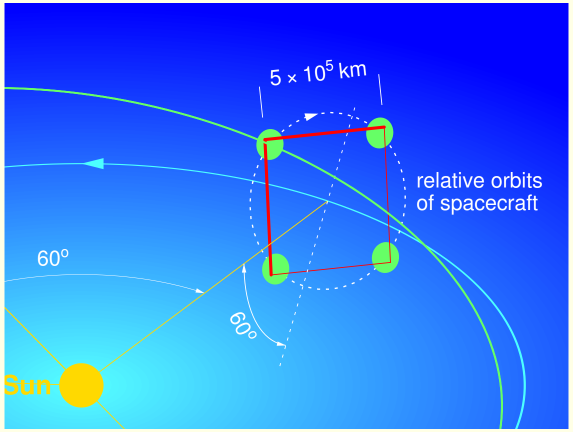


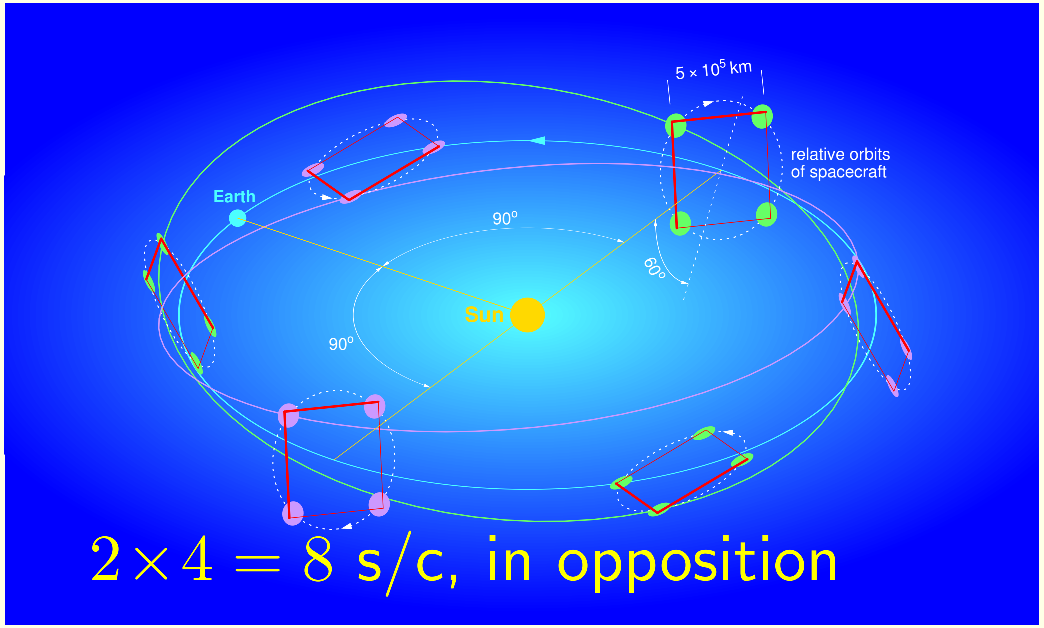
square configuration

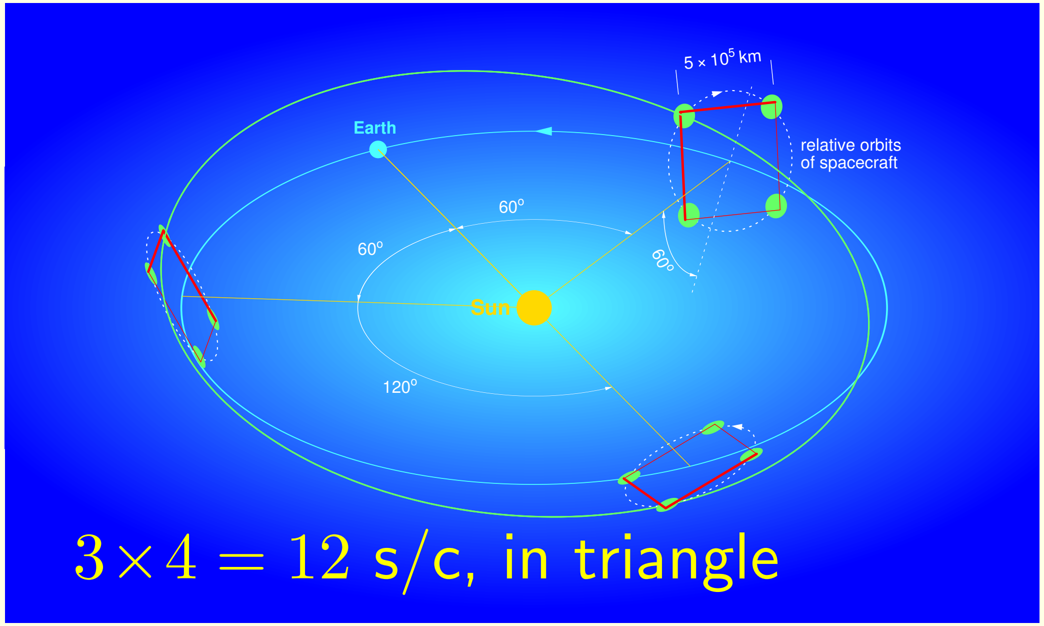
with 4 s/c is therefore

one alternative configuration



Configurations of Square GW Antennas





In all concepts:

importance of independent interferometers

to allow measurement of stochastic background

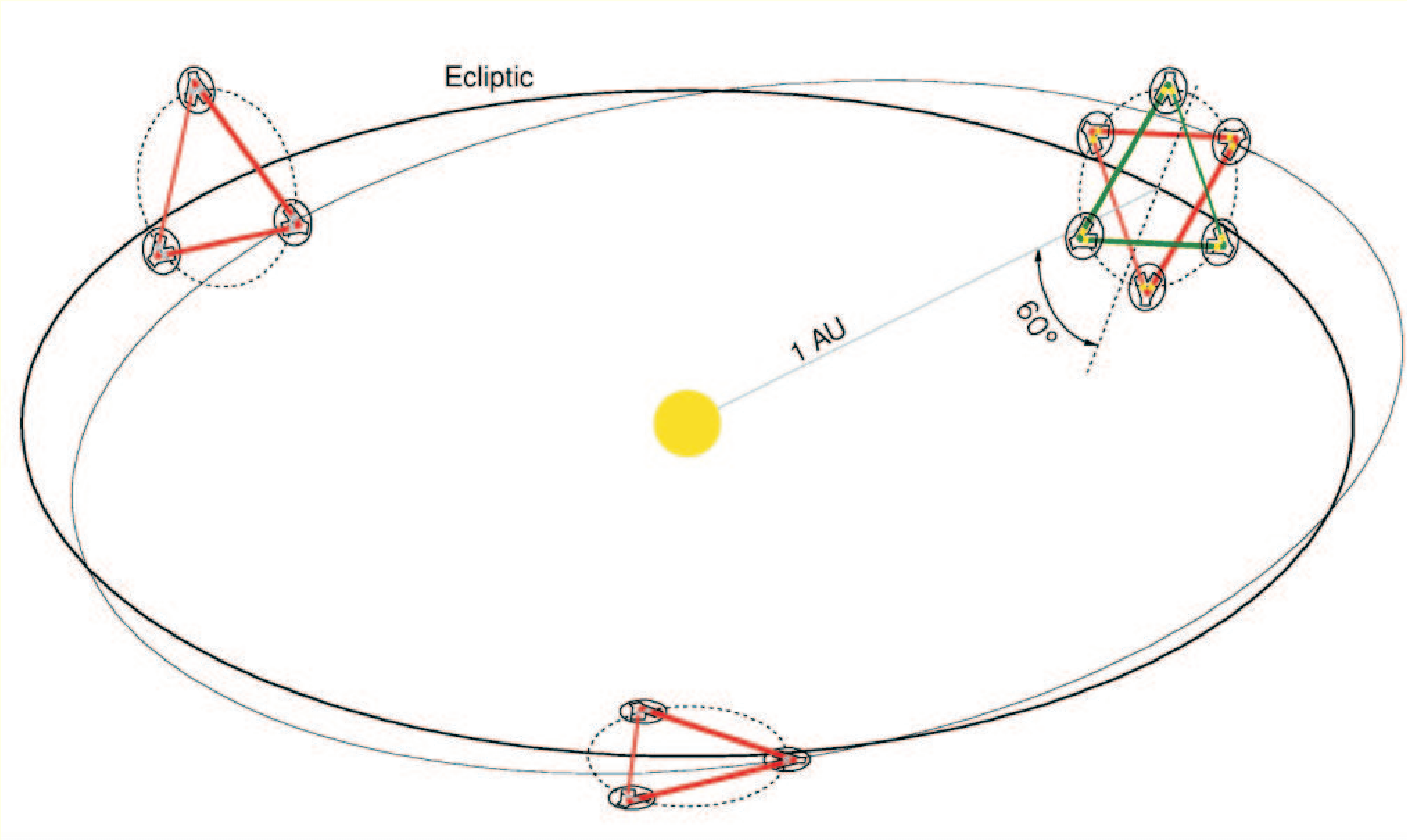
importance of long baselines between constellations

to provide high angular resolution

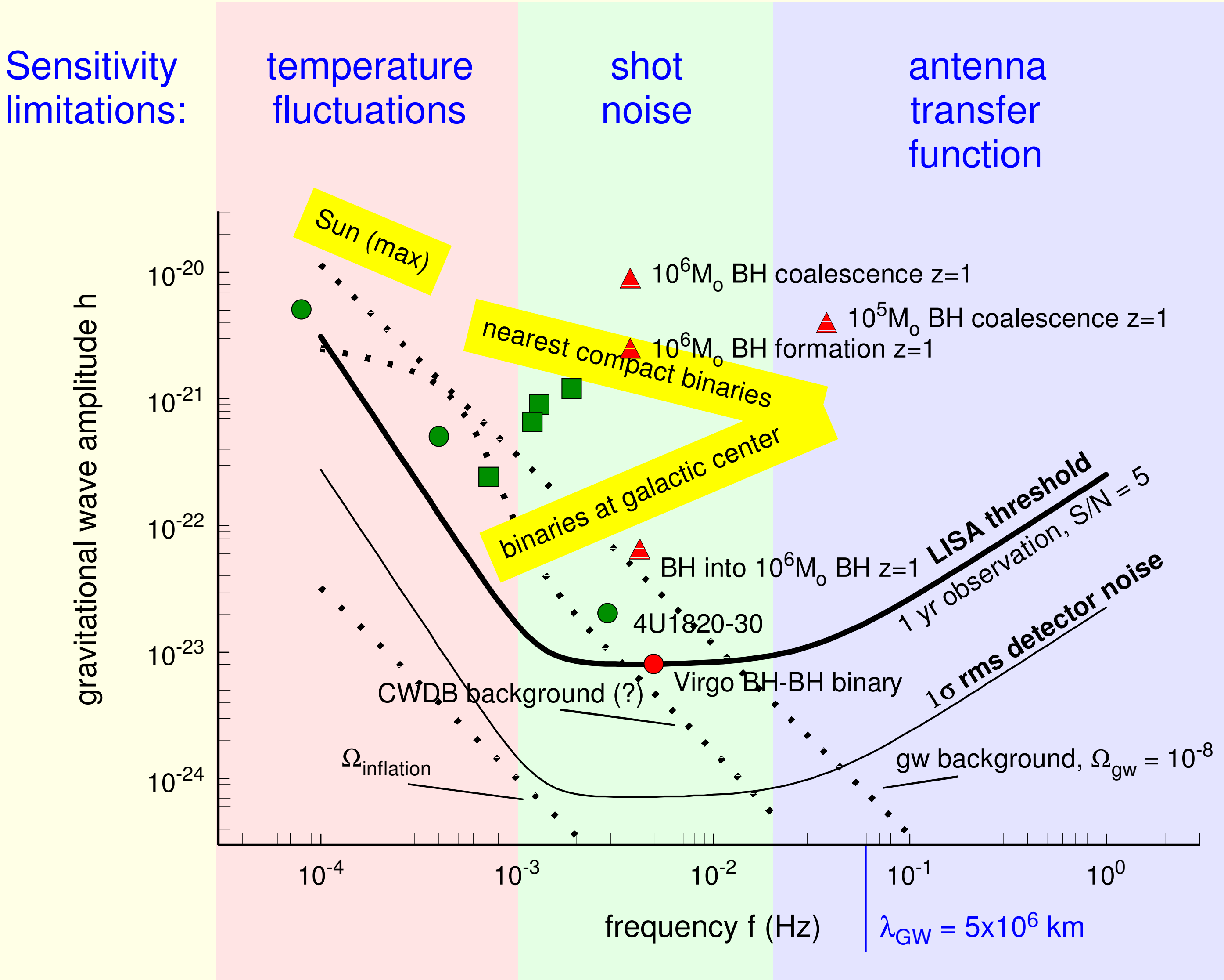
Alternative Configuration of an Advanced LISA

currently favored configuration:

$6 + 2\times 3 = 12$ spacecraft in ecliptic formation:



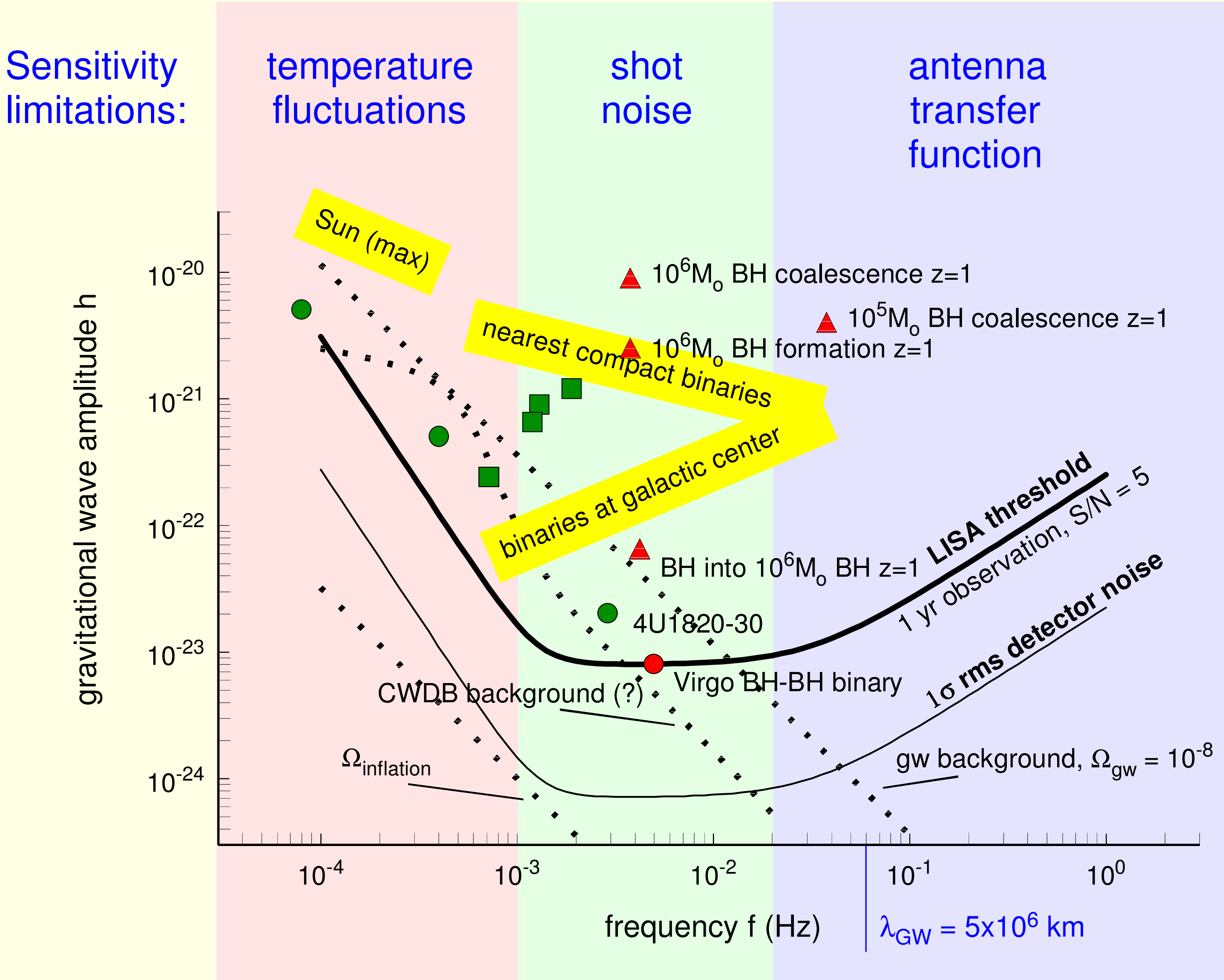
Sensitivity of LISA: three distinct regimes:



Sensitivity of LISA: three distinct regimes:

- acceleration noise

  below 10^{-3} Hz



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- acceleration noise
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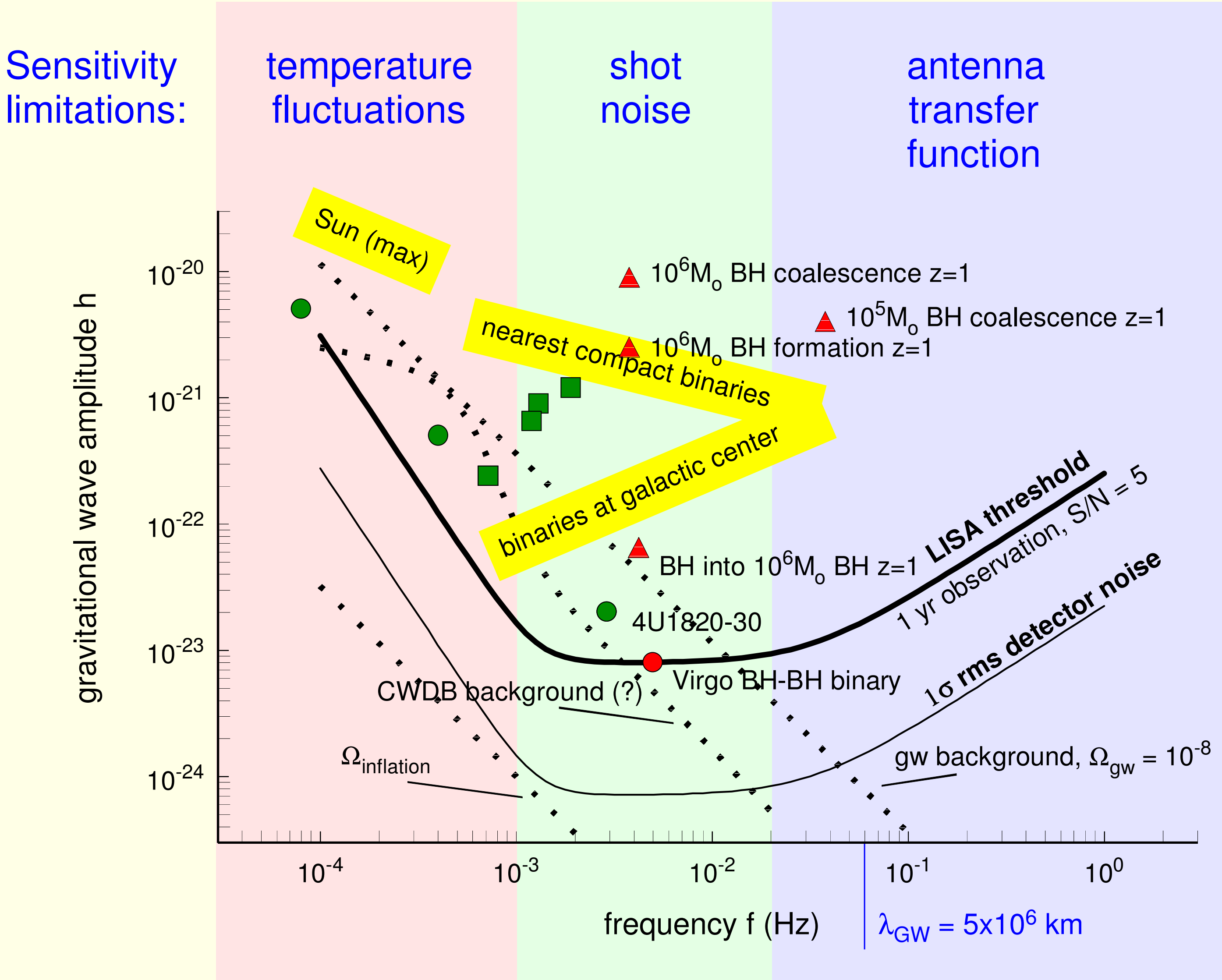
- shot noise floor
  10^{-3} to 2×10^{-2} Hz



Sensitivity of LISA: three distinct regimes:

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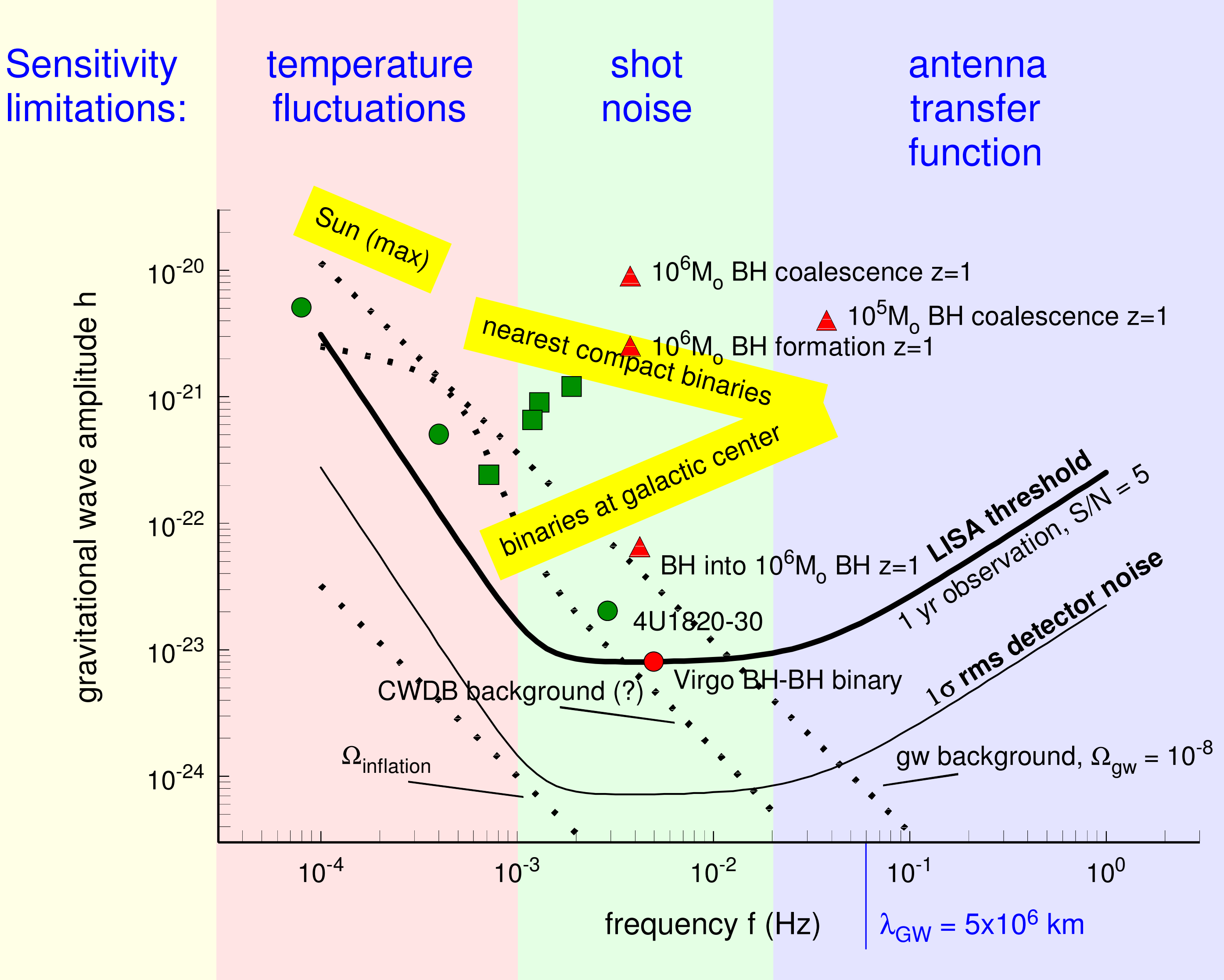
  below 10^{-3} Hz

- shot noise floor

  10^{-3} to 2×10^{-2} Hz

- antenna response

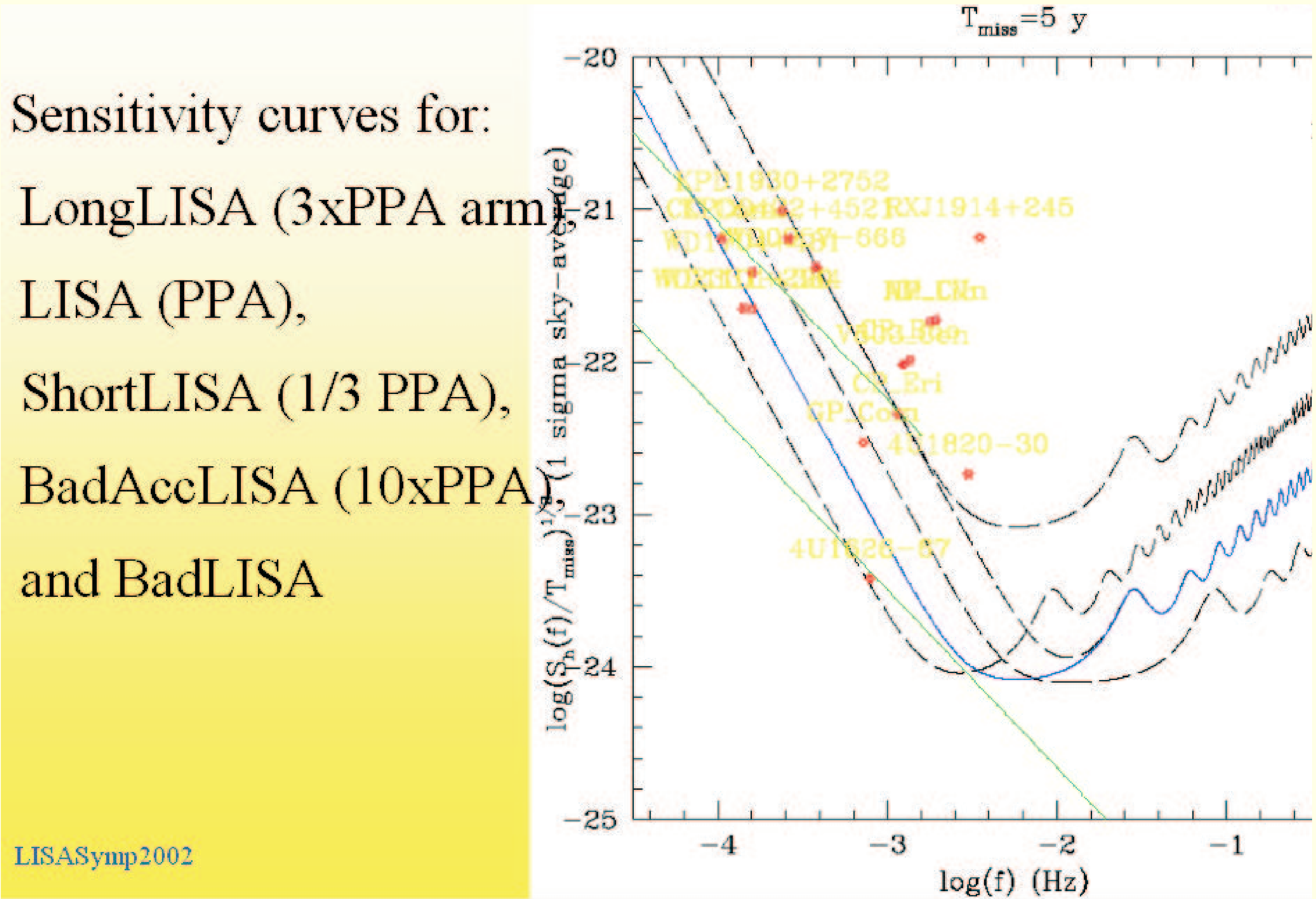
  above 2×10^{-2} Hz



Alternative Armlengths of LISA

being discussed in evaluations of LISA:

what can be gained in extremely low-frequency sources



Bad (Acc + Sh.n.)
Long
LISA, + BadAcc
Short

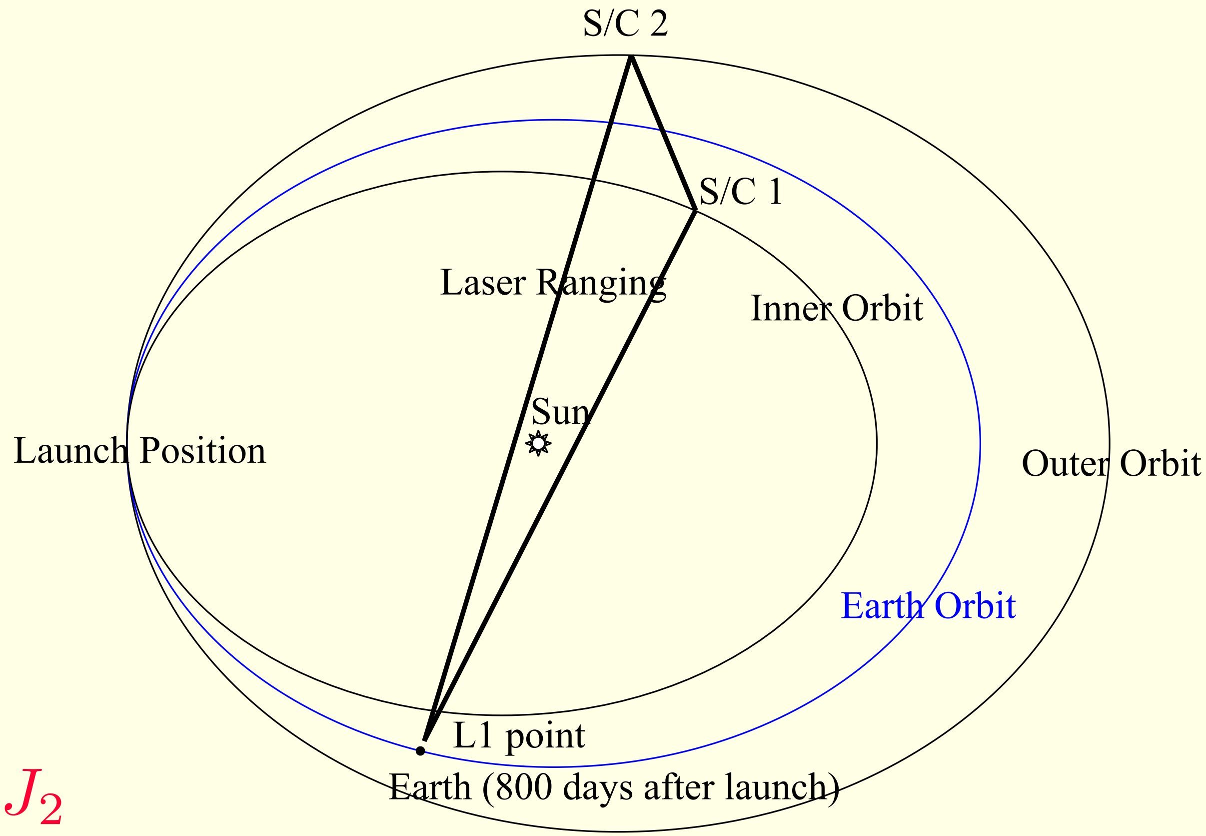
Concept of ASTROD proposed by Wei-Tou Ni

going to extremely long armlengths

measure (solar) relativistic effects, β, γ, and J_2

1 spacecraft near Earth
- at Lagrange point L1

2 s/c on Earth-like orbits
- slightly (20 %) bigger
- slightly (20 %) smaller



after about $2\frac{1}{2}$ years:
- 2 distant s/c behind Sun
- ideal for measurements of β, γ, J_2
- but particularly bad for GW detection

ASTROD for GW Detection:

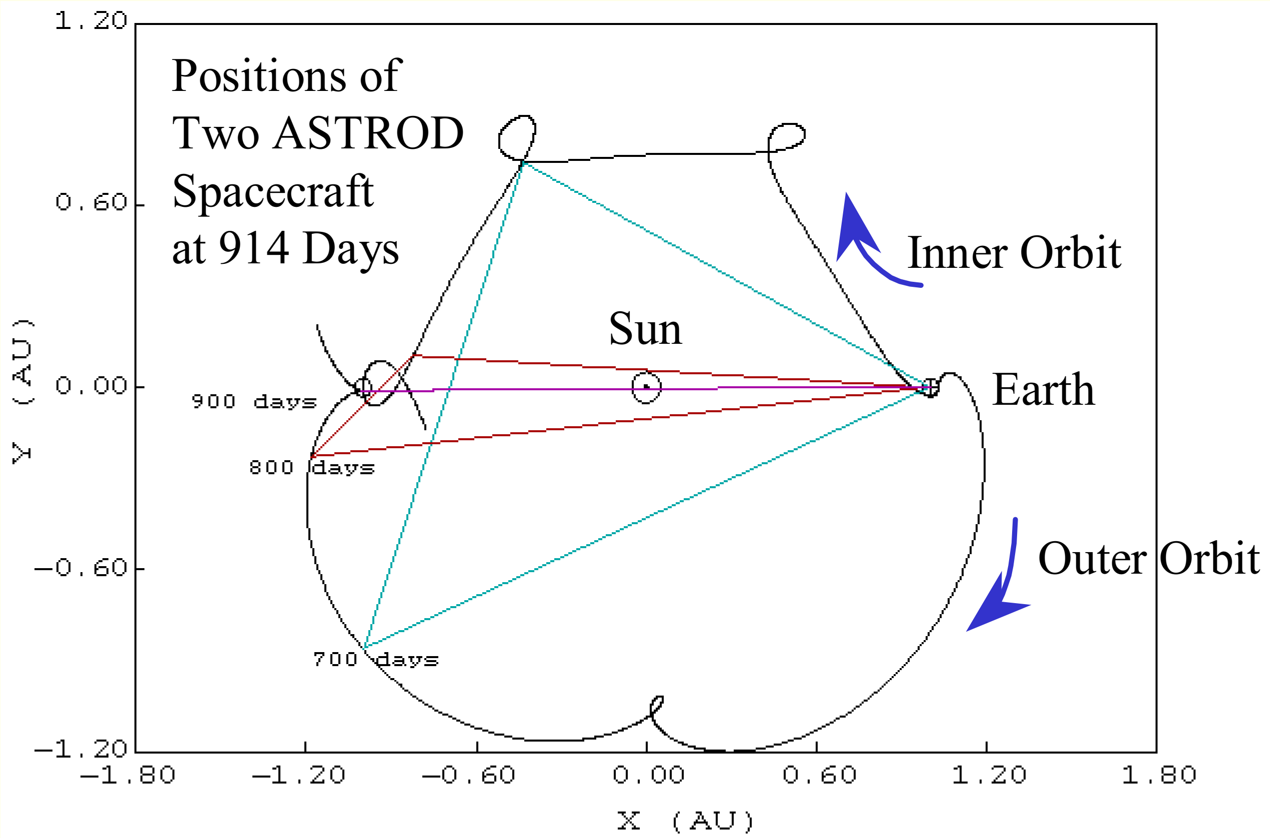
during approach, and after "relativistic" configuration

armlengths of $\sim 1 \cdots 2$ AU

good opening angles

only slowly varying

variation of equal sign



arms rather unequal:

a challenge to M. Tinto's *time delay interferometry*

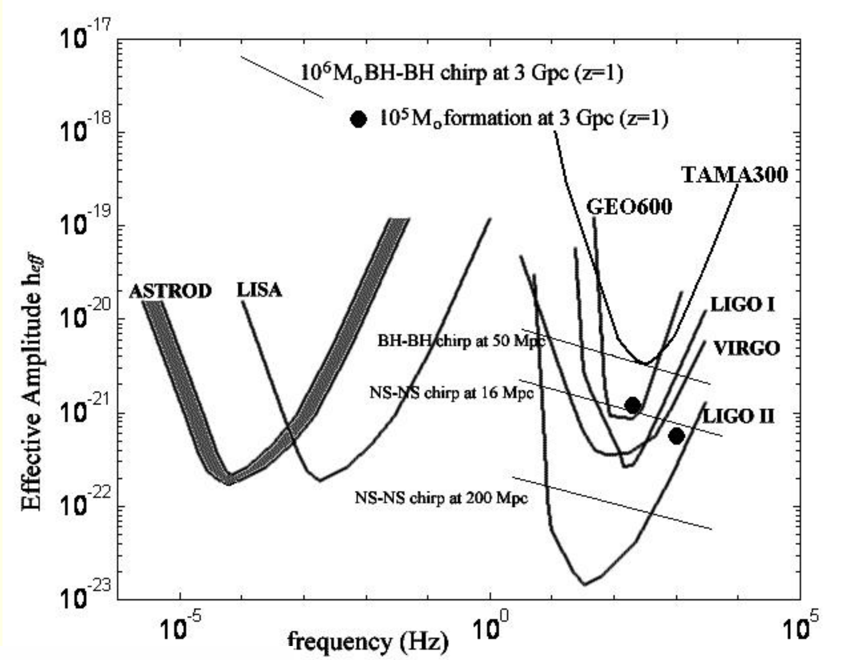
"breathing" armlength: further complication

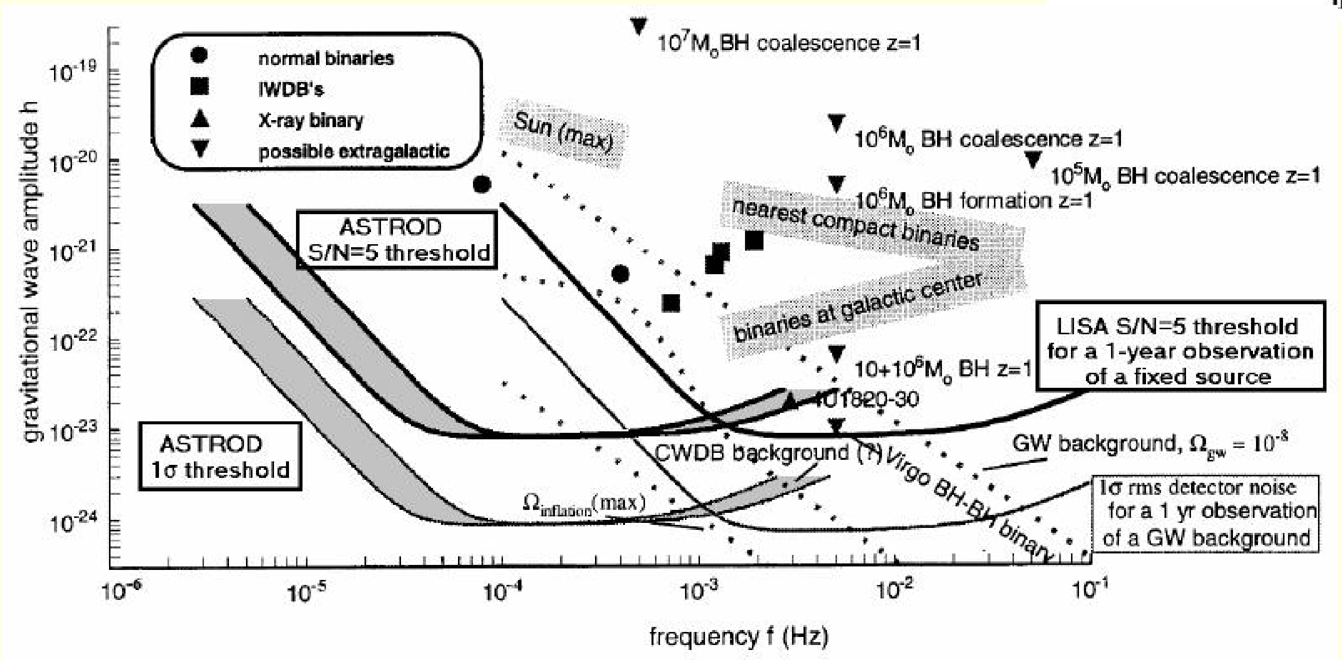
but also considered in some LISA variants

Sensitivity Given in Early ASTROD Literature

showed **ASTROD** sensitivity curve
as pure shift of **LISA** curve

Although desirable,
take with grain of salt





Sensitivity Law : shot noise as function of armlength

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- **shot noise effect**

$$\widetilde{h}_{\rm sh.n.} = \frac{\widetilde{\delta L_{\rm sh.n.}}}{L} \sim \frac{1}{L\sqrt{P_{\rm recv}}}$$

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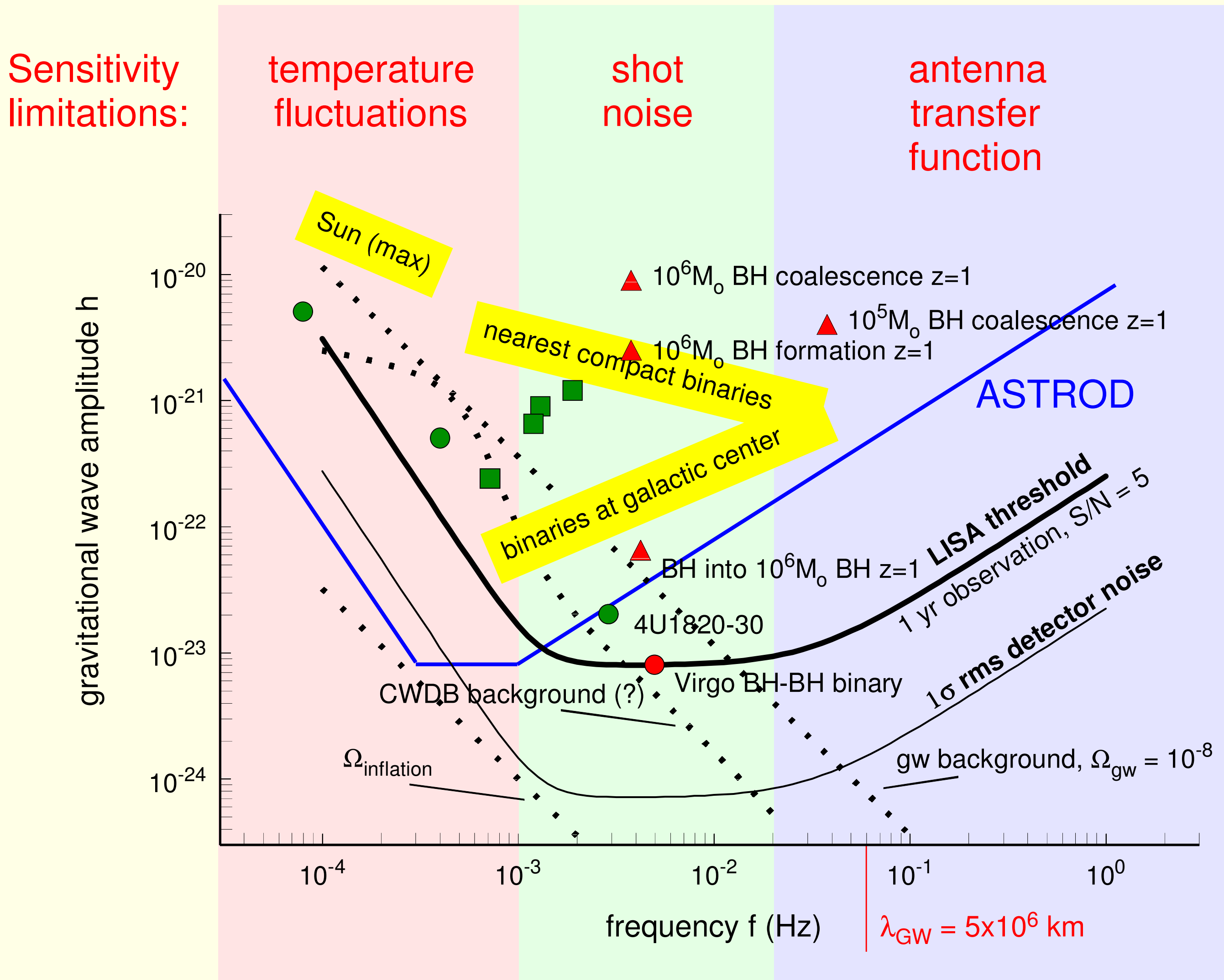
$$\widetilde{h}_{\text{sh.n.}} = \frac{\widetilde{\delta L_{\text{sh.n.}}}}{L} \sim \frac{1}{\sqrt{P_0}}$$

independent of arm length L

Sensitivity of ASTROD: as compared with **LISA**:

change in sensitivity due to armlength change by factor α



Sensitivity of ASTROD: as compared with LISA:

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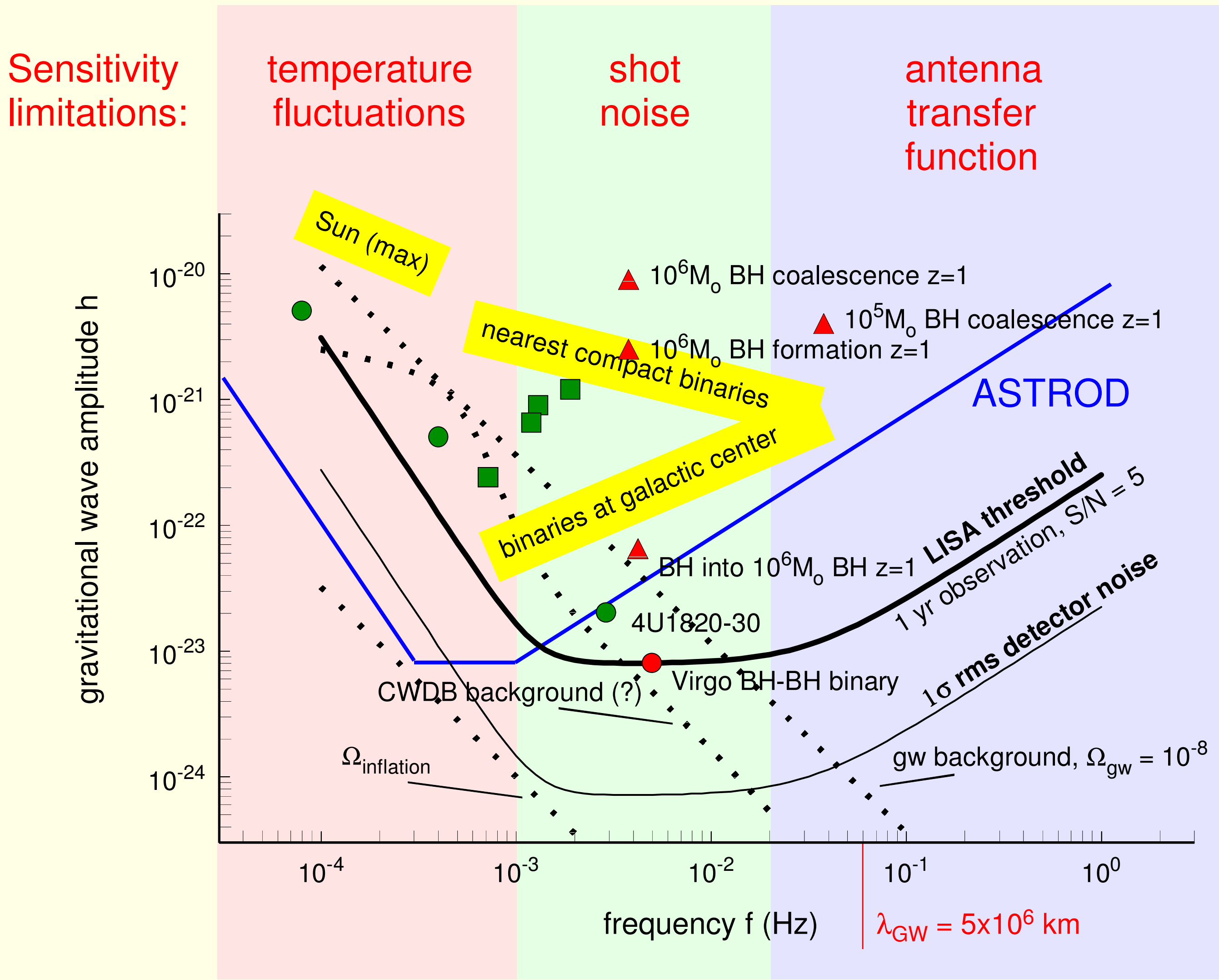
shot noise floor remains

acceleration as $1/\alpha$

response regime: as α



Sensitivity of ASTROD: as compared with **LISA**:

change in sensitivity due to armlength change by factor α

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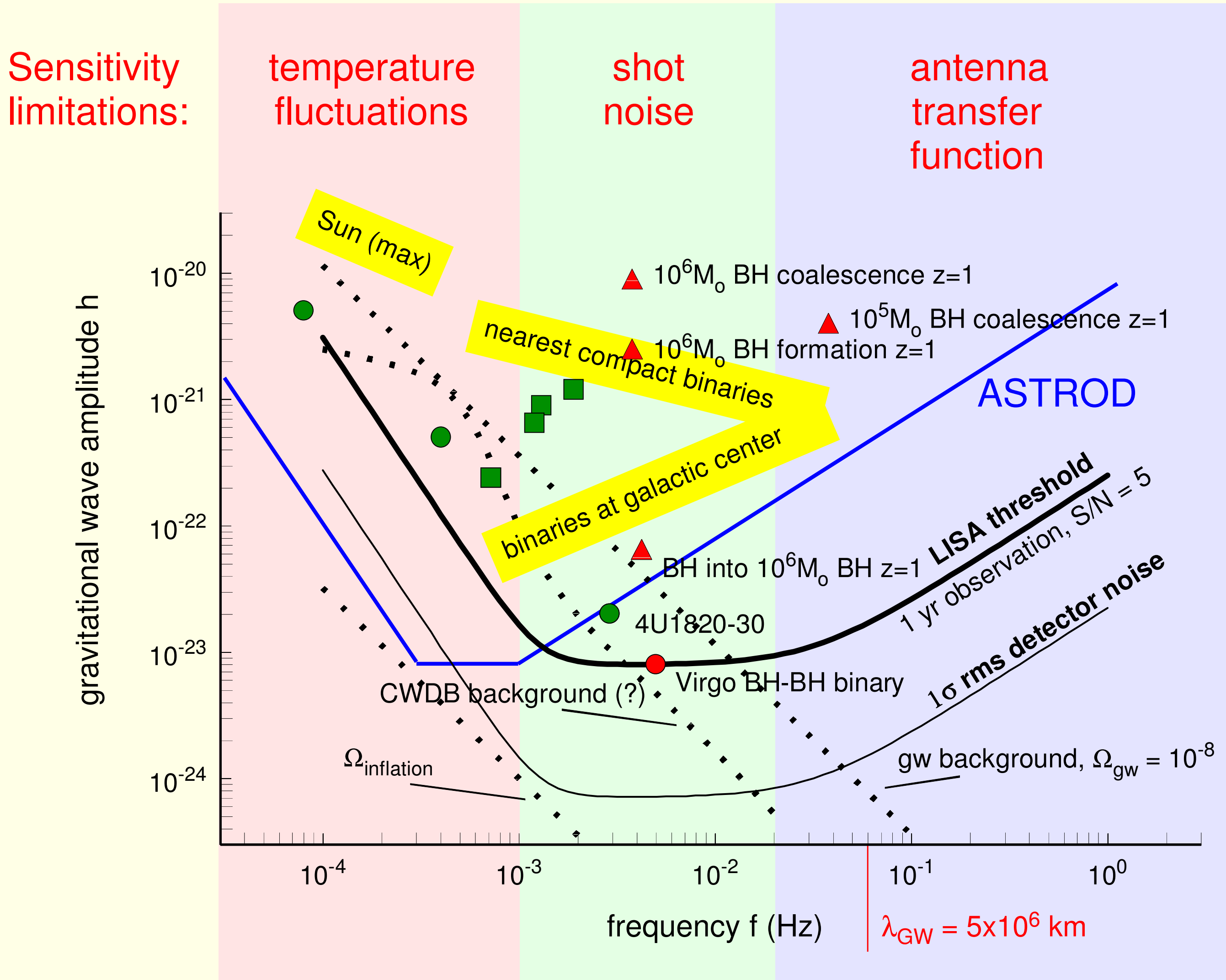
response regime: as α

express change as

shift in **frequencies**:

acceleration: as $1/\sqrt{\alpha}$

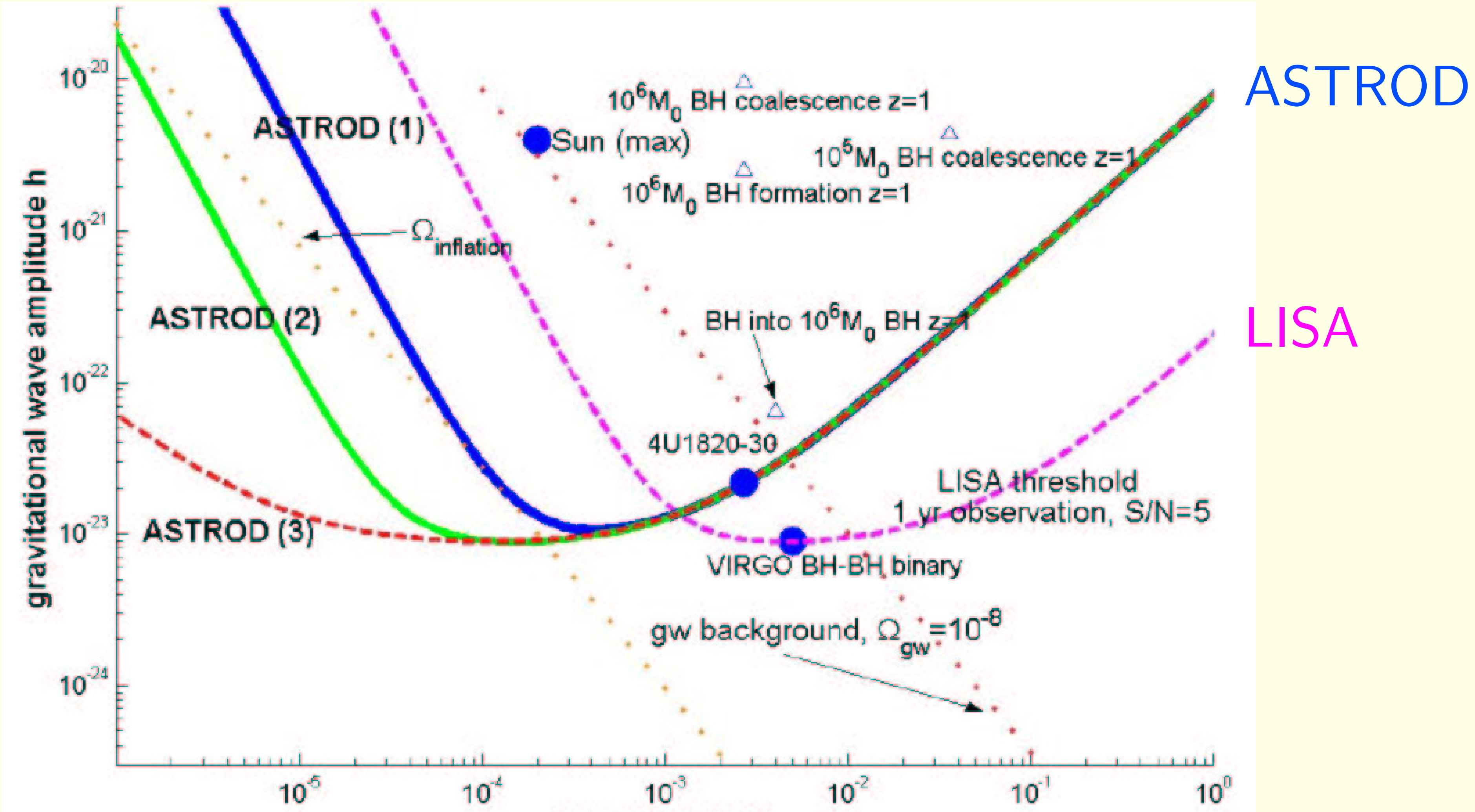
response: as α



Sensitivity of ASTROD (as compared with LISA)

given for three assumptions on accelerometer noise:

as in LISA, LISA/30, extreme; shot noise assumed constant



Technology Demonstrator Mini-ASTROD

as SMART-2 for LISA:

a mission Mini-ASTROD is to

test vital ASTROD technologies

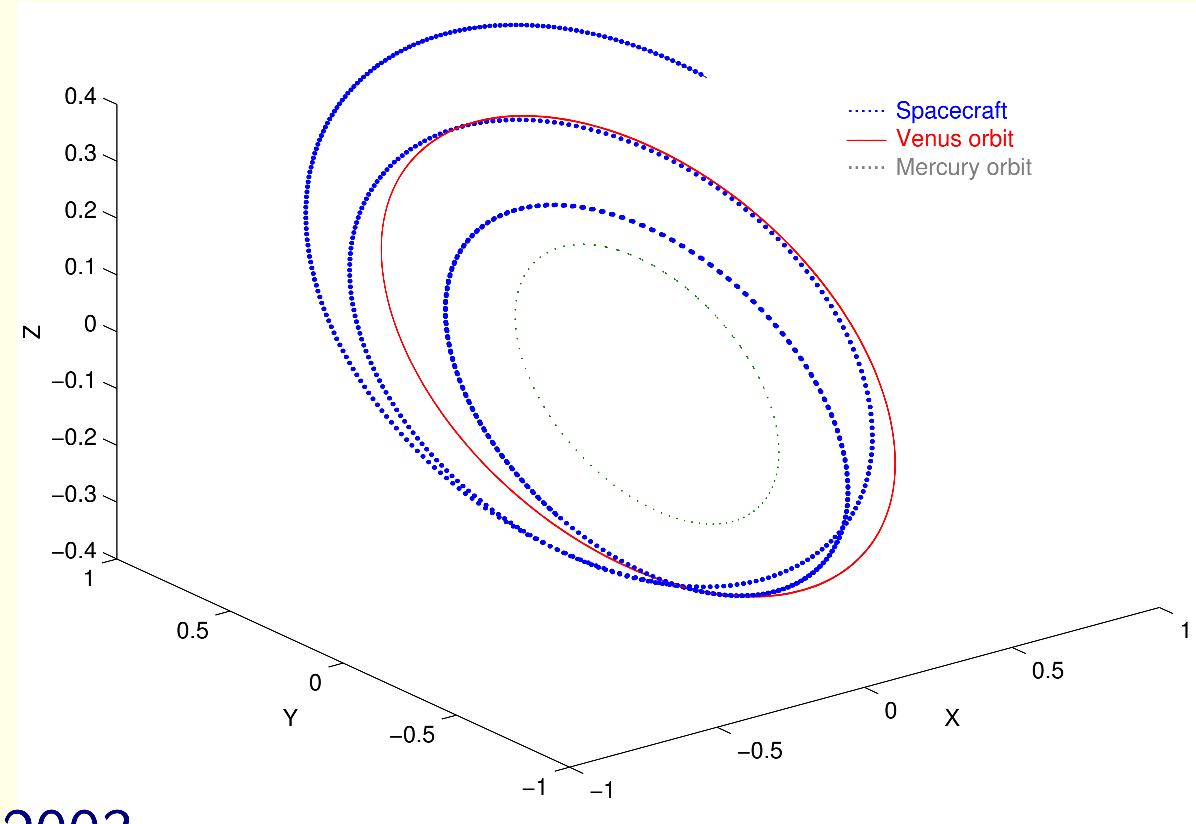
only **one** spacecraft launched:

behind the sun : after 400 days,

and again after 700, 1100 days

via double swing-by at Venus

with laser as for ASTROD



one telescope on ground:

at Kunming Observatory

dedicated for that mission

Phase-A Study to be performed in 2003

Trajectory of Mini-ASTROD

spacecraft launched from Earth (top)

(Earth orbit not shown)

1st swing-by at Venus

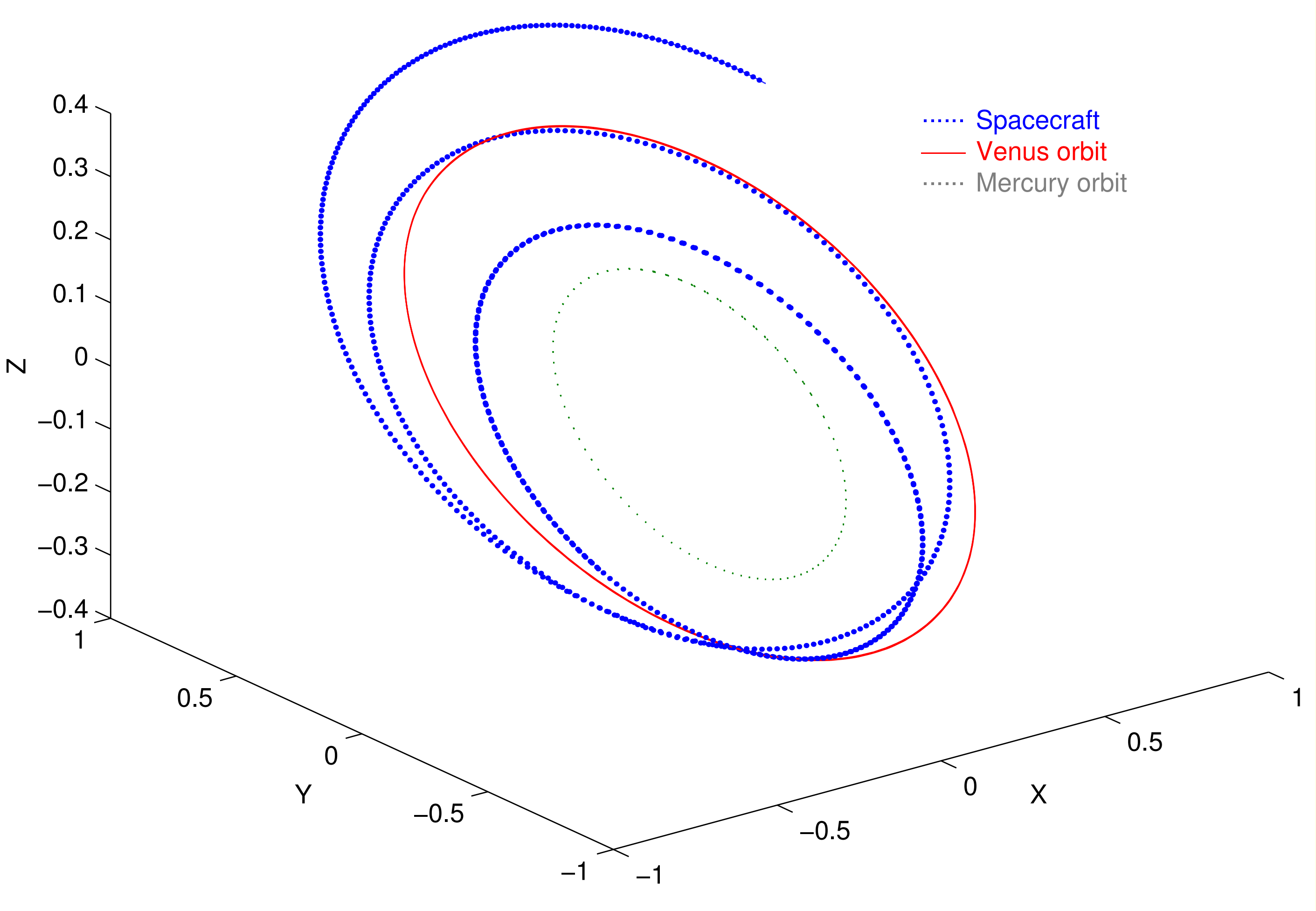
into Venus-like orbit

with 245 days' period

2nd swing-by at Venus

into smaller orbit

with 165 days' period



S/C behind the sun at days 400, 700, 1100

The Proposing Collaboration for **ASTROD**:

The project **ASTROD** has been studied intensely
at Tsing Hua University, Taiwan

It is now supported simultaneously by

- National Astronomical Observatory of China, Beijing
- Purple Mountain Observatory, Nanjing
- and other Institutions in China and Taiwan

International Collaboration for ASTROD:

ASTROD is a joint project of "the two Chinas",
as it is supported simultaneously by institutions in

- the People's Republic of China, PRC
- the Republic of China, ROC, Taiwan

Further collaborations have been started with

- France, CERGA*, CNES (2003–2005)
- Germany, ZARM** Bremen
- Germany, Universität Düsseldorf

* Centre d'études et de Recherches en Géodynamique et Astrométrie

** Zentrum für Angewandte Raumfahrttechnologie und Mikrogravitation

Schedule for Space GW Detectors :

- 2006: **LTP** on SMART-2
- 2006: **ST7** on SMART-2
- 2010: **Mini-ASTROD** launch ?
- 2011: **LISA** launch
- 2017: **ASTROD** launch ?
- 20??: **DECIGO** launch ? ("before end of this century")

"Beyond Einstein"

NASA initiative for future research in Relativity

Detector LISA is one prominent mission in this initiative *

* note added in proof: LISA now in top place

Detectors Beyond LISA will form further decisive field

Big Bang Observer (BBO) is one typical project

Such LISA follow-ons will again be opportunity
for close collaboration with ESA

Conclusion :

Although **LISA** not yet launched:

investigations into LISA follow-ons (below and above)

- are timely
- are necessary
- will encourage international collaboration
- will widen interest in special topics
- will yield great scientific returns

So: let's start working on them, working on an exciting future

The End