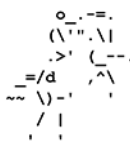
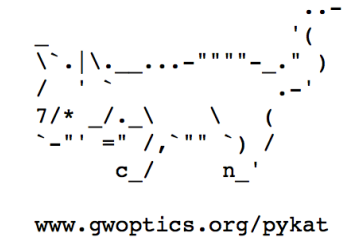


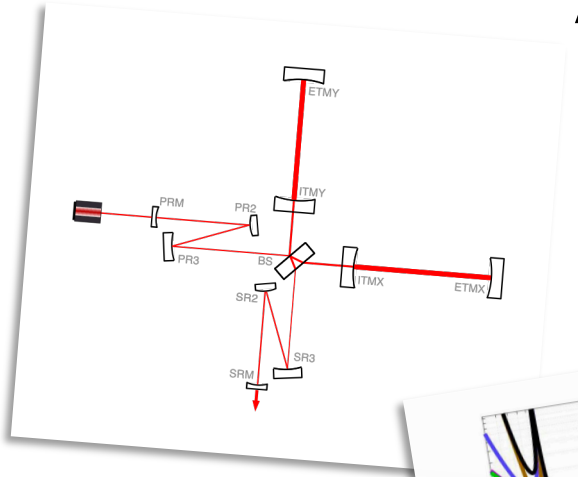
Finesse 2

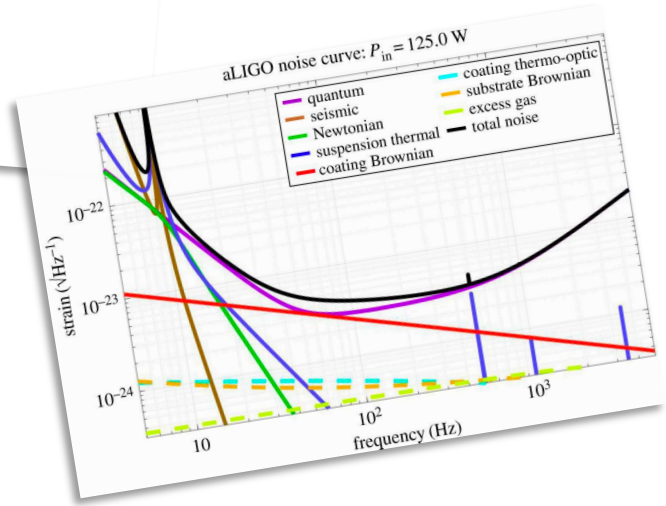
PyKat develop

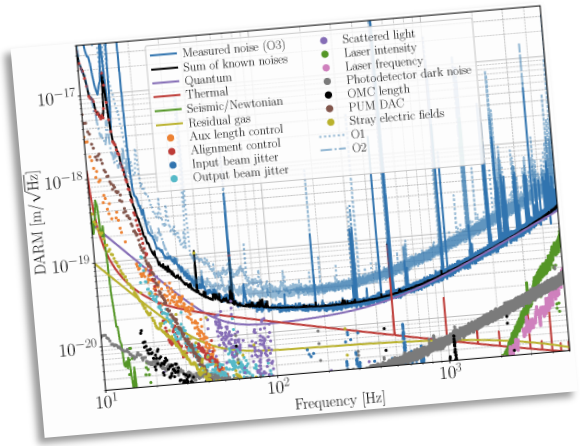


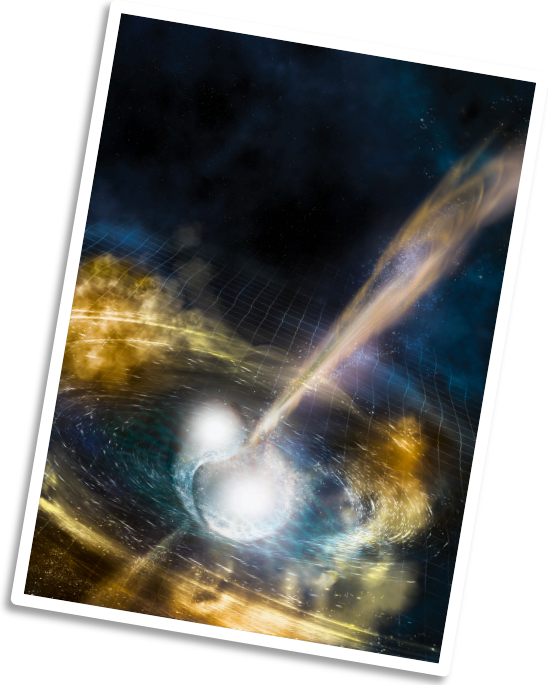
www.gwoptics.org/pykat

Advanced LIGO in brief



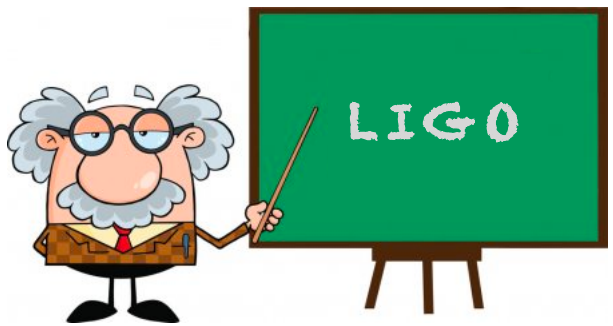






What we'll be covering

- Sensitivity Curve(s) of the Advanced LIGO design
- Optical layout
  - How is Advanced LIGO different to a simple Michelson?
- Timeline and highlights so far



depositphotos.com

Design Sensitivity of Advanced LIGO

What are we aiming for? What are the limiting noise sources we expected to see?

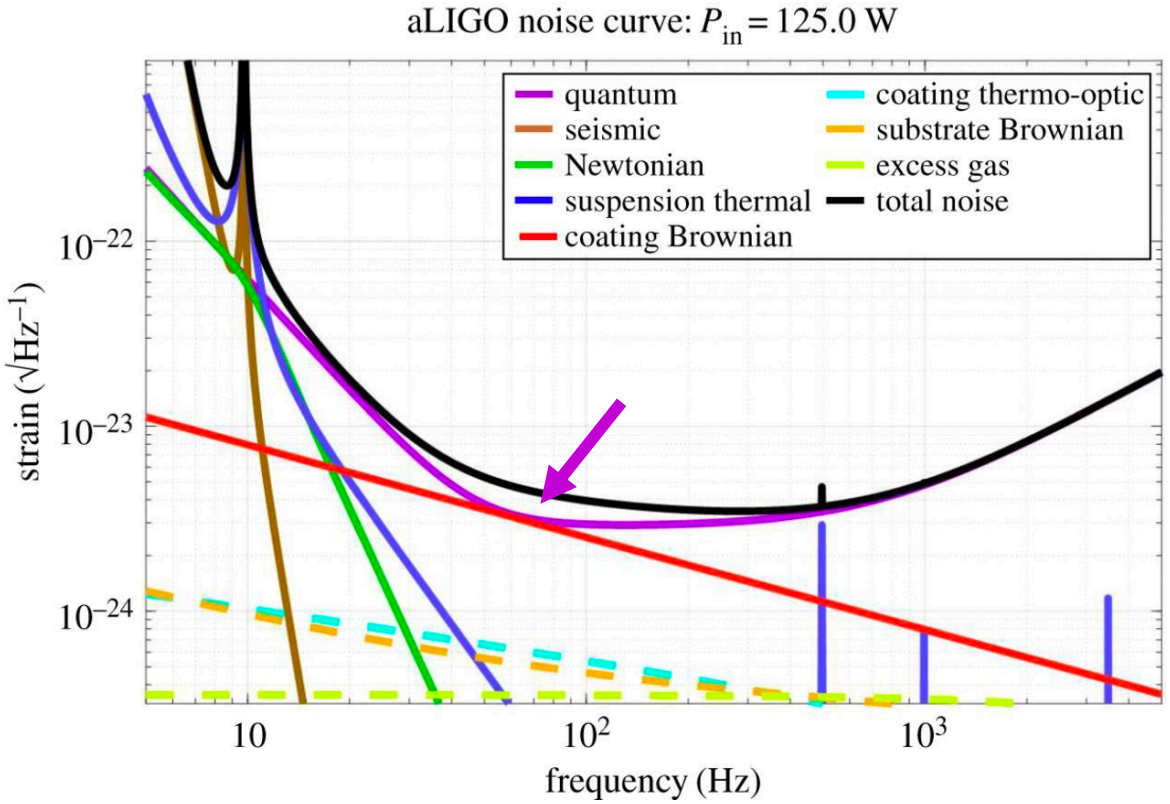
So far: quantum noise-limited sensitivity

- Set by the optical topology of the detector: layout, power, mirror masses, and squeezing

Low freqs:
Quantum **Radiation Pressure** Noise

$$S_{rp} \propto {}^{P}/_{m^2}$$

- Photons hitting mirrors
- Depends on beam power & mirror mass



High freqs:
Shot Noise

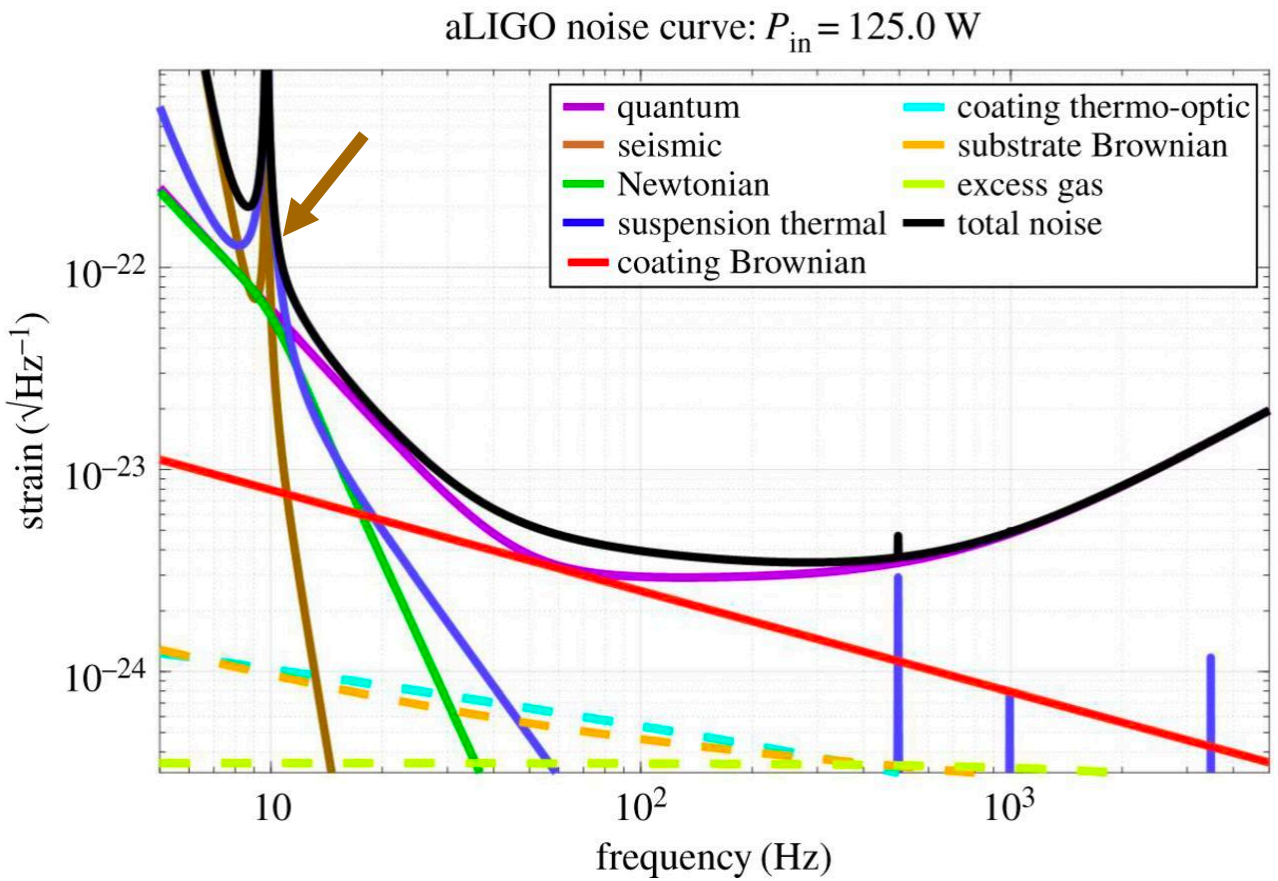
$$S_{sh} \propto {}^{1}/_{P}$$

- Photon counting at detector
- Depends on beam power

Many other noise sources, including:

Seismic Noise

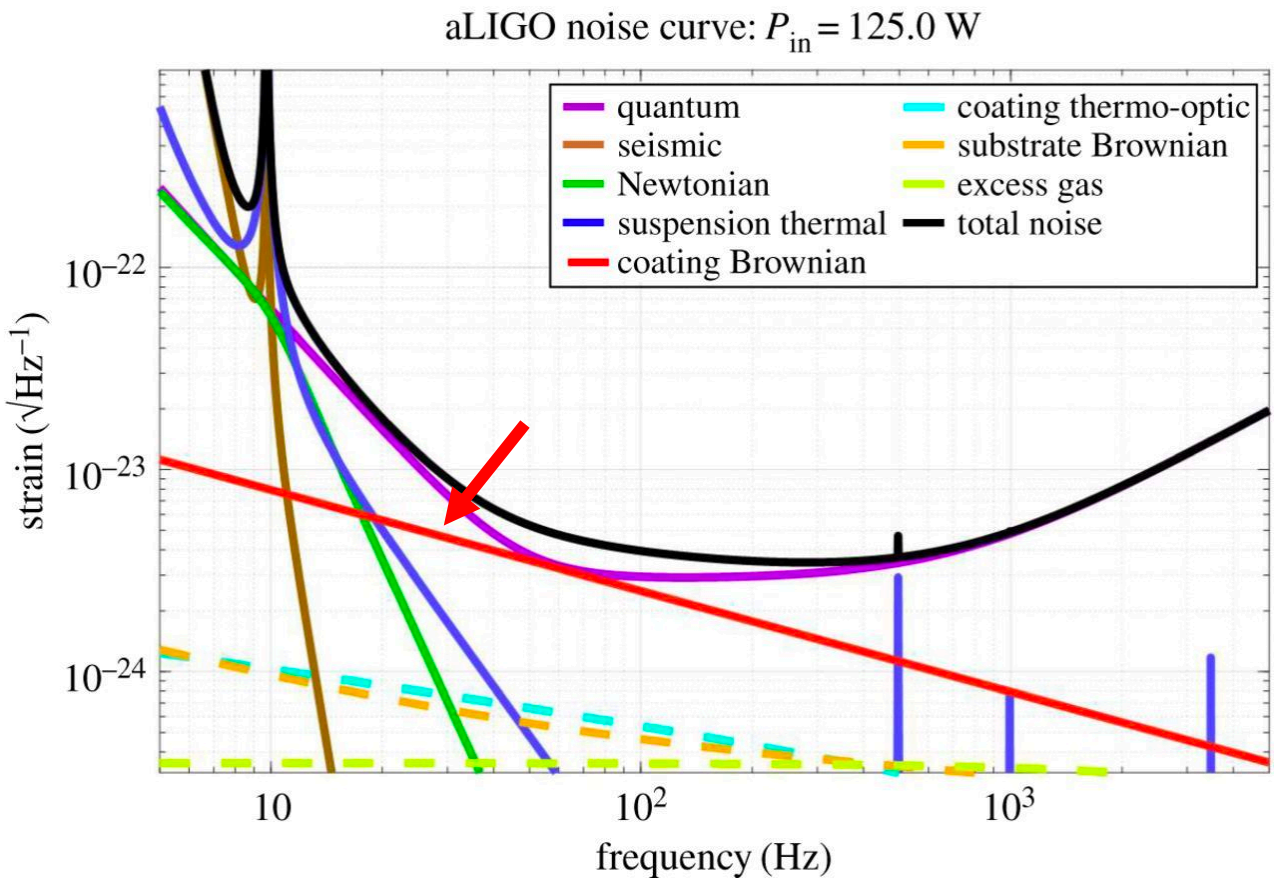
- Motion of the test masses due to ground motion
- Not just earthquakes! E.g. trucks passing, waves crashing, people dancing in the control room,…
- $1/f^2$ suppression from each pendulum stage; 4 stages.



Many other noise sources, including:

Coating Brownian

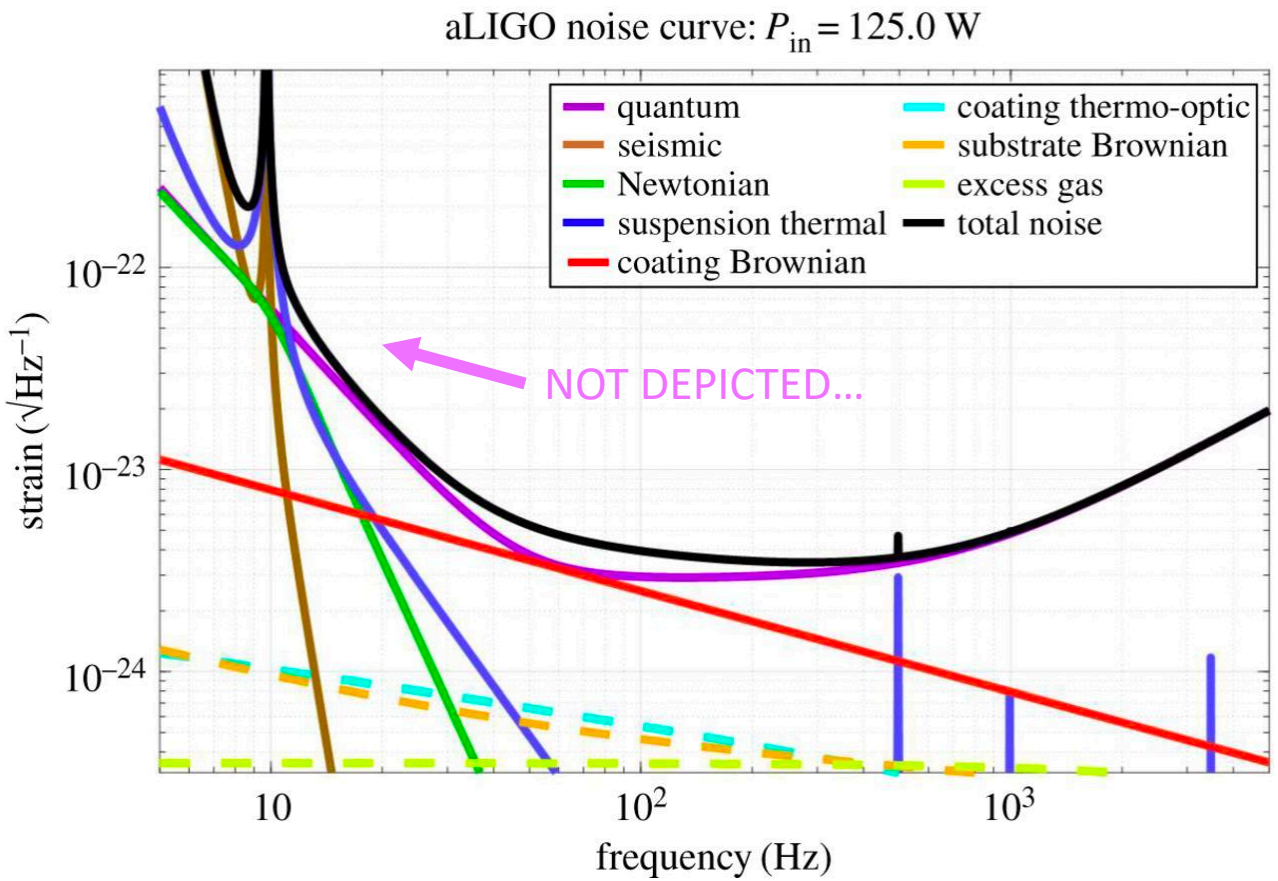
- Brownian motion of the atoms in the coatings of the mirrors
- Depends on material choices and temperature



Many other noise sources, including:

Controls noises

- Noise introduced when we try to control the interferometer
- Generally affect low frequencies more
- Many, many different types and sources, some understood more than others
(we'll come back to this…)

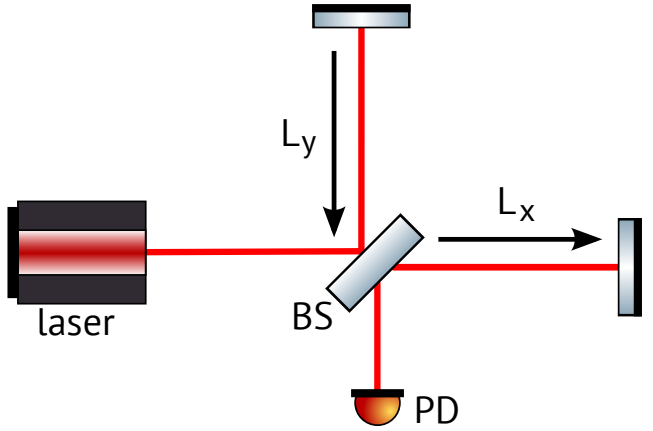


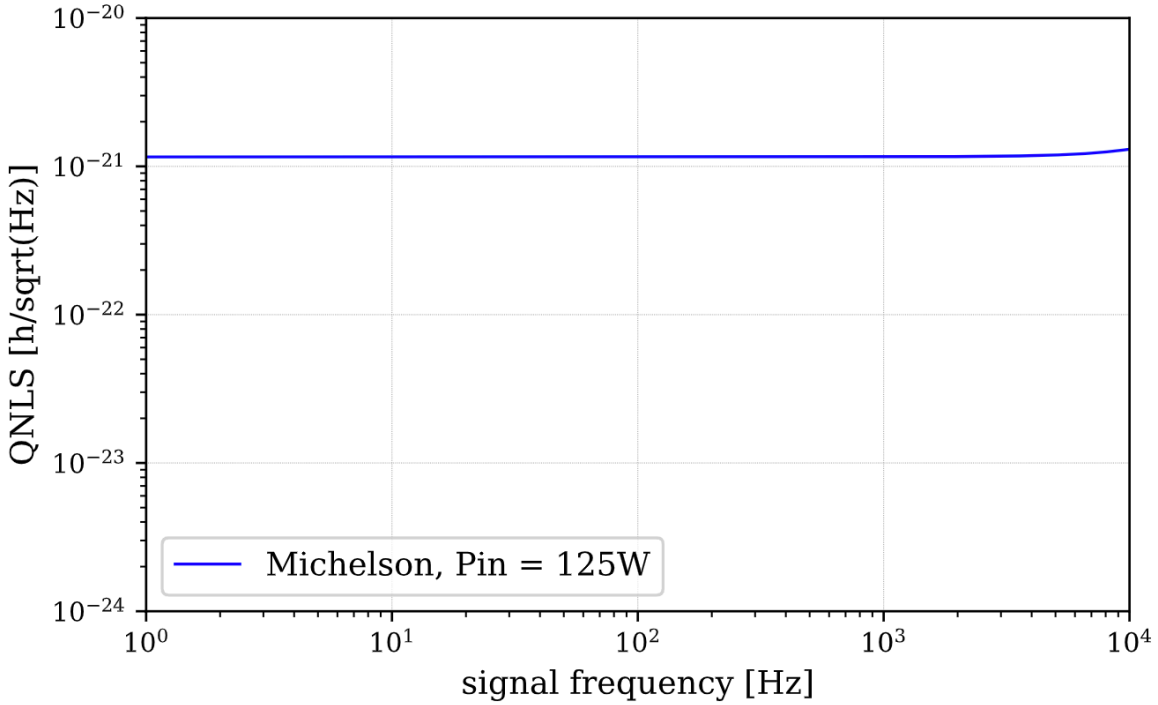
Optical Layout of Advanced LIGO

How does Advanced LIGO differ from a simple Michelson?

So far: simple Michelson

- Michelson you saw yesterday required **1MW** input power to achieve sensitivity of 10^{-23} h/sqrt(Hz)…unfortunately not very practical.
- Advanced LIGO *design* specifies **125W** input power

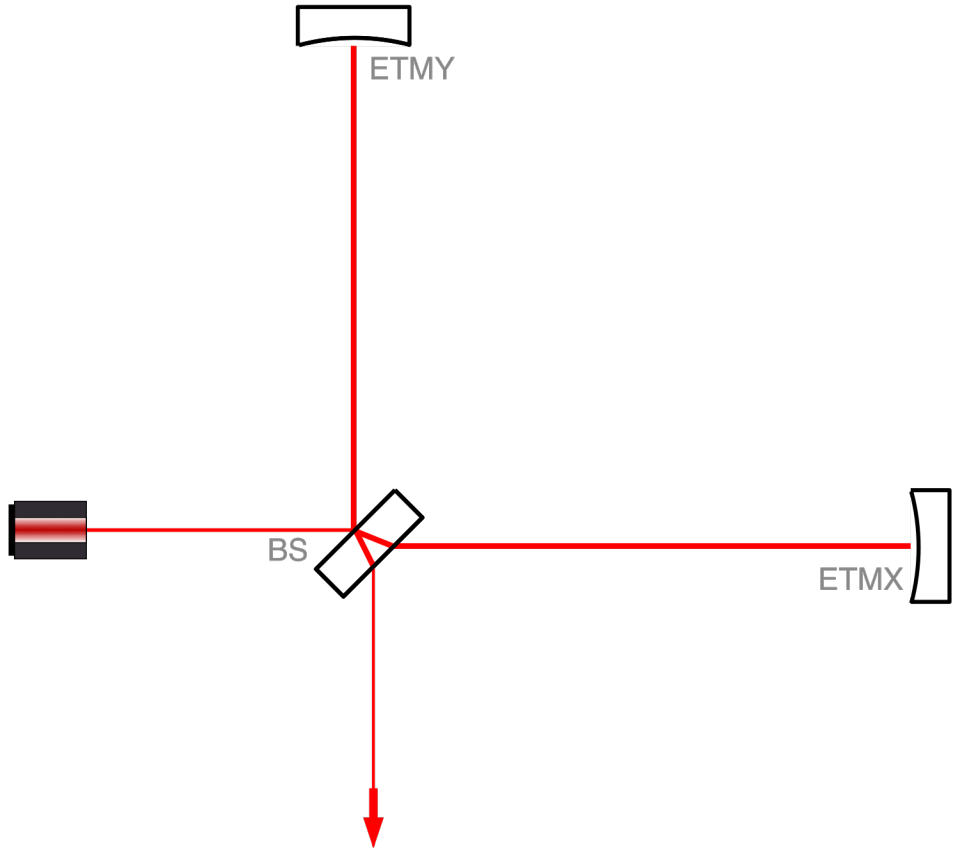




Optical Layout of Advanced LIGO

Goal: high signal strength, low quantum noise

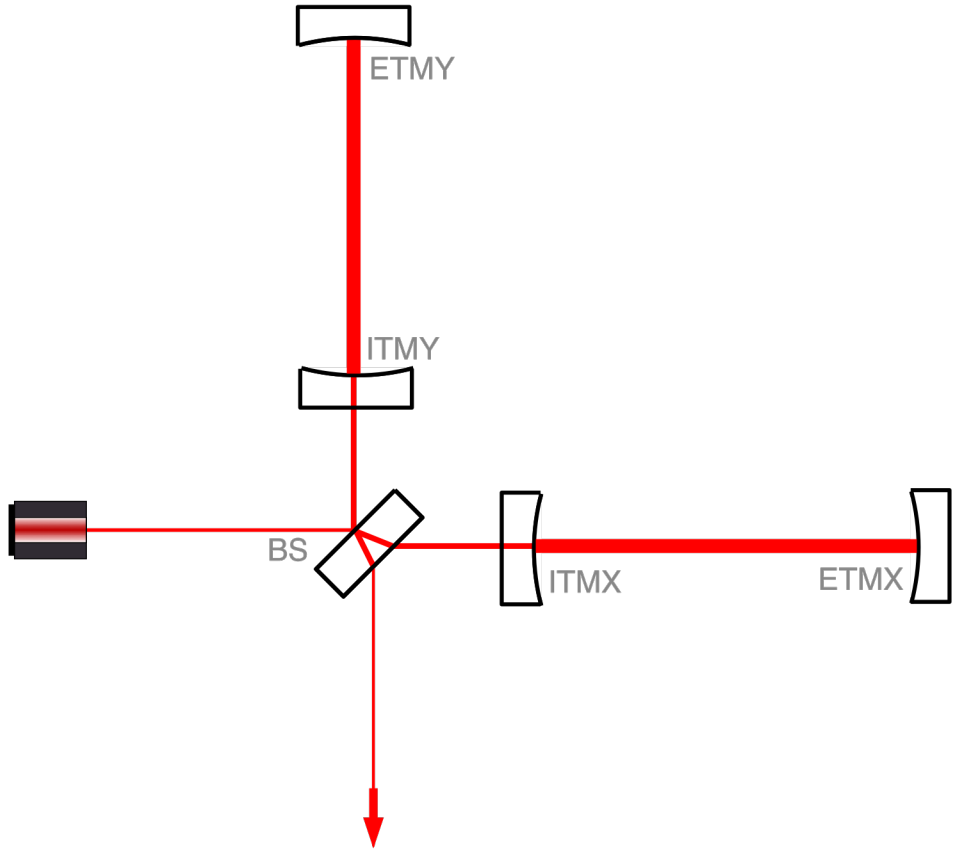
- Core Principal: Michelson



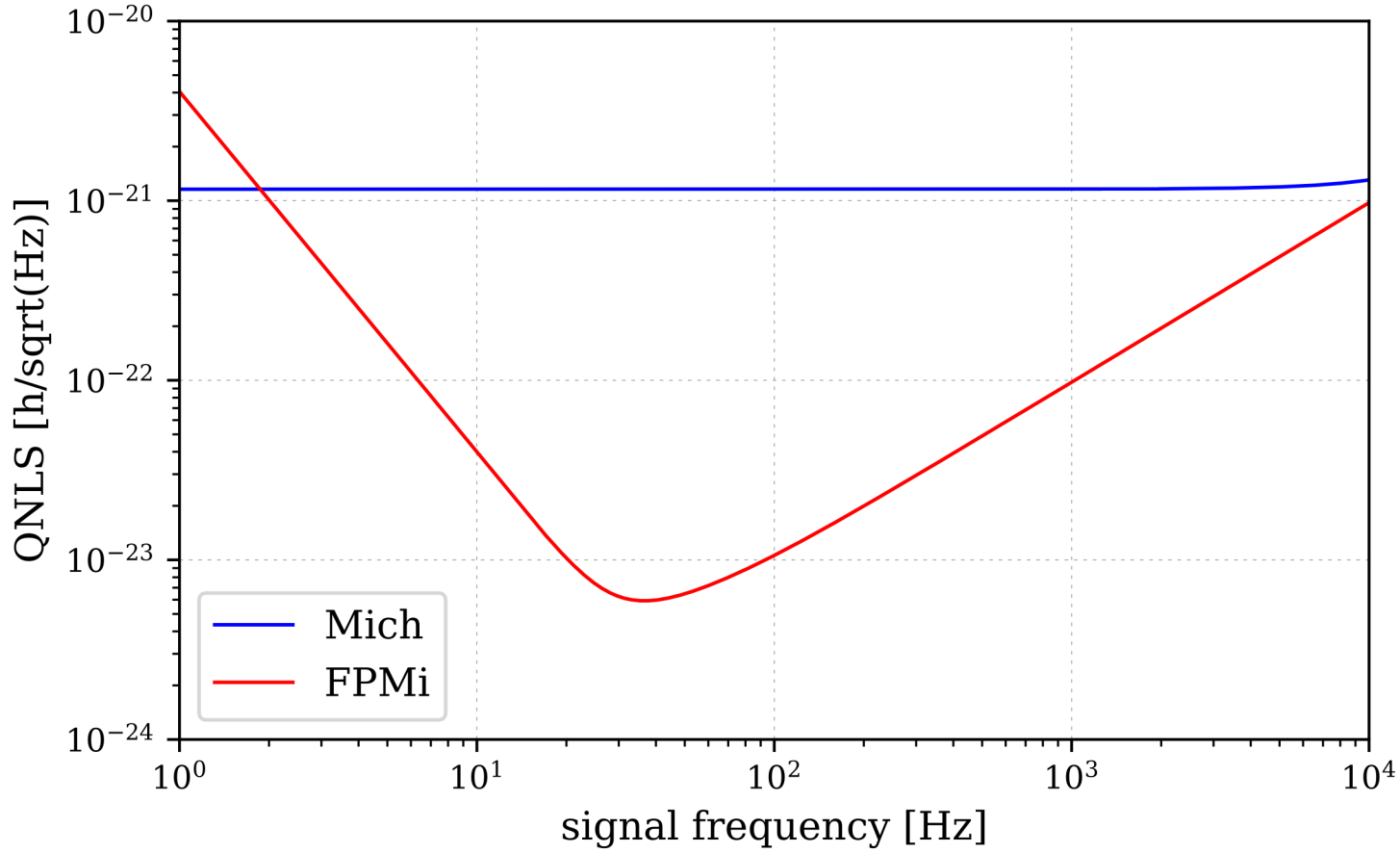
Optical Layout of Advanced LIGO

Goal: high signal strength, low quantum noise

- Core Principal: Michelson
- Arm Cavities
  - Amplify signal



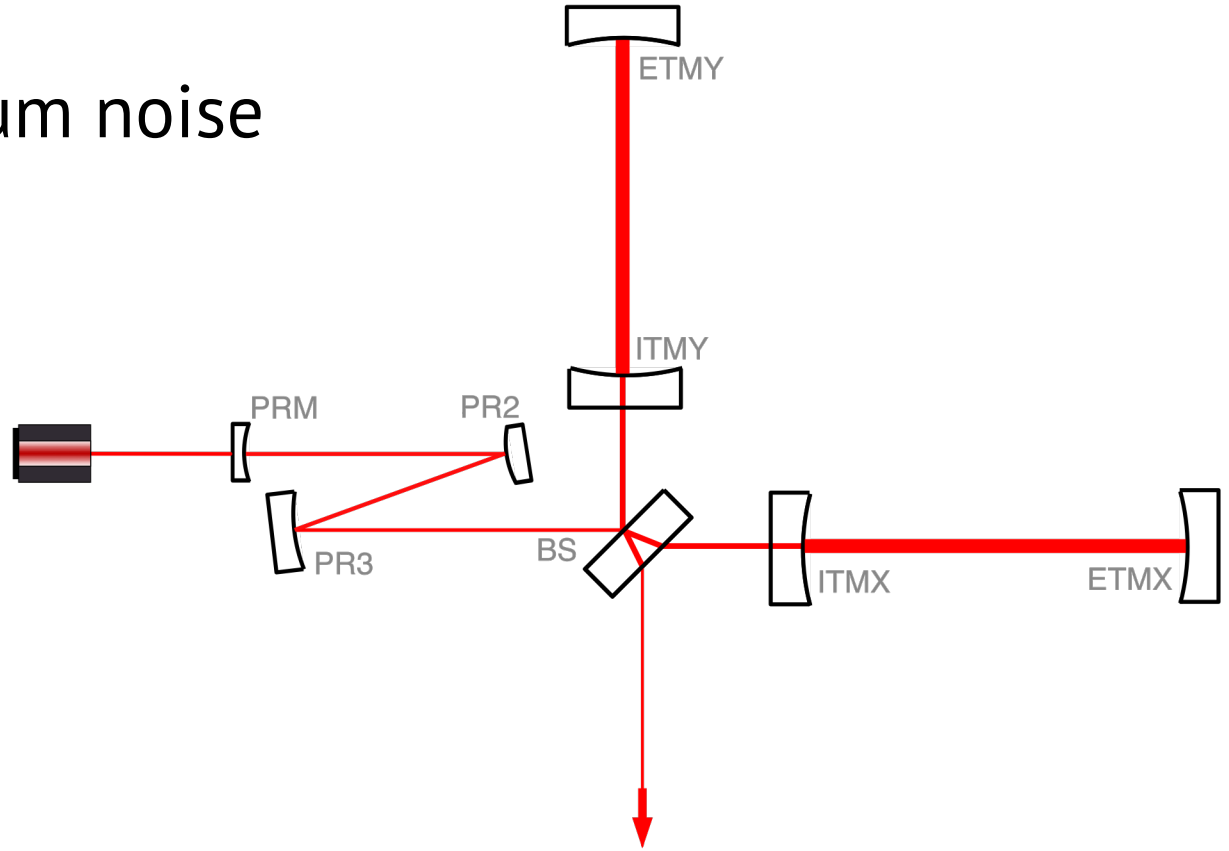
How does the sensitivity change?



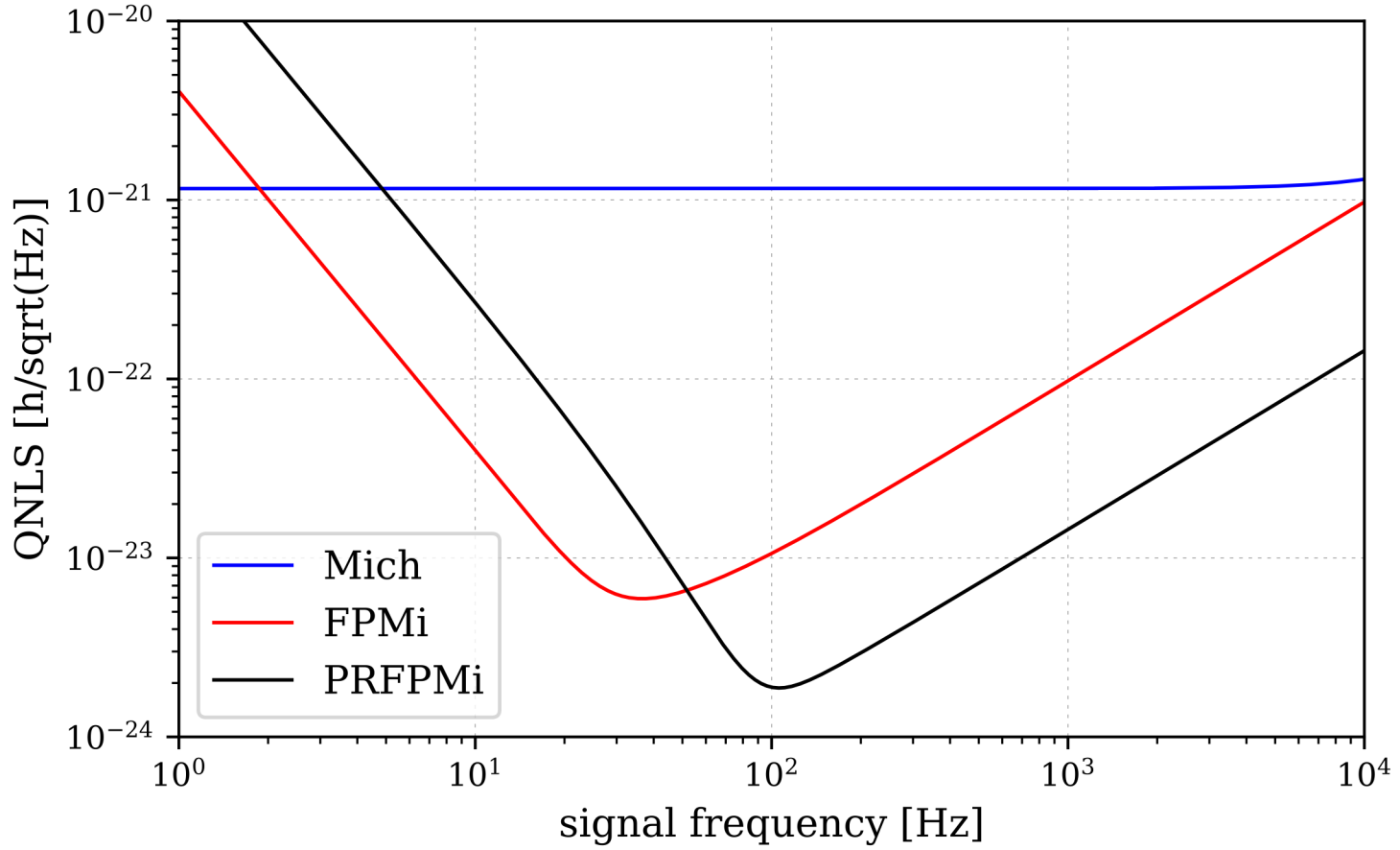
Optical Layout of Advanced LIGO

Goal: high signal strength, low quantum noise

- Core Principal: Michelson
- Arm Cavities
  - Amplify signal
- Power Recycling
  - Increases arm power (lower quantum shot noise)



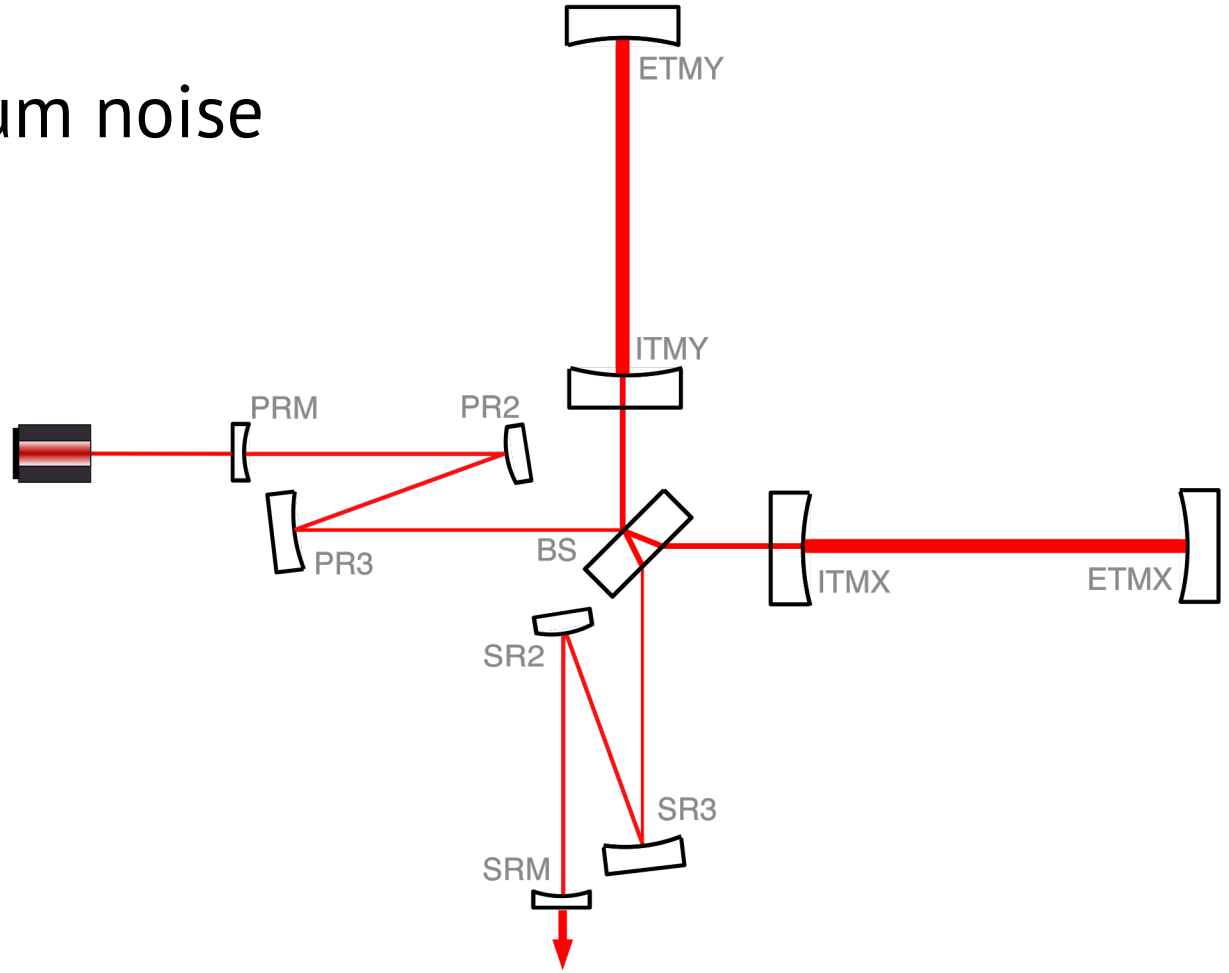
How does the sensitivity change?



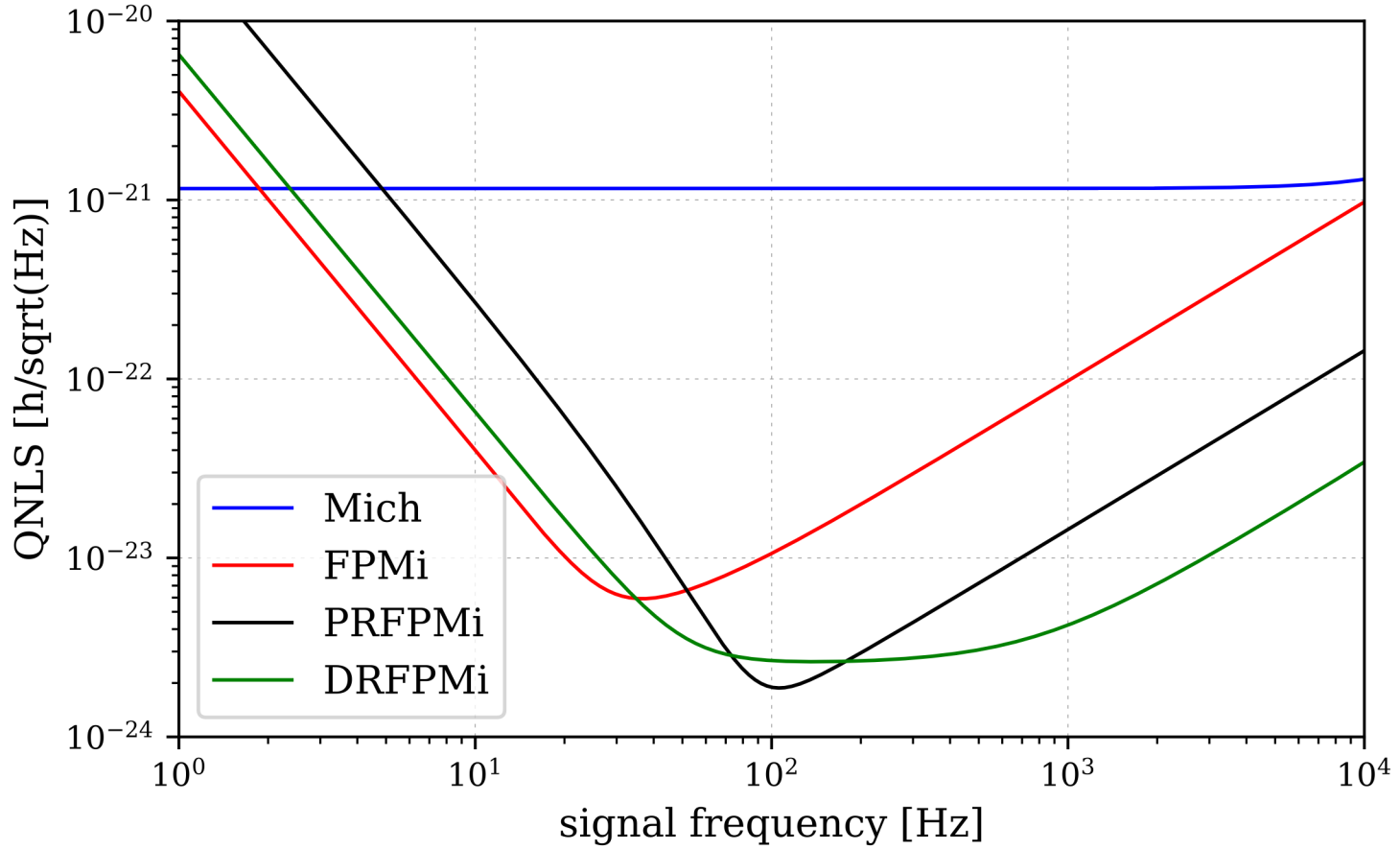
Optical Layout of Advanced LIGO

Goal: high signal strength, low quantum noise

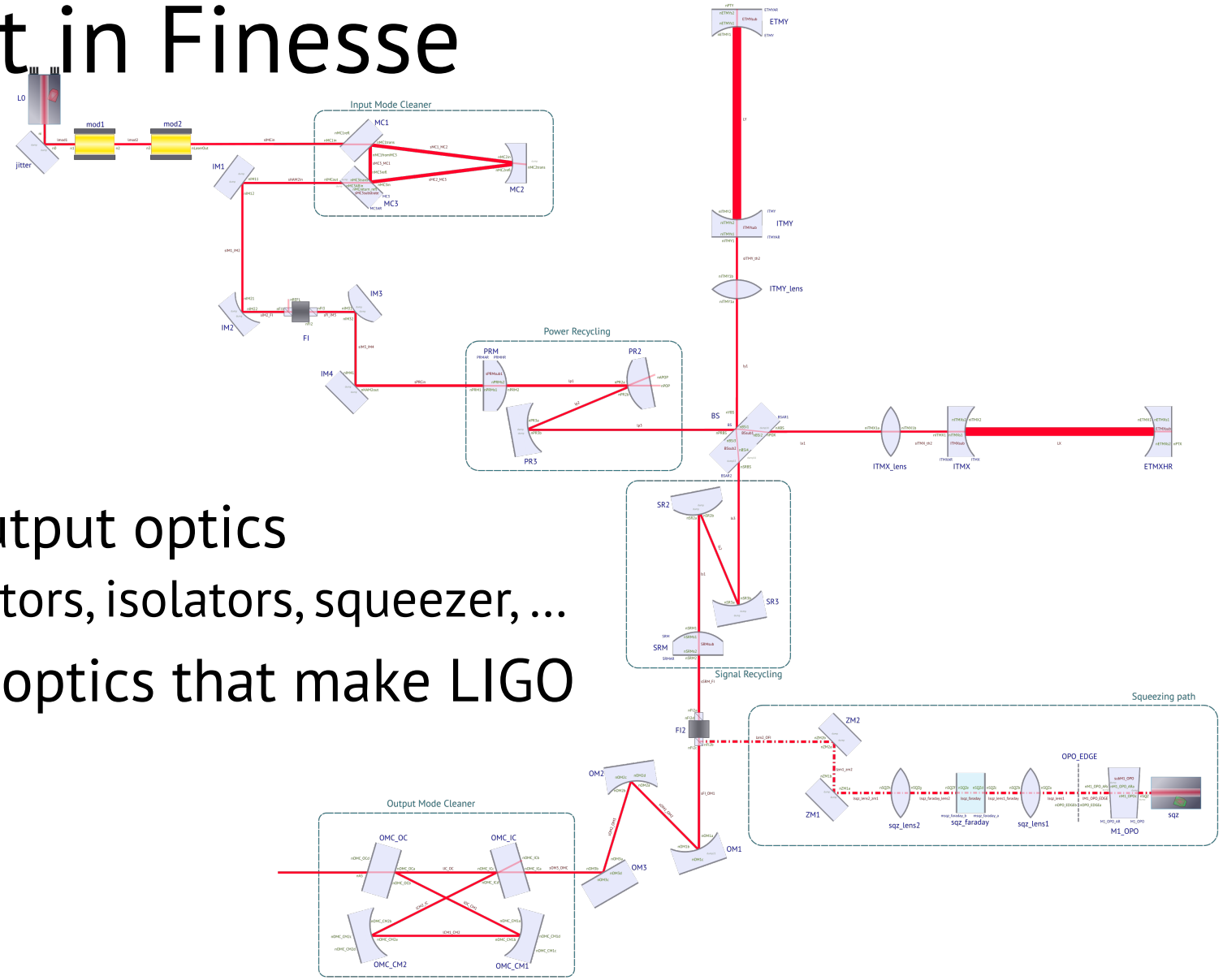
- Core Principal: Michelson
- Arm Cavities
  - Amplify signal
- Power Recycling
  - Increases arm power (lower quantum shot noise)
- Signal Recycling (actually Resonant Sideband Extraction)
  - Transmit signal efficiently to detector



How does the sensitivity change?



Detector layout in Finesse



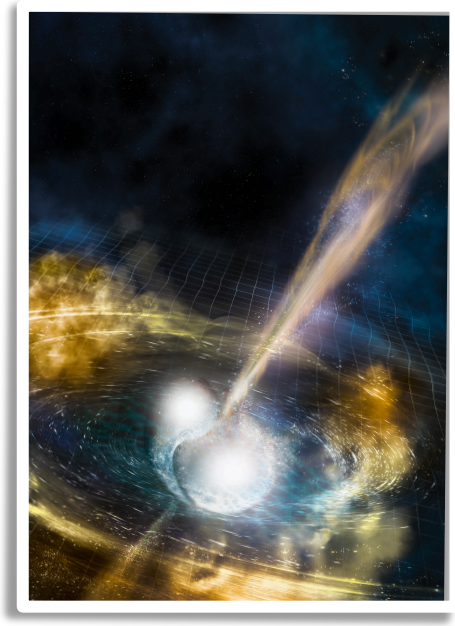
- DRFPMi + input and output optics
  - Mode cleaners, modulators, isolators, squeezer, …
- Still not the full set of optics that make LIGO happen!

Current Status – some highlights

Observing runs, sensitivity, and detections

aLIGO timeline

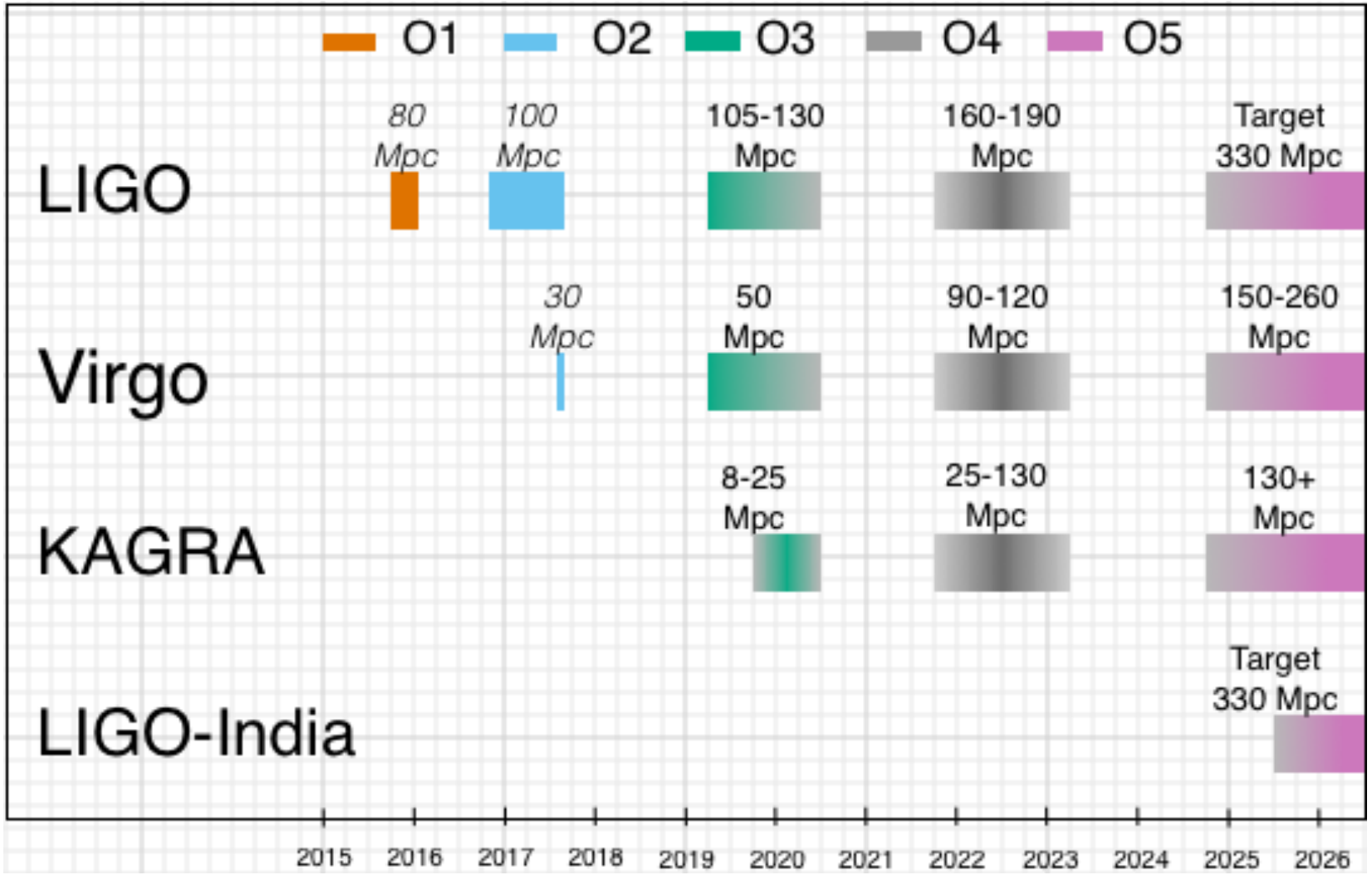
- 2000-2008: iLIGO, eLIGO
- 2008-2015: commissioning aLIGO
- 14th September 2015: aLIGO turns on, first detection
- Observing runs:



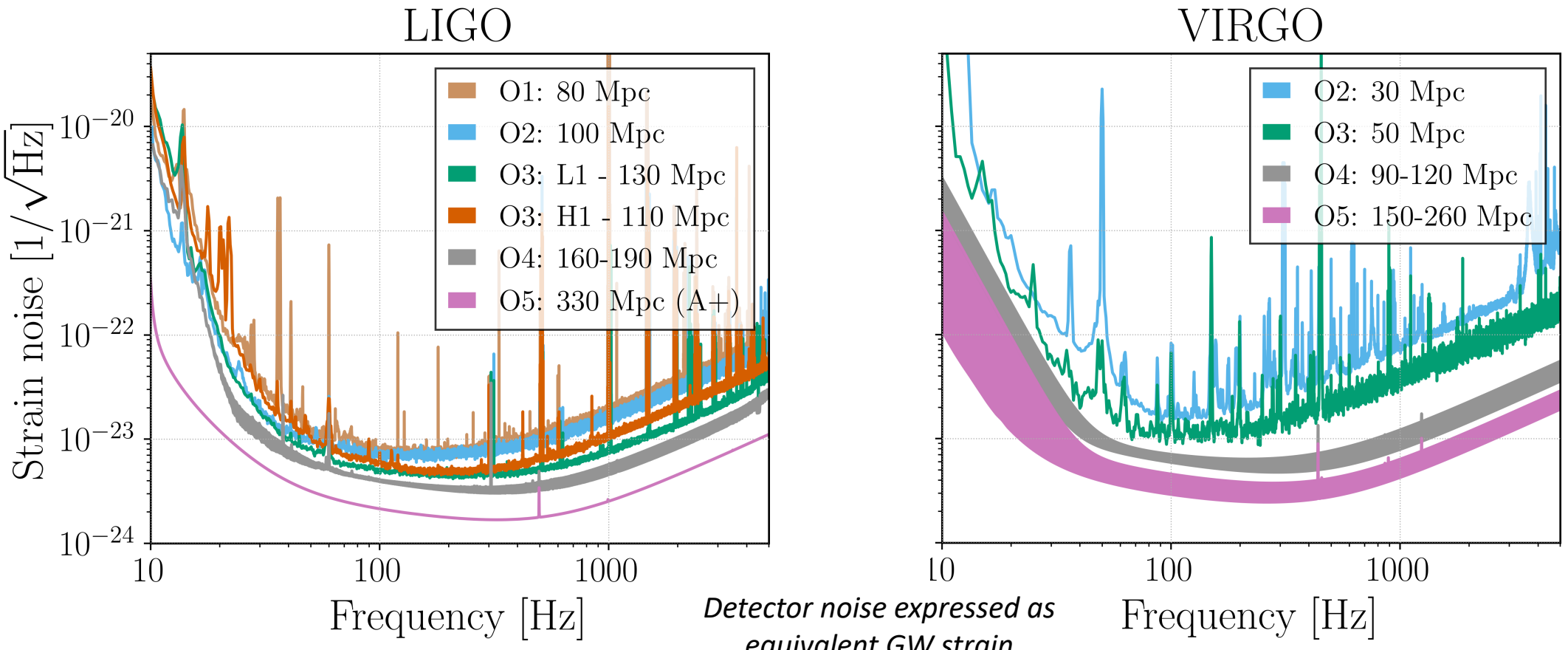
NSF/LIGO/Sonoma State University/Aurore Simonnet

Run	Dates	LIGO BNS characteristic inspiral range	Detections
O1	Sept 2015 - Jan 2016	~80Mpc	3 (all BBH)
O2	Nov 2016 - Aug 2017	~100Mpc	8 (1 BNS)
O3a	Apr - Oct 2019	~110Mpc	~40 *candidates* so far, many types
O3b	Nov 2019 -	~130Mpc +	

Observing runs



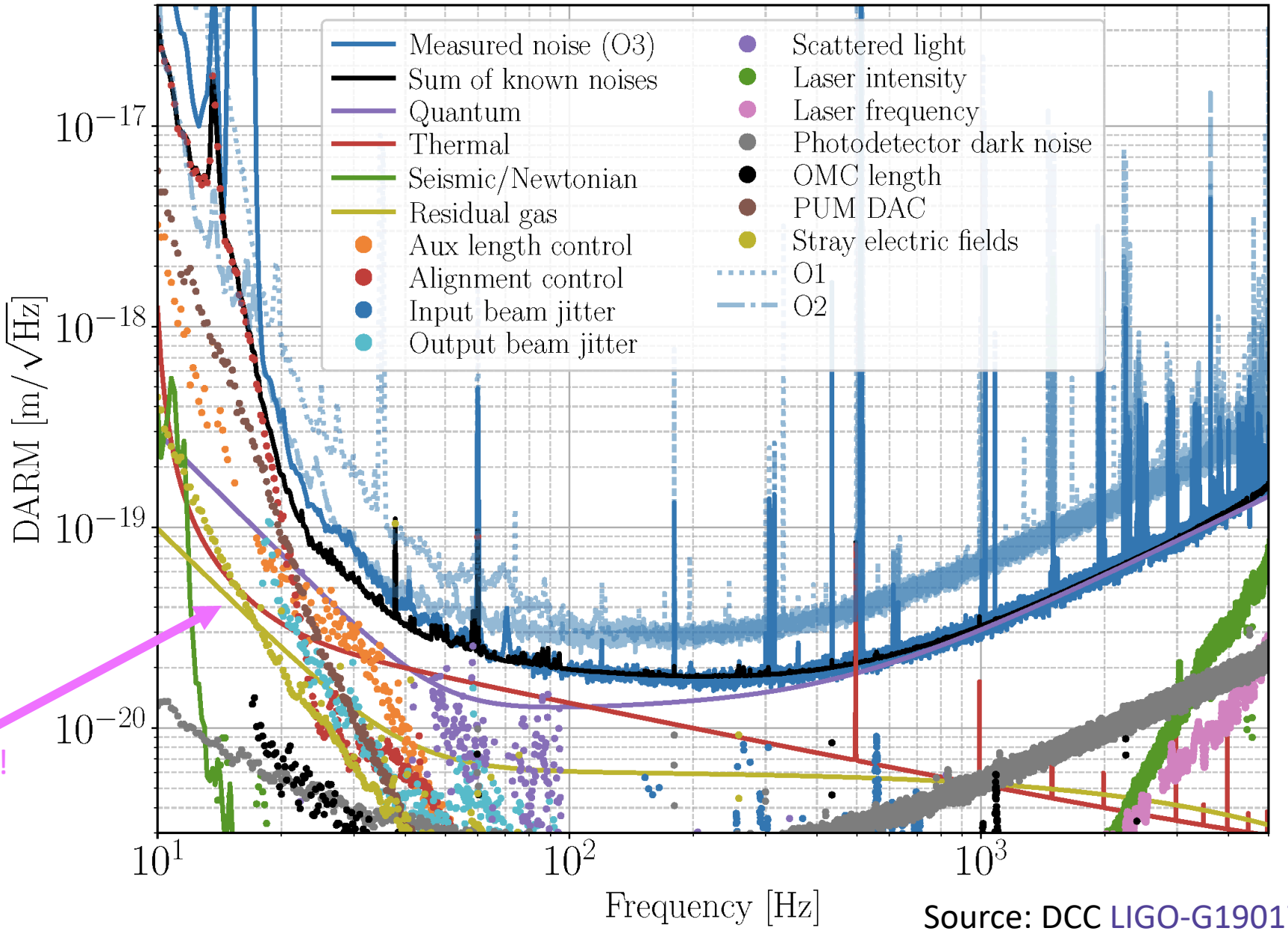
Change in sensitivity through the observing runs



Detector noise expressed as equivalent GW strain

Source: DCC LIGO-G1900897

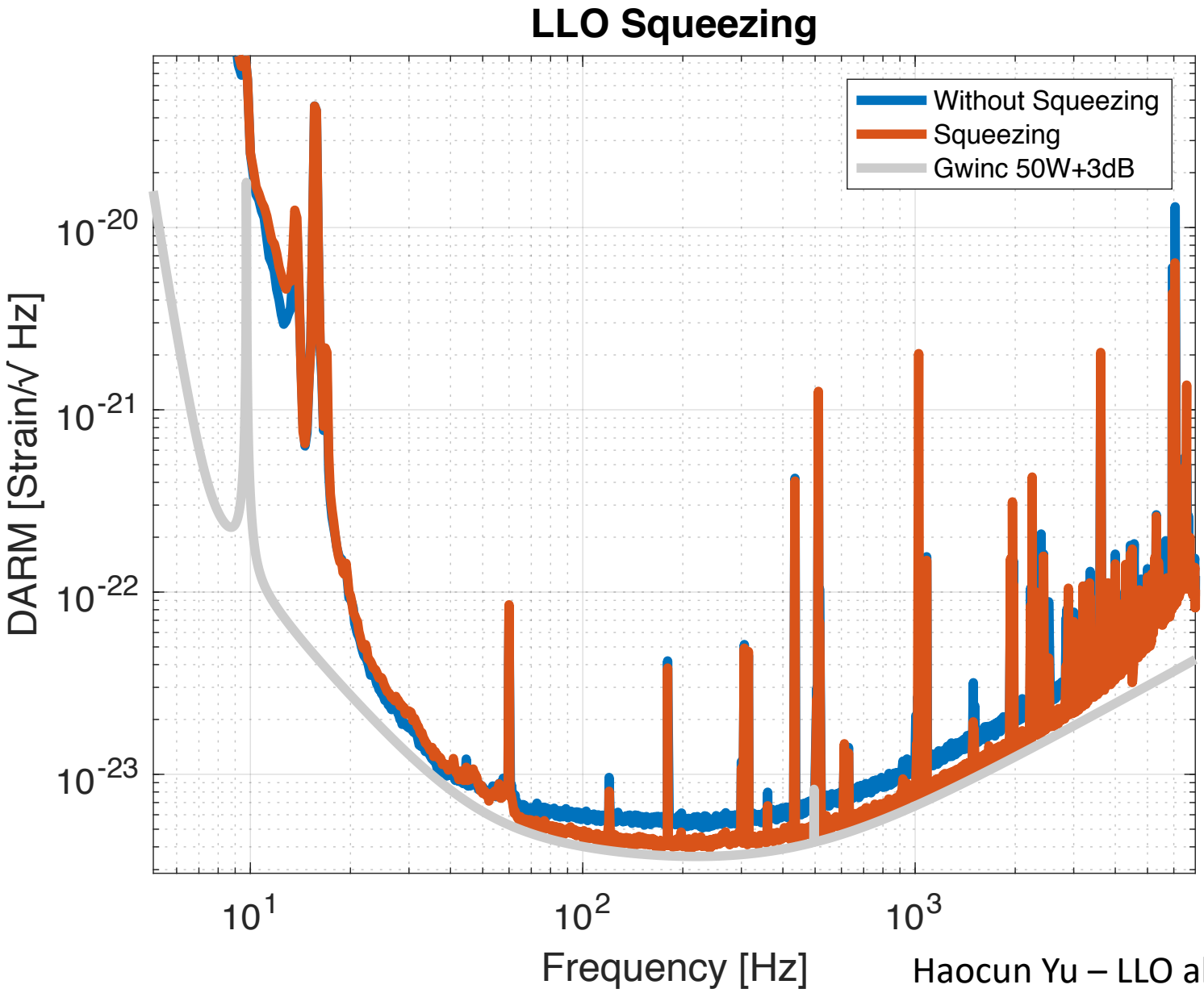
O3a LLO detector sensitivity



Many controls noises!

Source: DCC LIGO-G1901761

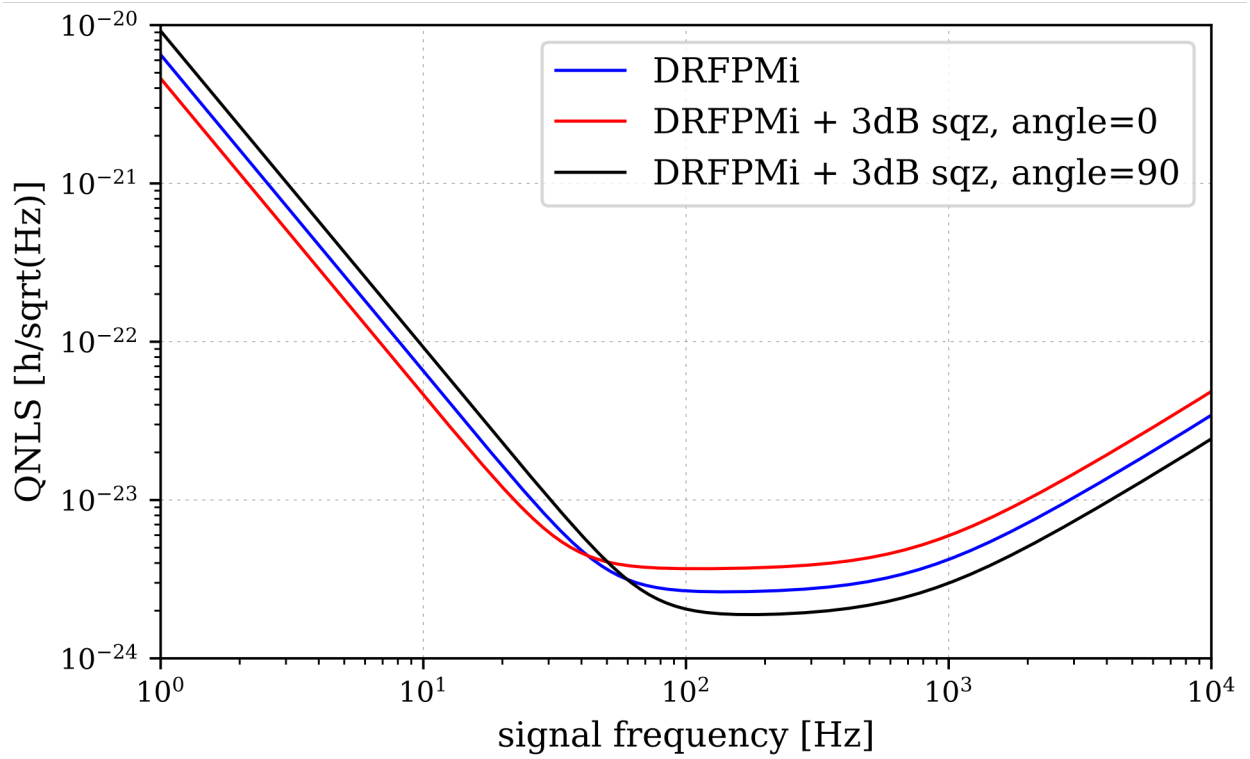
O3a: frequency-independent squeezing introduced



Haocun Yu – LLO alog 45069

Effect of squeezing on the sensitivity curve

- Frequency independent
- Looks like changing the input power
- Currently use to boost high-frequency sensitivity
- Future: frequency *dependent* – choose angle to suit each frequency. Aim: use in O4 (~2022)



Keep up with detector alerts

Chirp Home Latest All Alerts About Contact

Retracted Alert | Binary Black Hole Merger | Binary Neutron Star Collision | Neutron Star - Black Hole Collision | Terrestrial Noise | Mass Gap

GraceDB ID	Time Observed	False Alarm Rate	Most Likely Origin	Distance Range (Mpc)	Detected By
S191220af	20/12/2019, 12:24:14 UTC	1 per 79.96 years	Binary Neutron Star System	114 - 219	L1, V1
S191216ap	16/12/2019, 21:33:38 UTC	1 per 203.16 thousand times the age of the Universe	Source between 3 & 5 solar masses	3	
S191215w	15/12/2019, 22:30:52 UTC	1 per 31.48 years	Binary Black Hole System	1	
S191213ai	13/12/2019, 15:59:05 UTC	1 per 1.58 years	Terrestrial Noise	1	
S191213g	13/12/2019, 04:34:08 UTC	1 per 10.7 months	Binary Neutron Star System	1	
S191212q	12/12/2019, 08:27:28 UTC	1 per 11.3 months	Terrestrial Noise	6	
S191205ah	05/12/2019, 21:52:08 UTC	1 per 2.54 years	Neutron Star - Black Hole Binary System	2	
S191204r	04/12/2019, 17:15:26 UTC	1 per 7.48 million times the age of the Universe	Binary Black Hole System	5	
S191129u	29/11/2019, 13:40:29 UTC	1 per 86.66 quadrillion times the age of the Universe	Binary Black Hole System	5	
S191124be	24/11/2019, 09:59:18 UTC	1 per 18.88 years	Terrestrial Noise	2	

- gracedb.ligo.org
- Chirp