MOUs with LIGO Laboratory on Data Analysis Tasks

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15 - 17 August 2000

LAC Meeting at LIGO Hanford Observatory

MOUs between LIGO Laboratory and LSC member groups

- Present Status:
  - » At present LSC members enlist in data analysis activities (both ASIS and Detector Characterization) and software development activities and then separately sign MOUs with Lab in which these activities are described in general terms.
  - » Lab requires and posts a separate six month report which is submitted in parallel with negotiations for new six month attachment. Lab provides continuity by requiring that the format of the next six month report to follow the format of the previous six month work plan to allow a direct comparison of commitments with accomplishments.
  - » MOUs do not uniformly contain explicit lists of deliverables, schedules
  - » Working group chairs have been assessing group members' performance and submitting assessment as a separate notification to Lab

MOUs between LIGO Laboratory and LSC member groups

- Issues:
  - » Would like to streamline and tighten up process.
  - » At present it is not easy to obtain a uniform assessment of performance directly
  - » At present the proposed work in MOU needs to be "manually" corroborated with LSC working group documents.

MOUs between LIGO Laboratory and LSC member groups

- Possible changes for the coming six months attachment:
  - » Work plan itemizes deliverables that can be checked off in 6 months
  - » Outline of work to be done without deliverables (this is informational)
  - » FTE (by name and time) commitments for the coming six months against detailed work plan.
  - » Identify resources needed from the laboratory. (As we begin to integrate software, it will require efforts on our side and it is important that this be clearly defined)
  - » A rolling 18 month schedule in MOUs:
    - – previous 6-month period showing accomplishments, deferred work;
    - – next 6-month schedule showing proposed work;
    - – future 6-month period showing planned future work - need not be as specific as next 6 months).

MOUs between LIGO Laboratory and LSC member groups

- Possible changes for the coming six months attachment (continued):
  - » Provide a URL cross link to specific statements of work (may be more detailed than what might appear in MOU) that appear in LSC working group documents -- provides "big picture" context of the specific work proposed in the MOU.
  - » Require review of MOUs within LSC working groups? This would allow the LSC to self-regulate the MOUs before the Lab sees them, signs them.
  - » Formal institutional report at LSC meetings of progress - may require change in meeting format

LSC Computing
Current Activities & Long Range Planning

A. Lazzarini

2000 August 15 - 17

LIGO Hanford Laboratory

LSC Computing
Ongoing - GriPhyN

- LIGO is a member of the GriPhyN (Grid Physics Network) collaboration
  - » Composed of NSF-funded research projects seeking to enhance computational and database resources
    - – PIs: P. Avery/Ufl (HEP) & I. Foster/Chicago (CS)
    - – HEP - US collaborations at LHC - CMS & ATLAS
    - – **Gravitational physics** - LIGO Lab. (Prince, Lazzarini, Williams/CACR), UWM (Allen), and UTB (Romano)
    - – Astronomy - Sloan Digital Sky Survey (SDSS)
    - – Computer science - Chicago/ANL, Berkley, USC, others
  - » Formed in summer 1999 to develop a proposal for NSF's ITR (CISE) program

LSC Computing
Ongoing - GriPhyN

- GriPhyN wants to build a grid of computer, database resources to permit users across US to access data, computing facilities efficiently
  - » Largest need comes from US LHC collaborations
- CS R&D:develop/define new concepts for resource management, allocation, scheduling on a global scale
  - » Most of effort to go initially in developing protocols, middleware software that manages resourcs, user requests
- Physics R&D: users of technology
  - » Use models, testbeds, benchmarks, ...

LIGO-G000191-00-E

LSC Computing
Ongoing - GriPhyN

- Pre-proposal submitted on 30 Dec 1999
  - » One of 120 submitters that were asked to submit full proposal to ITR/CISE
- Full proposal submitted 17 April 2000 for $12.5M
  - » Reviewed very well
  - » Received request for clarification from NSF in late June
    - – Questions focused on determining extent of CS/R&D nature of proposed work (vs. applications orientation)
  - » Advised that funding would be 10% less than requested (across-the-board cut for all NSF ITR grants)
  - » Expecting notification of award - August 2000
    - – Proposal covers a 5-year period
    - – Later startup likely due to 10% reduction

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LSC Computing
Ongoing - GriPhyN

- Proposal includes 3 FTEs (postdocs) for LIGO-related research:
  - » LIGO Lab : 1 FTE (postdoc) - research to implement grid-based distributed computing for computationally intensive, non-critical analyses (e.g., constrained all-sky CW searches) that do not require parallel computing
  - » UWM : 1 FTE (postdoc) - research to implement data distribution using large-scale disk systems (I.e., no tape robots)
  - » UTB: 1 FTE (postdoc) - support GriPhyN program outreach (required by NSF)

LSC Computing
Ongoing - GriPhyN

- Proposal to ITR is a ***first step*** to building GriPhyN
  - » Follow up meeting held at NSF held on 31 May 2000 to present strategic plan to NSF principals from MPS, CISE
    - – Received endorsement from MPS, CISE
- $70M will be requested over period 2001 - 2006, mostly to support HEP
  - » LIGO/LSC would be allotted 5 Tier 2 GriPhyN centers
    - – Centers to be built up over period 2001 - 2006
    - – Total funds identified for LSC : ***$14M***
      - $3.2M for hardware (initial purchases, plus 33% replacement per year)
      - $5.4M for personnel to run the centers
      - $5.4M for network access
- Next:
    - – Awaiting receipt of ITR CISE funds;
    - – Awaiting announcement of FY2001 NSF budgets to determine how to propose

LSC Computing
Long Range Planning

- At present, LIGO Lab., UWM, UTB are *fiducíaries* for LSC involvement.
- Broader LSC involvement is required if this model for computing is to succeed for gravitational physics
- Involvement needs to be as a collaboration, not as individual researchers

LSC Computing
Long Range Planning

- *WHEN* the next proposal is written, LSC needs to have in place a mechanism in place by which the collaboration determines how it is represented and who represents it:
  - » Funding of LSC computing resources through GriPhyN would represent a shift away from entrepreneurial MRI-based requests by investigators
  - » New mechanism needed to ensure equitable sharing of acquired resources across the LSC
  - » Providing access to resources would require a service commitment to the LSC
  - » Need to include funds for postdocs, students - monies identified to date cover only hardware, operations, CS R&D

LSC Computing
Long Range Planning

- (At least) Two actions needed

1. Revise the LSC White Paper on Data Analysis to describe how GriPhyN fits into the long-range computing strategy of LSC
2. Form a new LSC working group that is charged with developing an implementation strategy for the long range plan, including defining mechanism(s) for member representation, where resources are placed, how they are shared and operated.

Use HEP community as a model? Invent our own?

Chopping the Stochastic Background

Albert Lazzarini

LIGO Laboratory Caltech

LSC Meeting at LIGO Hanford Observatory

15 - 17 August 2000

LIGO-G000191-00-E

Allegro+LLO

Modulation of the Stochastic Background Correlation

References

- P.F. Michelson, *Mon. Not. Roy. Astron. Soc.* **227**, 933 (1987).
- N. Christensen, *Phys. Rev.* **D46**, 5250 (1992)
- E. Flanagan, *Phys. Rev.* **D48**, 2389 (1993)
- B. Allen and J. Romano, *Phys. Rev.* **D59**, 102001 (1999)

Allegro+LLO

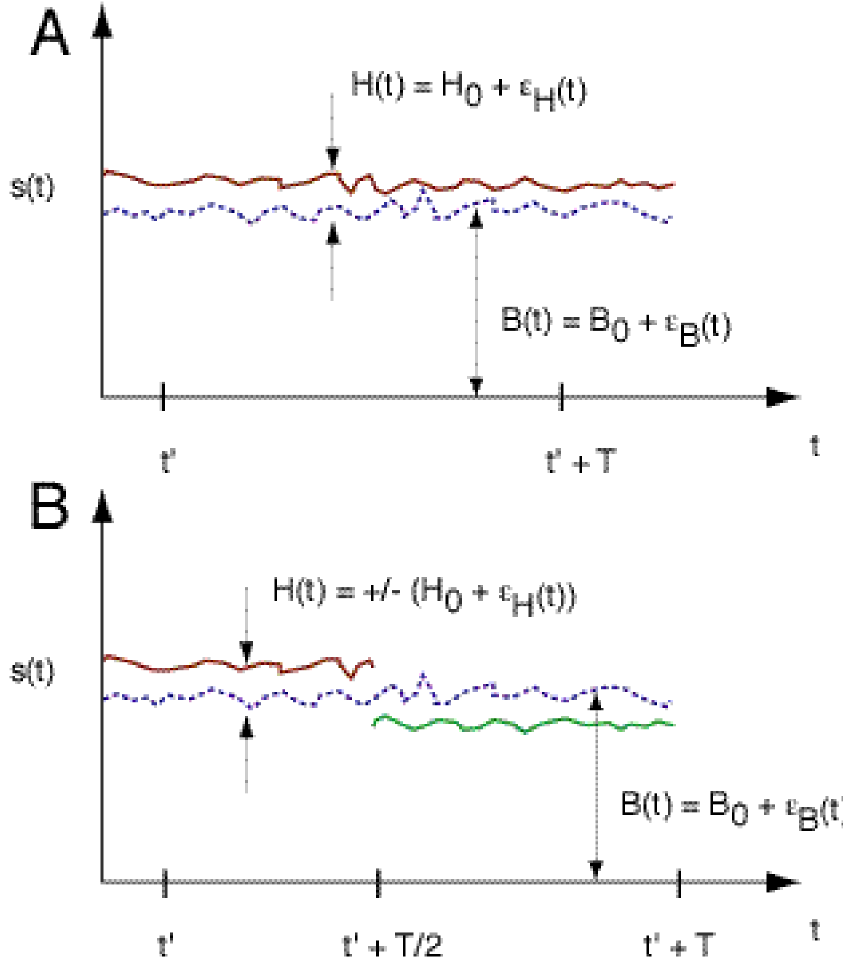
Modulation of the Stochastic Background Correlation

- Ideally, the stochastic background correlation increases with integration time as:

$$SNR \quad \frac{3H_0^2}{10\pi^2}\sqrt{T_{\text{int}}}\left[\frac{\gamma(f_0)\Omega_{GW}^2\Delta f}{f^6 S_{1,n}|f| S_{2,n}|f|}\right]^{\frac{1}{2}}$$

  - » Assumes no additional sources of correlated noise - cannot discriminate with a single measurement
  - » Mutual orientation dependence of GW background signal may be exploited to discriminate among possible correlated sources
- Optimal filter changes sign with orientation

$$Q(t-t';\Omega_1,\Omega_2) = \int_{-\infty}^{\infty} df\, e^{-2\pi i f(t-t')} \frac{\gamma(f;\Omega_1,\Omega_2)\Omega_{GW}(f)}{f^3 \quad S_A(f)S_L(f)}$$



$$\langle \varepsilon_B(t) \rangle = \langle \varepsilon_H(t) \rangle = 0$$

$$\langle \varepsilon_B(t)\varepsilon_H(t) \rangle = 0$$

$$\langle \varepsilon_B(t)^2 \rangle = \sigma_B^2; \langle \varepsilon_H(t)^2 \rangle = \sigma_H^2$$

Allegro+LLO

Modulation of the Stochastic Background Correlation

- Overlap reduction function, γ, is a geometric function determined by detector antenna tensors, $\mathbf{d}_{A,L}$, vector separating detectors, $\mathbf{n}_{AL}$ and frequency dependent functions, ρ_i:

$$
\begin{aligned}
\gamma(f;\Omega_1,\Omega_2) = {} & \rho_1(\alpha)\ \mathbf{d}_A : \mathbf{d}_L + \\
& \rho_2(\alpha)\left(\hat{n}_{AL}\ \ \mathbf{d}_A\right)\left(\mathbf{d}_L\ \ \hat{n}_{AL}\right) + \\
& \rho_3(\alpha)\left(\hat{n}_{AL}\ \ \mathbf{d}_A\ \ \hat{n}_{AL}\right)\left(\hat{n}_{AL}\ \ \mathbf{d}_L\ \ \hat{n}_{AL}\right)
\end{aligned}
$$

Allegro+LLO

Modulation of the Stochastic Background Correlation

$$\mathbf{d}_L(\sigma_1) = \sin(2\sigma_1)\left[\frac{\hat{n}_x\hat{n}_x - \hat{n}_y\hat{n}_y}{2}\right] - \cos(2\sigma_1)\left[\frac{\hat{n}_x\hat{n}_y + \hat{n}_y\hat{n}_x}{2}\right]$$

$$\mathbf{d}_A(\sigma_2) = \frac{3\left(\cos(\sigma_2 - \frac{\pi}{4})\,\hat{n}_x + \sin(\sigma_2 - \frac{\pi}{4})\,\hat{n}_y\right)\left(\cos(\sigma_2 - \frac{\pi}{4})\,\hat{n}_x + \sin(\sigma_2 - \frac{\pi}{4})\,\hat{n}_y\right) - I}{3}$$

Allegro+LLO

Modulation of the Stochastic Background Correlation

$$\begin{pmatrix} \rho_1(\alpha) \\ \rho_2(\alpha) \\ \rho_3(\alpha) \end{pmatrix} = \begin{pmatrix} 5 & \frac{-10}{\alpha} & \frac{5}{\alpha^2} \\ -10 & \frac{40}{\alpha} & \frac{-50}{\alpha^2} \\ \frac{5}{2} & \frac{-25}{\alpha} & \frac{175}{2\alpha^2} \end{pmatrix} \begin{pmatrix} j_0(\alpha) \\ j_1(\alpha) \\ j_2(\alpha) \end{pmatrix}$$

Allegro+LLO

Modulation of the Stochastic Background Correlation

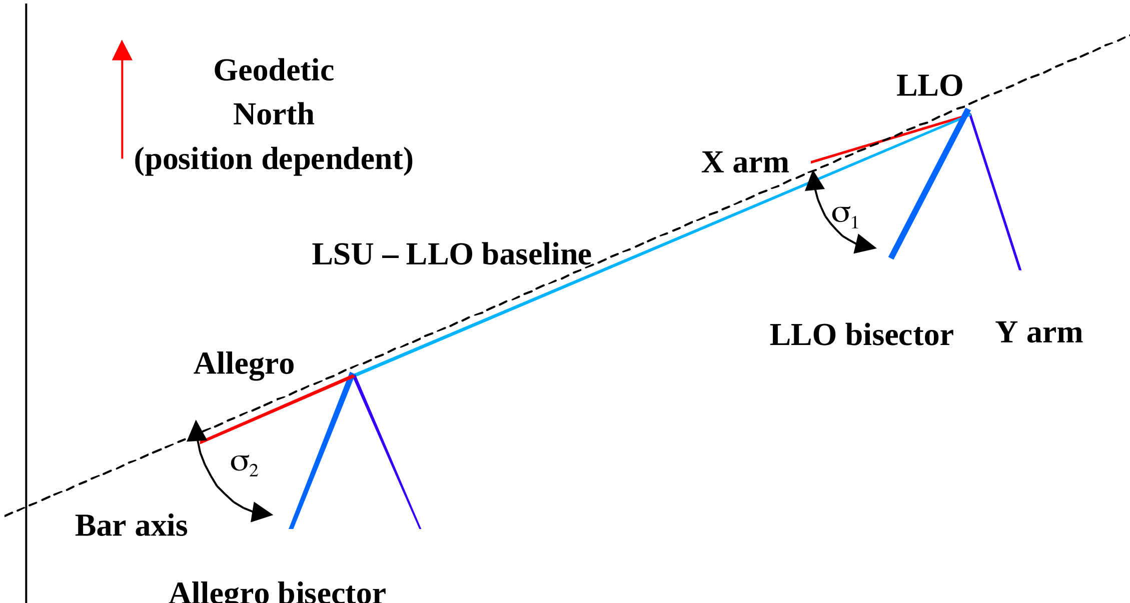
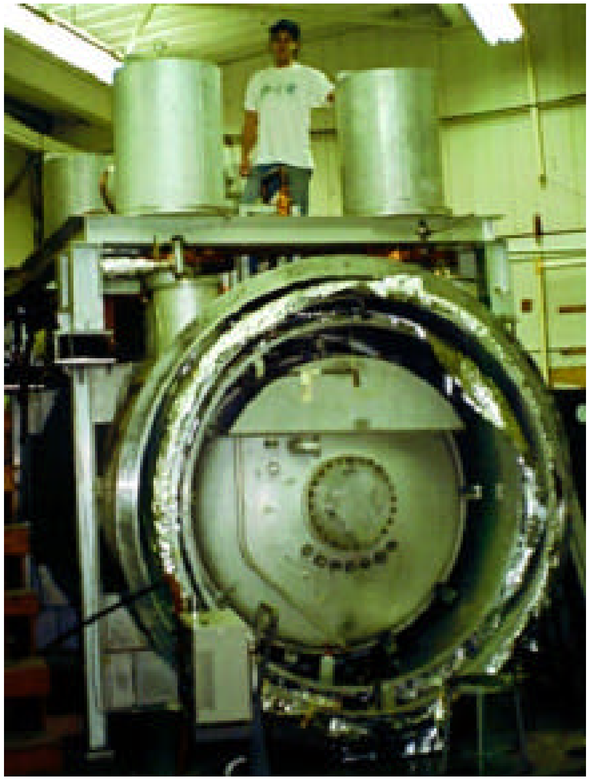


Figure 1: Schematic showing Allegro and LLO orientations with respect to geodetic north and the LLO-LSU baseline.

Allegro at LSU

Will be moved to new laboratory



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Allegro

Geodetic Parameters

Table II: Geographic Data for Allegro Bar Detector at LSU		
Quantity	**Value**	**Units**
Allegro Vertex	{-113258.848, 5504077.706, 3209892.353} {30°24' 45.110", W91°10'43.766"}	meter* {θ,λ}
Bearing of LLO vertex at Allegro	N66.67°E	Reference is geodetic north (not grid north)
Angle σ, between Allegro coordinate axis bisector, $(\hat{x}+\hat{y})/\sqrt{2}$, and LLO-to-LSU baseline at various values of correlation	Correlation maximum: γ_{max}(921 Hz) = 0.953 σ=39.60°CCW (Bar axis bearing: S72.08°W) Correlation null: γ_{null}(921 Hz) = 0.0 σ=85.52°CCW (Bar axis bearing: S26.15W) Correlation minimum: γ_{min}(921 Hz) = -0.893 σ=129.60°CCW (Bar axis bearing: S17.92E)	
LLO – Allegro Baseline baseline distance	42269.951	meter
Angle subtended by LLO – Allegro baseline at center of Earth	0.358°	

*Positions are with respect to the Earth Centered Frame [ECF], defined as follows: $\hat{z}$ pierces the Earth at the north pole; $\hat{x}$ pierces the Earth at the intersection of the prime meridian and the equator; $\hat{y}=\hat{z}\times\hat{x}$

LIGO Livingston Laboratory

LIGO-G000191-00-E

LLO

Geodetic Parameters

Table I: Geographic Data for LIGO Livingston Laboratory (LLO)		
Quantity	**Value**	**Units**
LLO Vertex	{-74276.044, -5496283.721, 3224257.018} {-6.568, N30°33'6.871", W90°48'50.229"}	meter* {h(m), θ, λ}
X arm unit vector	{-0.954574,-0.1415805,-0.2621887}	In ECF
Y arm unit vector	{0.2977412,-0.4879104,-0.8205447}	In ECF
Bearing of Allegro at LLO vertex	S66.88°W	Reference is geodetic north (not grid north)
Angle between LLO arm bisector, $(\hat{x}+\hat{y})/\sqrt{2}$, and LLO-LSU baseline	39.59° CCW (Bearing: S27.28°W)	

*Positions are with respect to the Earth Centered Frame [ECF], defined as follows: $\hat{z}$ pierces the Earth at the north pole; $\hat{x}$ pierces the Earth at the intersection of the prime meridian and the equator; $\hat{y} = \hat{z} \times \hat{x}$

Allegro+LLO

Modulation of the Stochastic Background Correlation

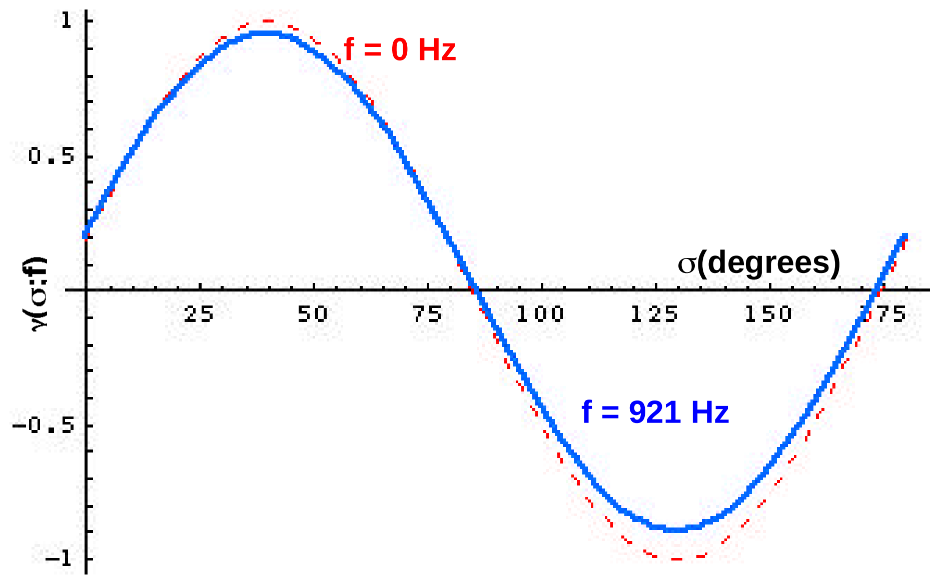

Figure 2: Dependence of the Allegro-LLO correlation function on the angle between the Allegro bar bisector and the LLO-to-LSU baseline (refer to Figure 1). Dashed line is for DC and the solid line is for the Allegro resonant frequency.

Allegro+LLO

Modulation of the Stochastic Background Correlation

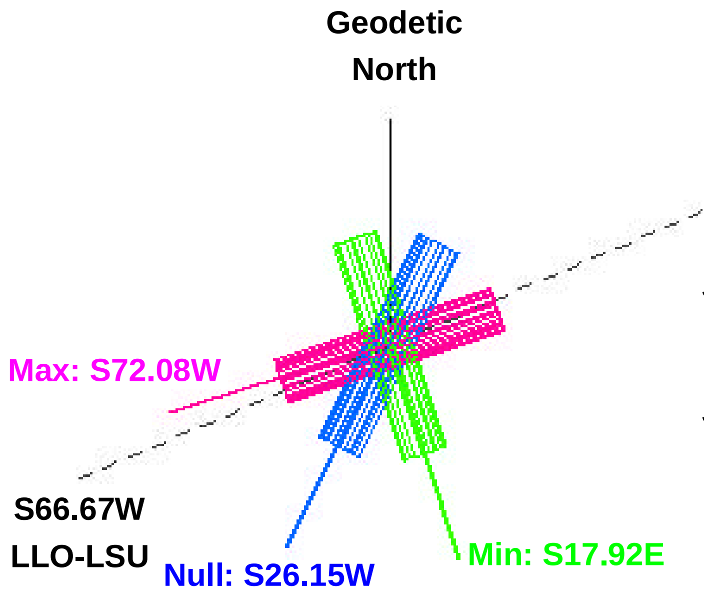

Figure 3: Schematic showing Allegro orientations with respect to geodetic north and the LLO-LSU baseline

$$S_{+}(\sigma_2 = 39.6°) \approx T_{\mathrm{int}} \Delta f \left(\frac{3H_0^2}{20\pi^2} \frac{\gamma^2 \Omega_{GW}^2(f_0)}{f_0^6 S_A(f_0) S_L(f_0)} + S_{LA}(f_0) \frac{\gamma \ \Omega_{GW}(f_0)}{f_0^3 S_A(f_0) S_L(f_0)} \right)$$

$$S_{-}(\sigma_2 = 129.6°) \approx T_{\mathrm{int}} \Delta f \left(\frac{3H_0^2}{20\pi^2} \frac{\gamma^2 \Omega_{GW}^2(f_0)}{f_0^6 S_A(f_0) S_L(f_0)} - S_{LA}(f_0) \frac{\gamma \ \Omega_{GW}(f_0)}{f_0^3 S_A(f_0) S_L(f_0)} \right)$$

LLO - Allegro Detector Parameters

Quantity	Symbol	Value	Units
Lower Allegro resonant frequency	$f_<$	896.8	Hz
Upper Allegro resonant frequency	$f_>$	920.3	Hz
Linewidth (FWHM)	Δf	1	Hz
Sensitivity	**LIGO**	**Allegro**	**Units**
$h[f_<]$	5×10^{-19}	2×10^{-21}	$Hz^{-1/2}$
$h[f_>]$	5×10^{-19}	1×10^{-21}	$Hz^{-1/2}$