LIGO

Directional Stochastic Search: a Gravitational Wave Radiometer

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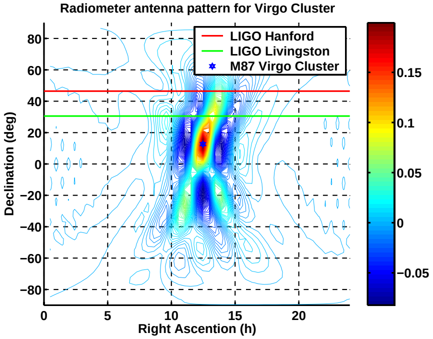


LIGO

The idea

- 2-site full-sky stochastic search is limited to lower frequency
  - higher frequencies (>~100Hz) average out in source position integration

- But the nearby universe is not isotropic:
  - Our galactic center
  - Nearest galaxy: M31 Andromeda
  - Virgo galaxy cluster
  - Voids
  - ➔ Compare different sky patches!

- We can get source position information from:
  - Signal time delay between different sites (sidereal time dependent)
  - Sidereal variation of the antenna pattern

➔ Recipe: time-shift and cross-correlate!

Signal and Noise: Matched Filtering

- Use sidereal time & sky position dependent optimal filter:

$$S = \int dt \int dt' \, s_1(t) s_2(t') Q_{t_{sidereal}\Omega}(t-t')$$

$$s_i = n_i + h_o F^{A}_{i,t_{sidereal}}(\Omega)$$

$$\mu = \int dt_{sidereal} \int df \left| \tilde{h}_0(f) \right|^2 \gamma_{t_{sidereal}\Omega}(f) \tilde{Q}^{*}_{t_{sidereal}\Omega}(f)$$

$$\sigma^2 = \int dt_{sidereal} \int df \, \tfrac{1}{4} P_1(f) P_2(f) \left| \tilde{Q}_{t_{sidereal}\Omega}(f) \right|^2$$

where

$$\gamma_{t_{sidereal}\Omega}(f) = \sum_{A=+,\times} e^{i 2\pi f \hat{\Omega} \frac{\Delta\vec{x}(t_{sidereal})}{c}} F^{A}_{1,t_{sidereal}}(\Omega) F^{A}_{2,t_{sidereal}}(\Omega)$$

$$\tilde{Q}_{t_{sidereal}\Omega}(f) = \lambda \cdot \frac{\left| \tilde{h}_0(f) \right|^2 \gamma_{t_{sidereal}\Omega}(f)}{P_1(f) P_2(f)}$$

Following notation of gr-qc/9710117

The antenna pattern DC part

- Look at frequency independent (geometric) part first:

$$\frac{\mu}{\sigma} \propto \gamma_{DC}^{\Omega} := \left(\frac{1}{T_{sidereal}} \int dt \left(F_{1,t}^{+}(\Omega) F_{2,t}^{+}(\Omega) + F_{1,t}^{\times}(\Omega) F_{2,t}^{\times}(\Omega) \right)^2 \right)^{1/2}$$

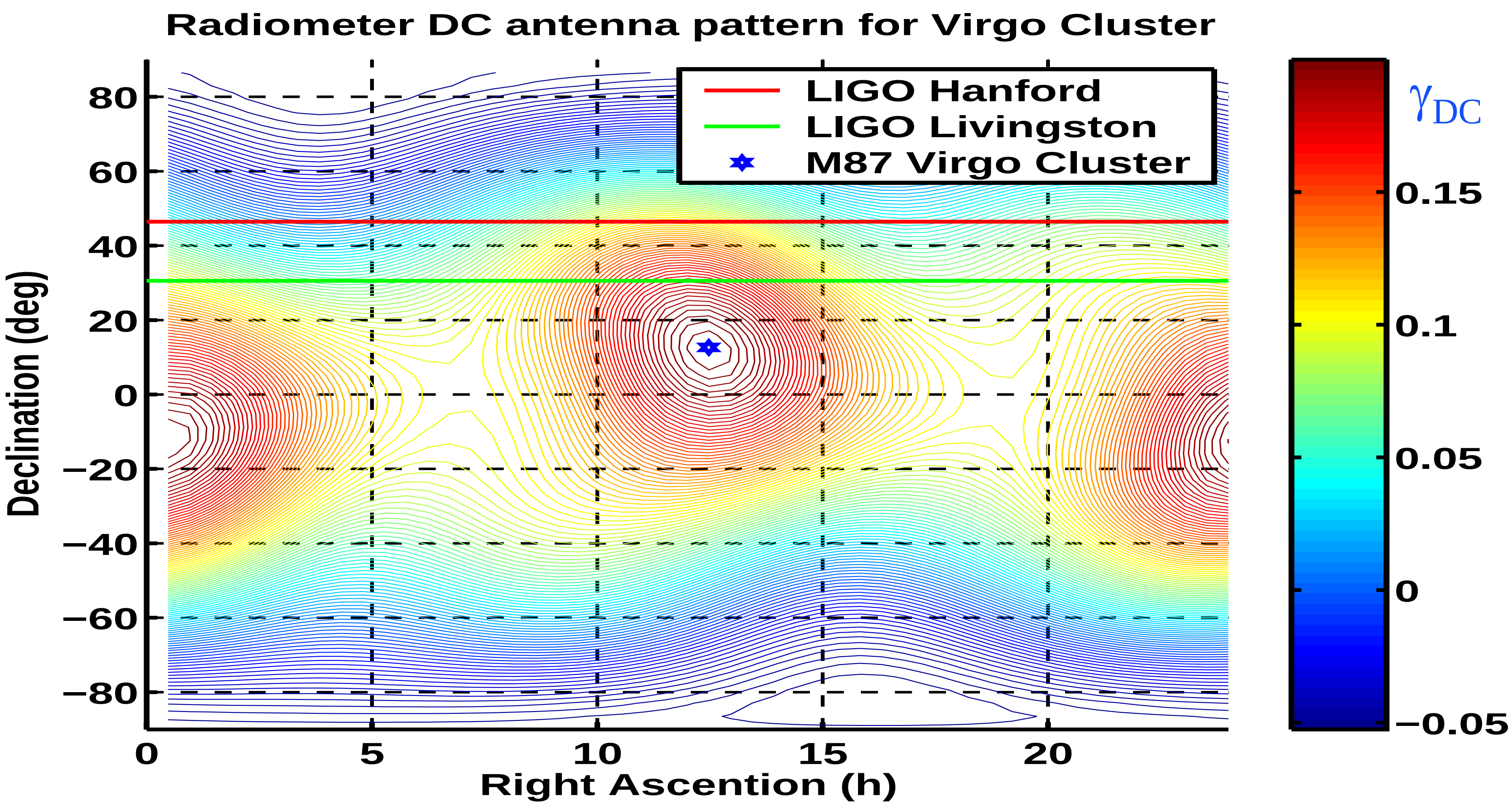
- Interpretation:
  - Power coupling loss relative to 2 permanently optimally aligned detectors

- How bad is it for existing interferometers?

γ_{DC} for various targets

Object	LHO-LLO	LHO-VIRGO	LLO-VIRGO
Galactic center	0.189	0.256	0.251
M31 Andromeda	0.158	0.296	0.231
M81	0.064	0.465	0.114
M87 Virgo cluster	0.202	0.252	0.262

Coupling from other sky directions
Antenna pattern, DC part



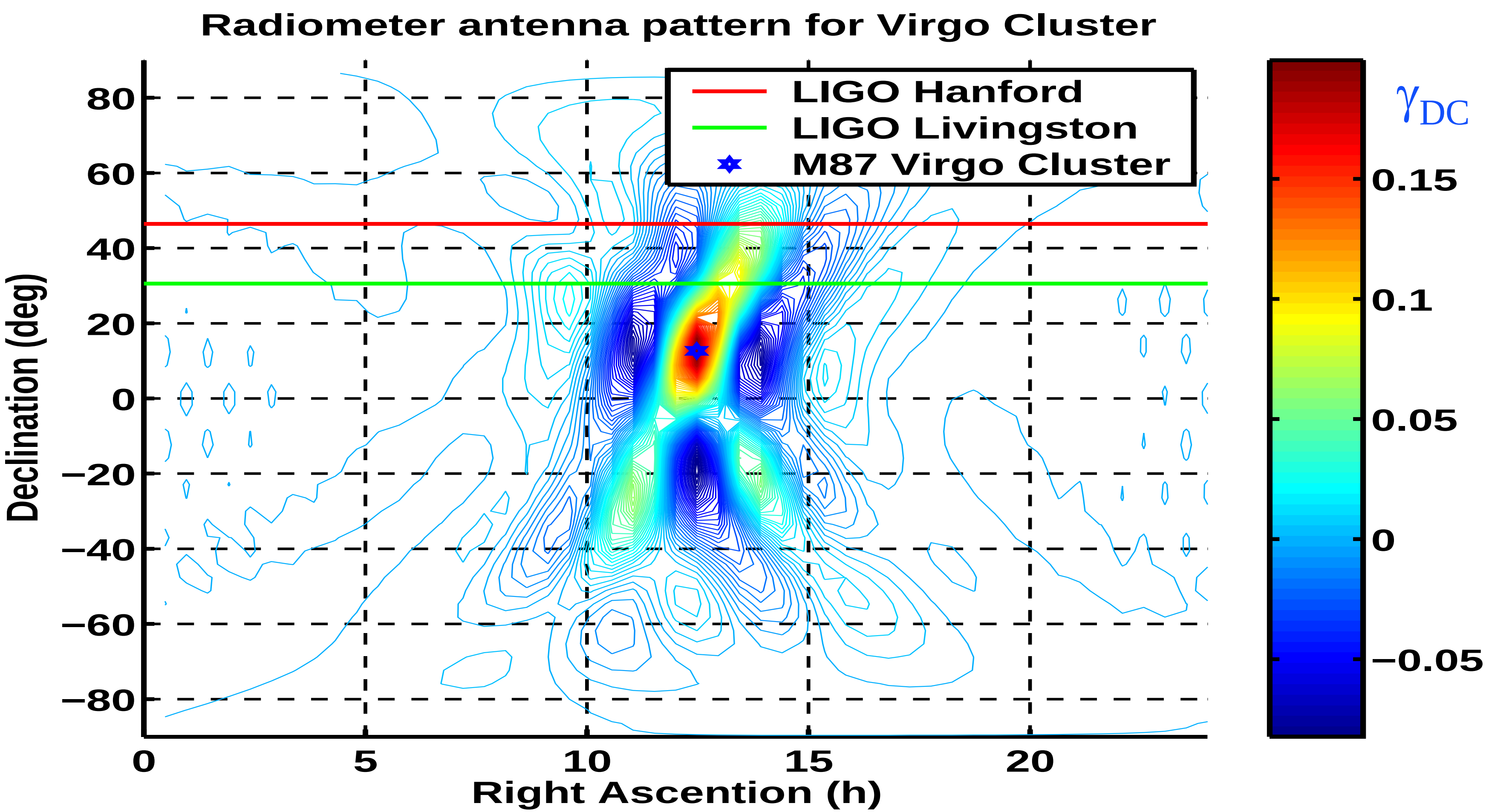
The antenna pattern for a flat spectrum

- Optimal filter (and therefore spatial resolution in the sky) depends on:
  - Detector power spectra (known)
  - Frequency content of expected signal (not known)

$$\tilde{Q}_{t_{sidereal}\Omega}(f) = \lambda \cdot \frac{\left|\tilde{h}_0(f)\right|^2 \gamma_{t_{sidereal}\Omega}(f)}{P_1(f) P_2(f)}$$

- Source modeling possible, but arguably the simplest assumption is a flat signal spectrum
  - For this case and assuming the LIGO SRD curve (shape only) we can calculate the full antenna pattern.

The antenna pattern for a flat spectrum



The sensitivity

- Again for a flat signal spectrum we have

$$h_0 = \left(\frac{SNR}{2\sqrt{T}\,\gamma_\Omega^{DC} \left(\int df \, \frac{1}{P_1(f) P_2(f)} \right)^{1/2}} \right)^{1/2}$$

- For 2 interferometers at the current H1 sensitivity this is

$$h_0 = 3 \times 10^{-24} \, Hz^{-1/2} (SNR)^{1/2} \left(T / 1yr \right)^{-1/4}$$

The work to do

Implementation

- Almost identical to current Stochastic pipeline
  - Only modification: time-dependent overlap reduction function