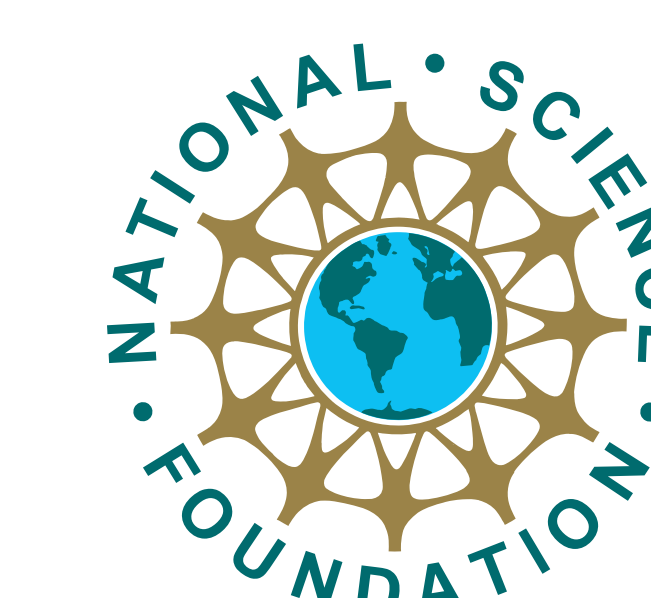


Ultra-low Frequency Electromagnetic Monitoring of Earthquakes in the San Francisco Bay Area: Initial Results of an Earthscope PBO Project



T51B-1343



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1 ABSTRACT

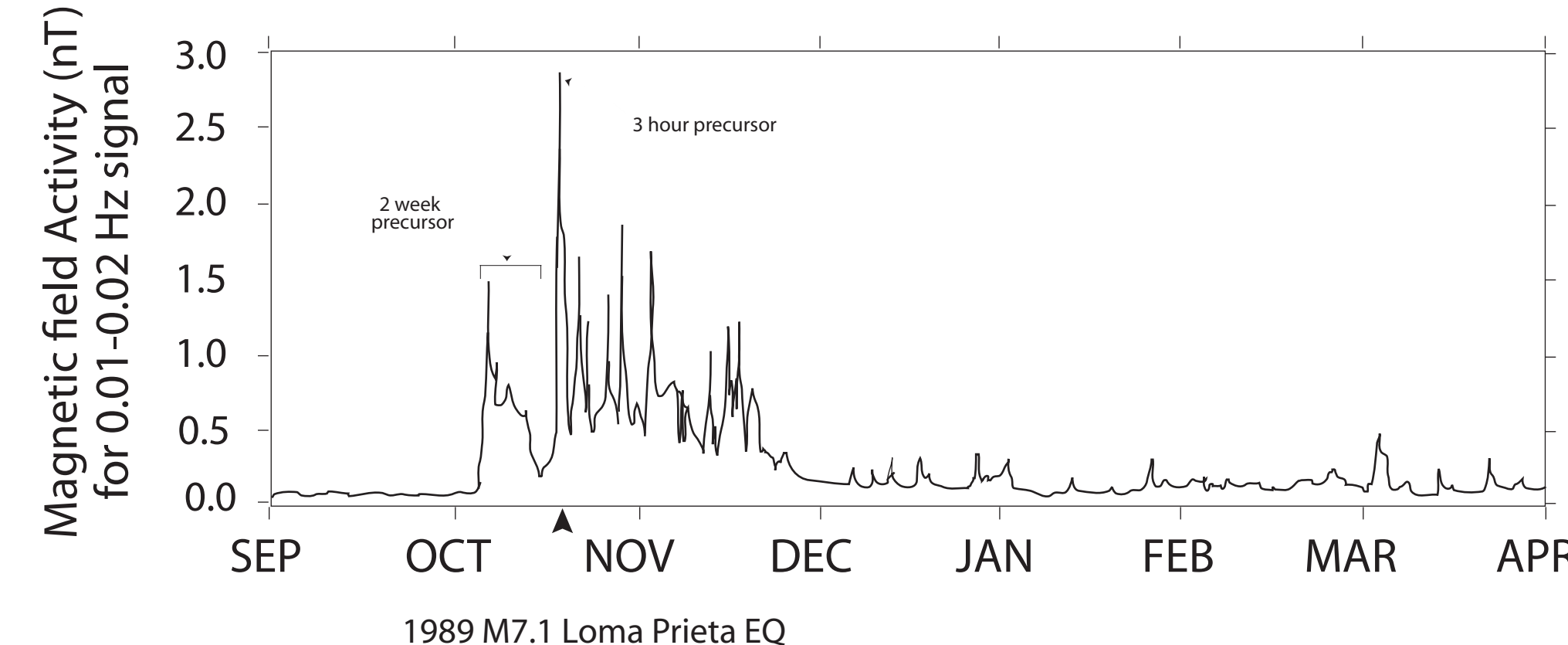
As part of the PBO (Plate Boundary Observatory) mission we are installing three ultra-low frequency electromagnetic (ULF-EM) recording sites in northern California to understand earthquake physics and to detect pre-seismic transients if such exist. These three sites will complement two existing sites maintained by UC Berkeley at Parkfield and Hollister in central California (T51B-1345), and a growing California network of magnetometers managed by Quakefinder Inc (T51B-1344).

In 2005 our first station came online close to the campus of Stanford University; our data are freely available through the Northern California Earthquake Data Center web-site <http://quake.geo.berkeley.edu/ncedc/>. In 2006 we intend to complete two additional installations in the North Bay and East Bay, pending continuing discussions with landowners. Each site will have three orthogonal magnetometers and duplicate sets of orthogonal horizontal electrode pairs, recording signals from 0.01 to 20 Hz, collocated with an existing broadband seismometer.

We present preliminary data from our Jasper Ridge station (JRSC), aimed at establishing a systematic baseline against which any future potential seismogenic anomalies may be tested. We do not (yet) present any claims for signals related to earthquakes. We plan to continue monitoring for the duration of the project, ideally beyond the next large Bay Area earthquake.

MOTIVATION

ULF (0.01-10 Hz) magnetic field anomalies prior to and following $M > 6.5$ earthquakes have been reported from different regions of the world. If real, these signals contain important information about earthquake physics, particularly fluid motion in and around the fault before, during and after seismic activity.

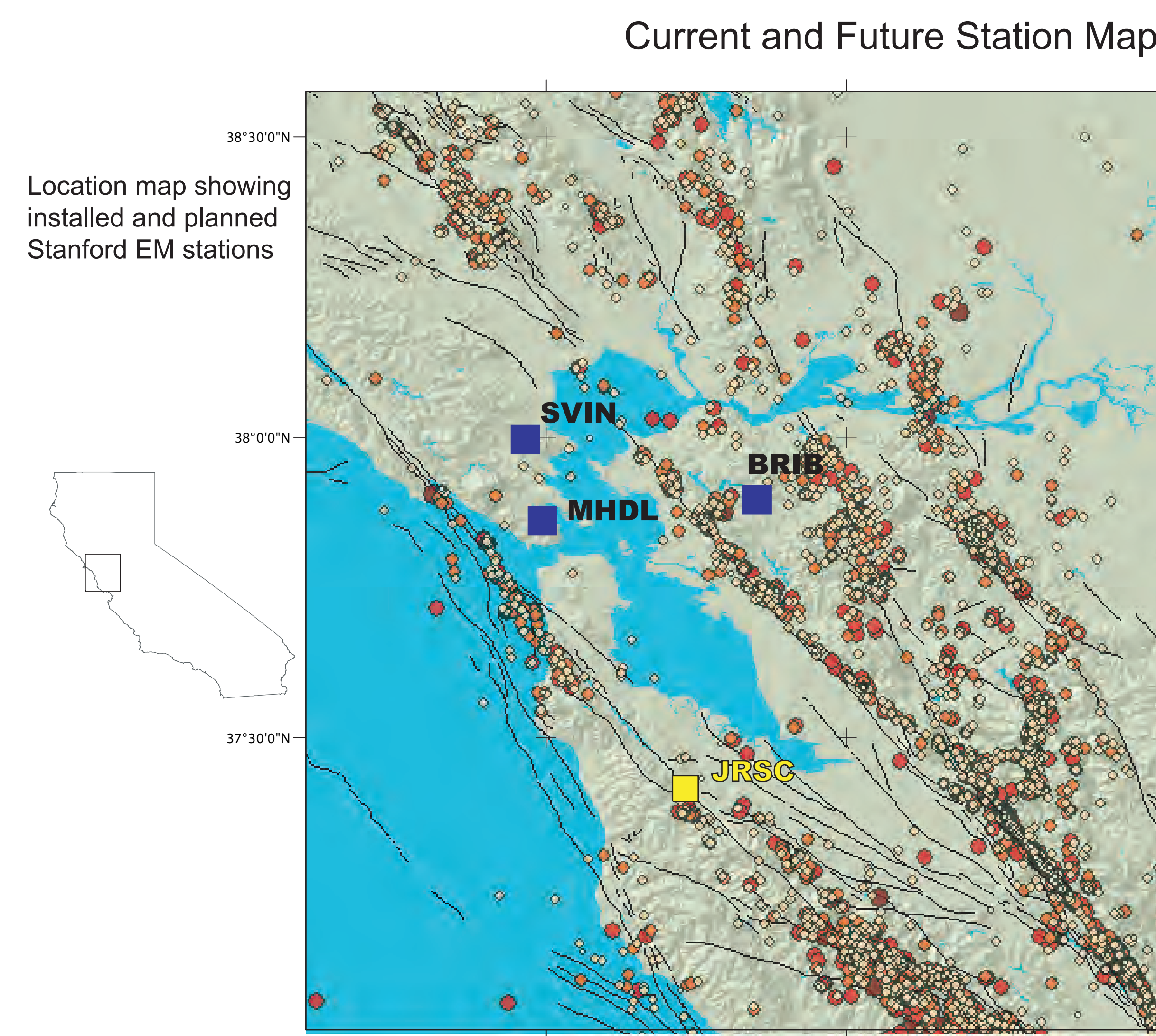


ULF anomalies were serendipitously recorded 10 km from the Loma Prieta epicenter in 1989. Data shown are from 9/89 to 4/90, from six weeks prior to six months post the earthquake (Fraser-Smith et al., 1993; Fenoglio et al., 1993).

Note the increase in activity two weeks prior to the main shock, much larger amplitudes starting three hours before the main shock and the continuing high fields for several months following the main shock.

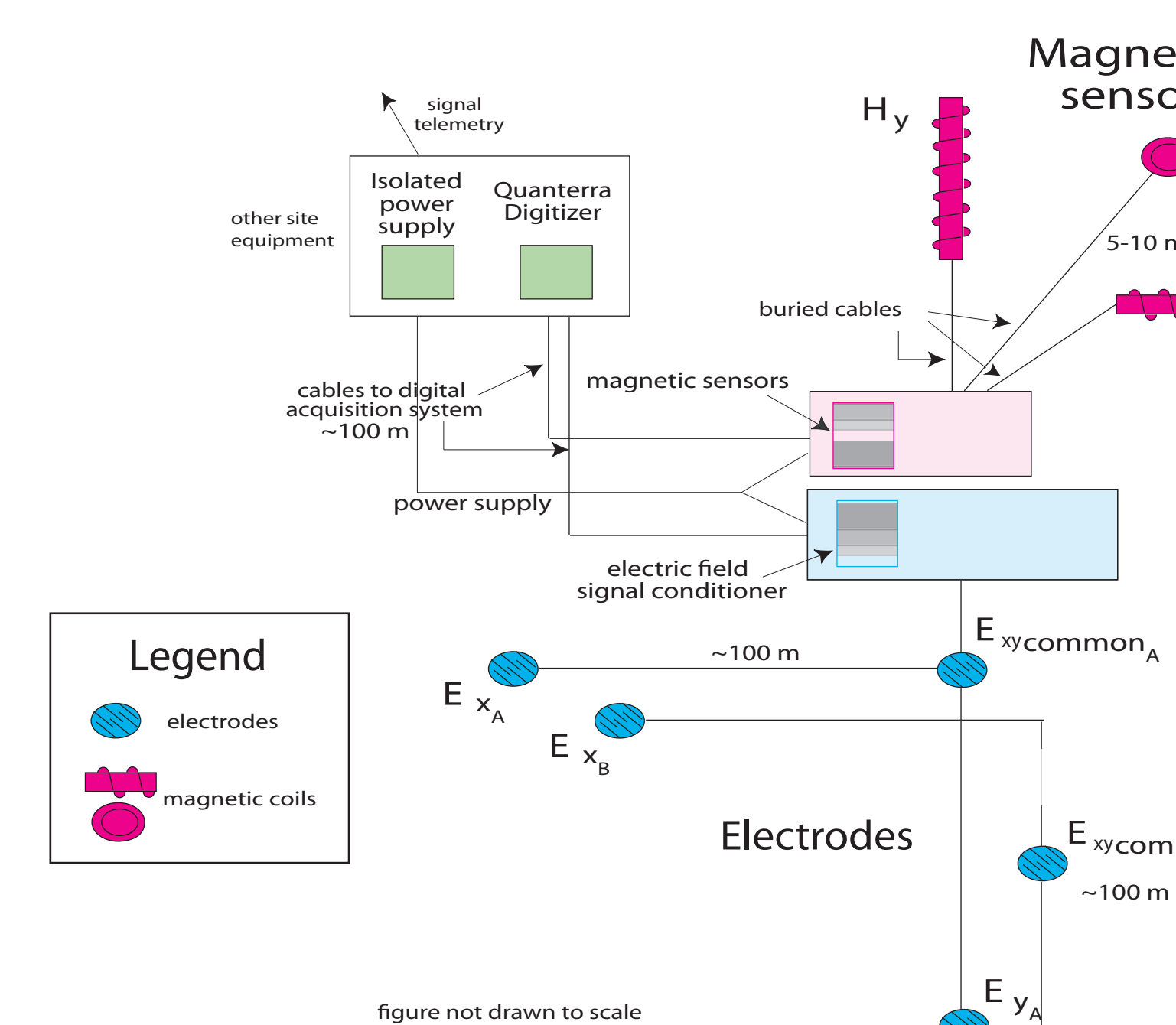
This experiment only recorded half-hour signal averages, not the raw time series; only recorded a vertical component, not 3 magnetic and two electric components; lacked close-by stations to record signals from the same source; and lacked remote reference sites that did not record these signals. All these deficiencies in the serendipitous recordings of the Loma Prieta earthquake are mitigated by our experiment design. Unfortunately the next Bay Area $M > 7$ earthquake may not occur for a decade or more, so that we must be prepared to design and maintain our instruments as near-permanent observatories.

2 SITES AND STATUS



Yellow square = currently installed station Jasper Ridge (JRSC). Blue squares = proposed sites (two of three, dependent on permitting issues) at Ox Mtn (OX), St Vincent's (STV), and Lake Chabot (LC). Red triangles = existing BDSN reference stations at Hollister (SAO) & Parkfield (PKD).

ULF Station Block Diagram



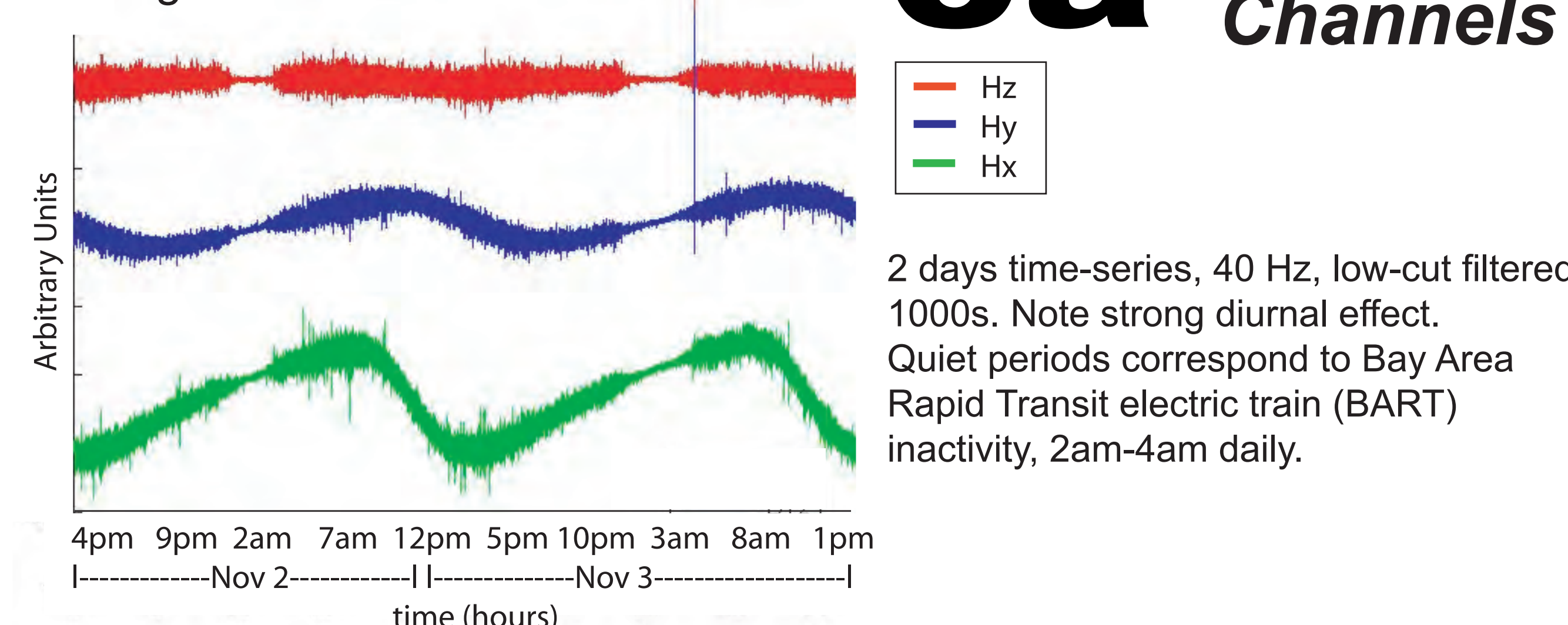
Block diagram of the equipment at a typical ULF station to be collocated with a PBO site. Ez will be installed in the existing borehole.

Photograph of Jasper Ridge Installation



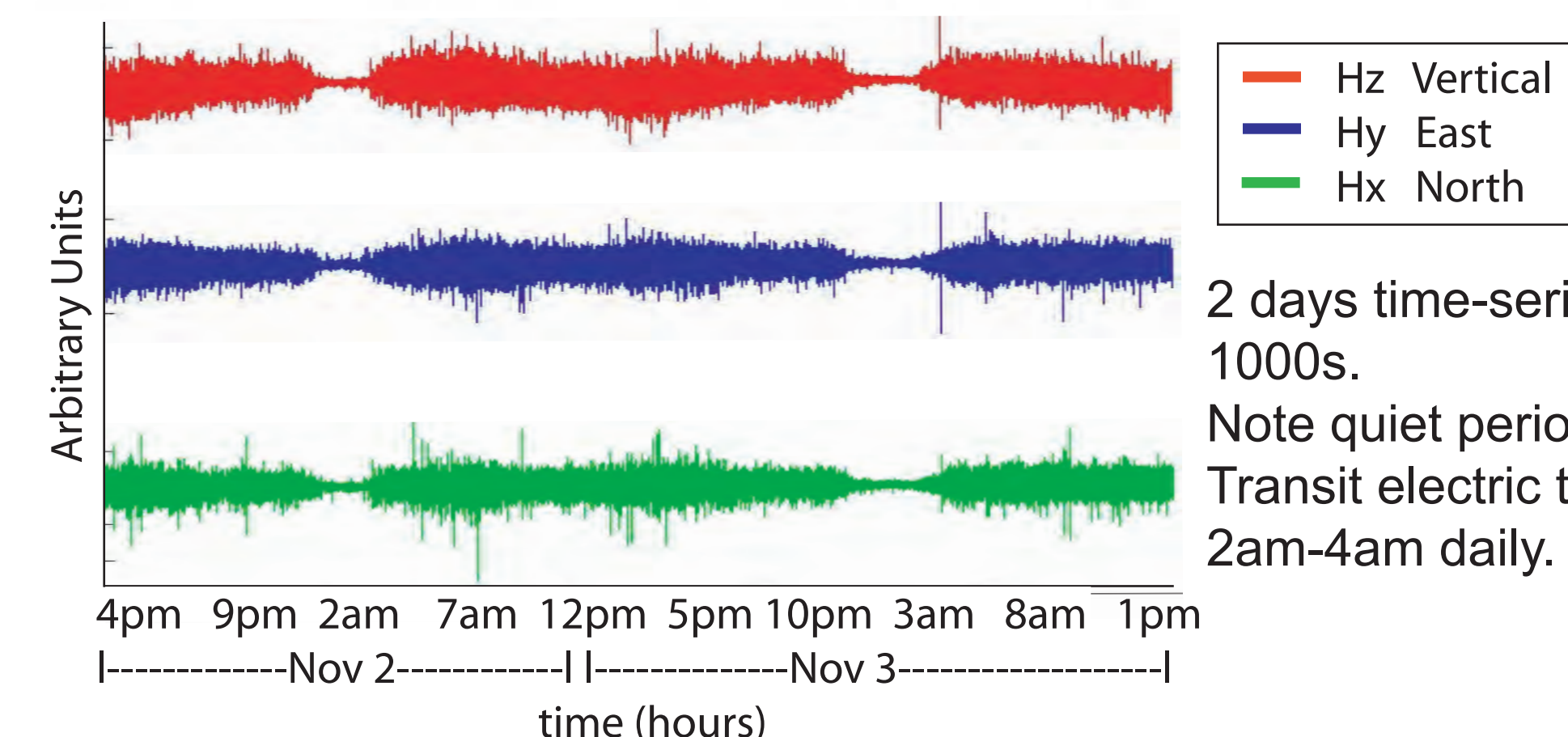
3 NEW SITE AT JASPER RIDGE: Examples of Data Quality

Magnetic Channels Time Series



3a Magnetic Channels

2 days time-series, 40 Hz, low-cut filtered 1000s. Note strong diurnal effect. Quiet periods correspond to Bay Area Rapid Transit electric train (BART) inactivity, 2am-4am daily.

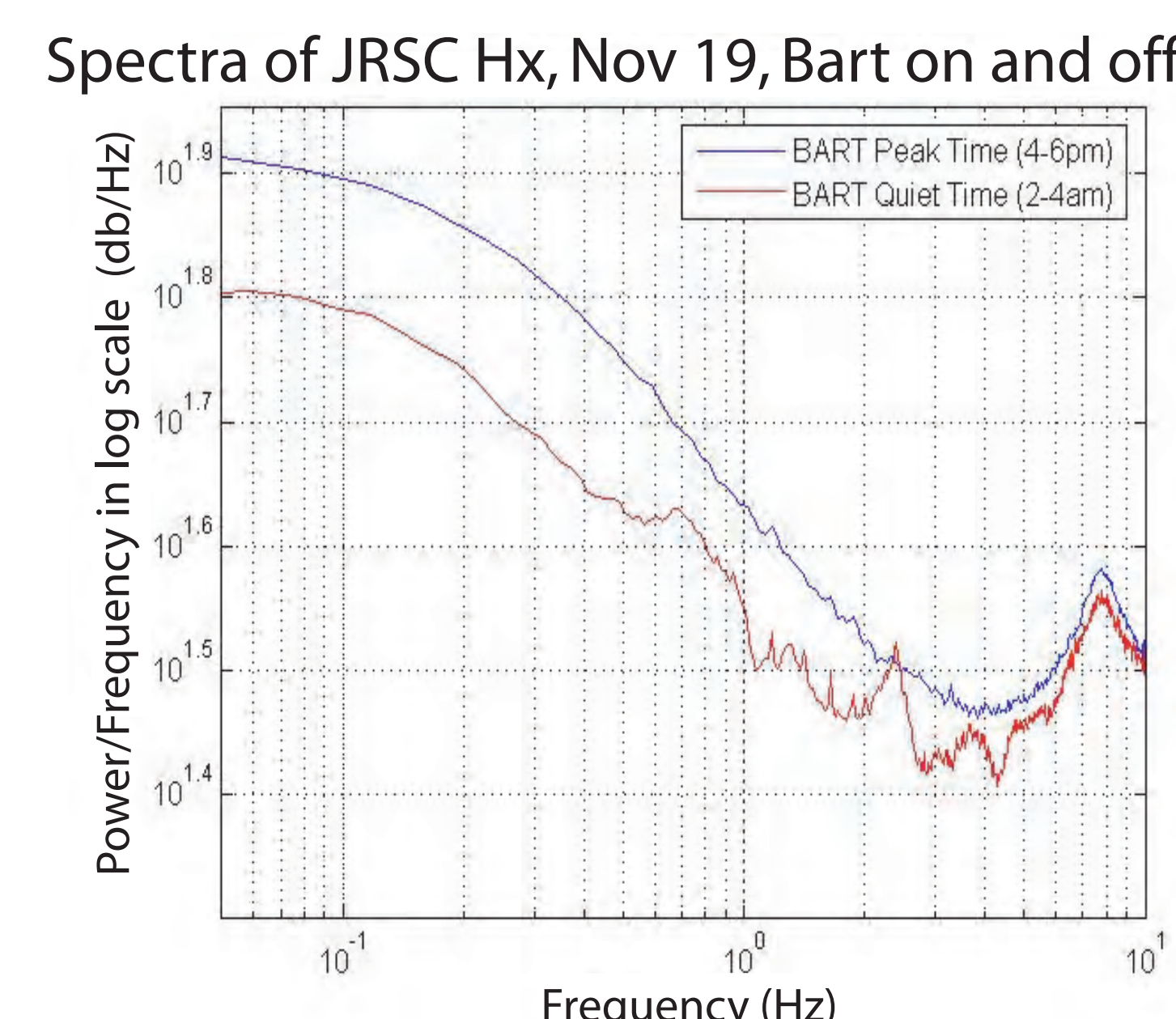
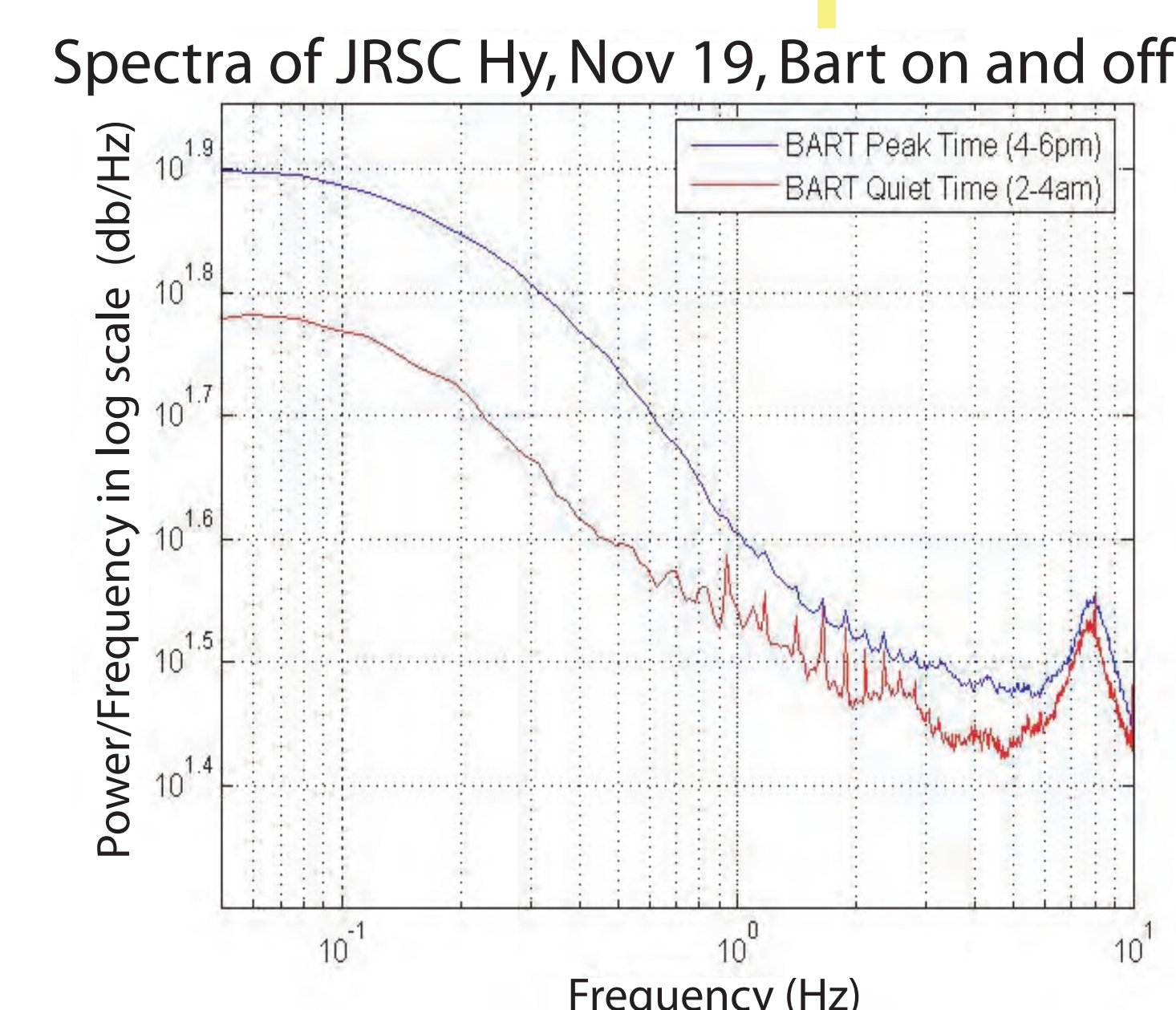
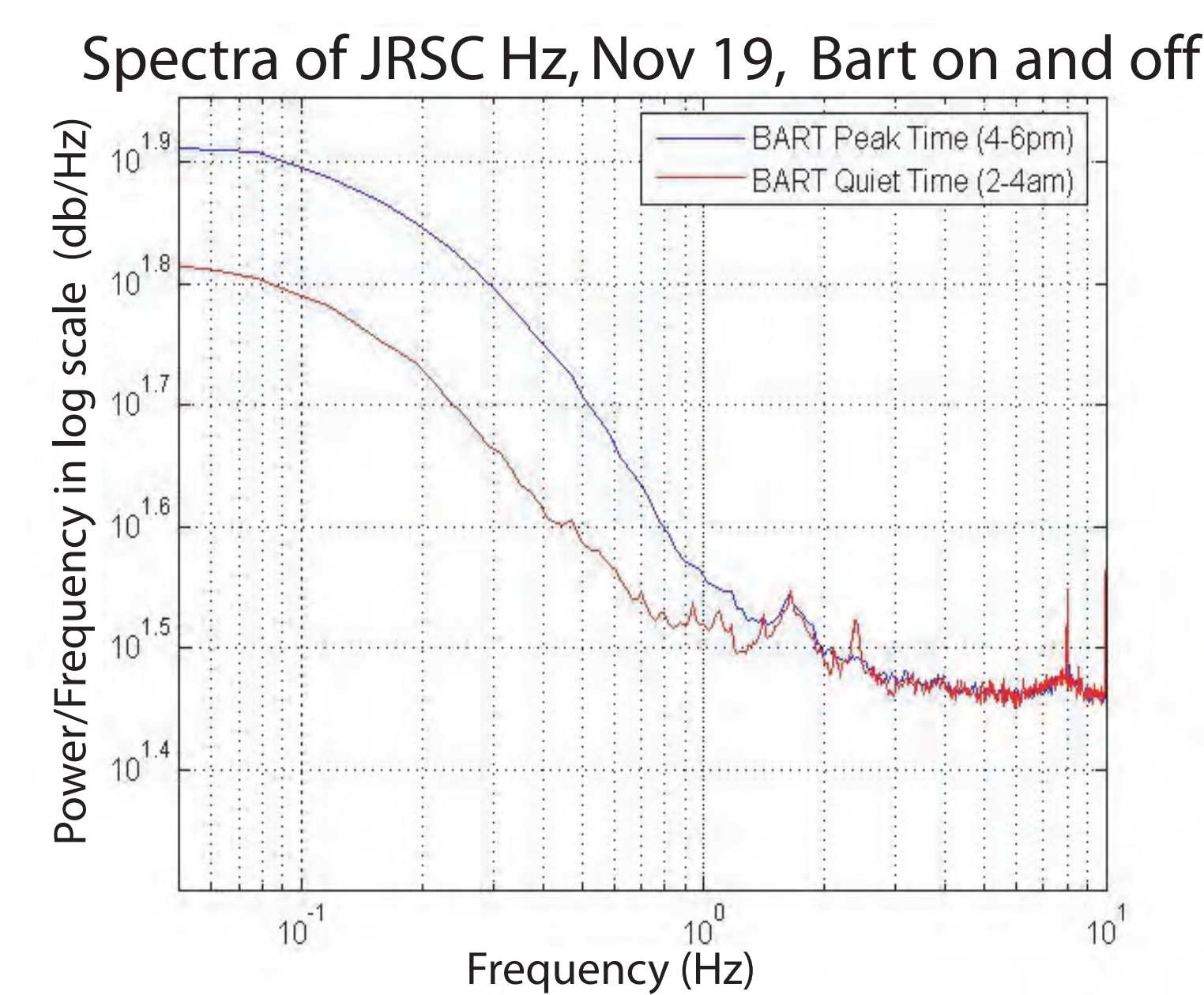
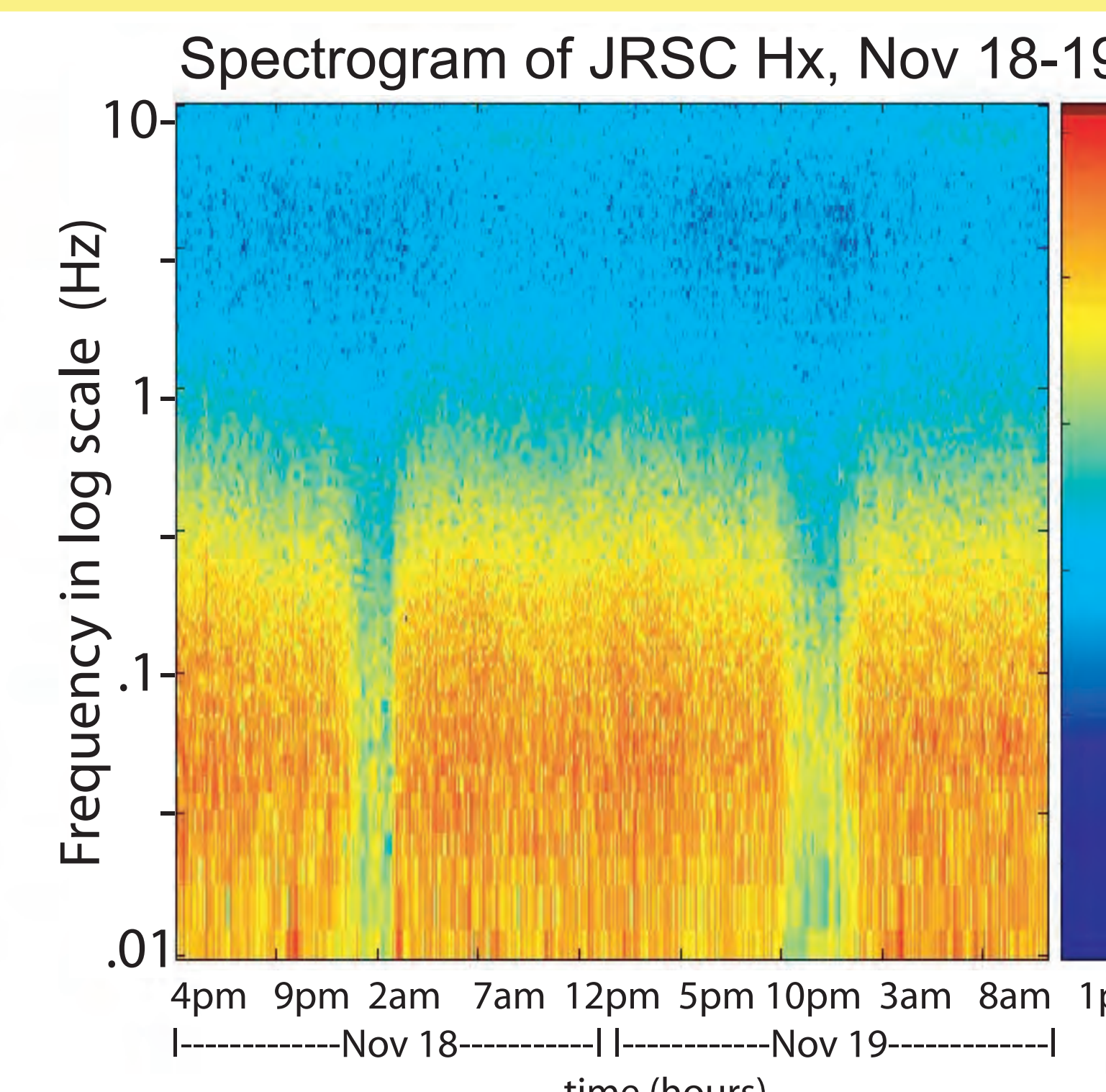
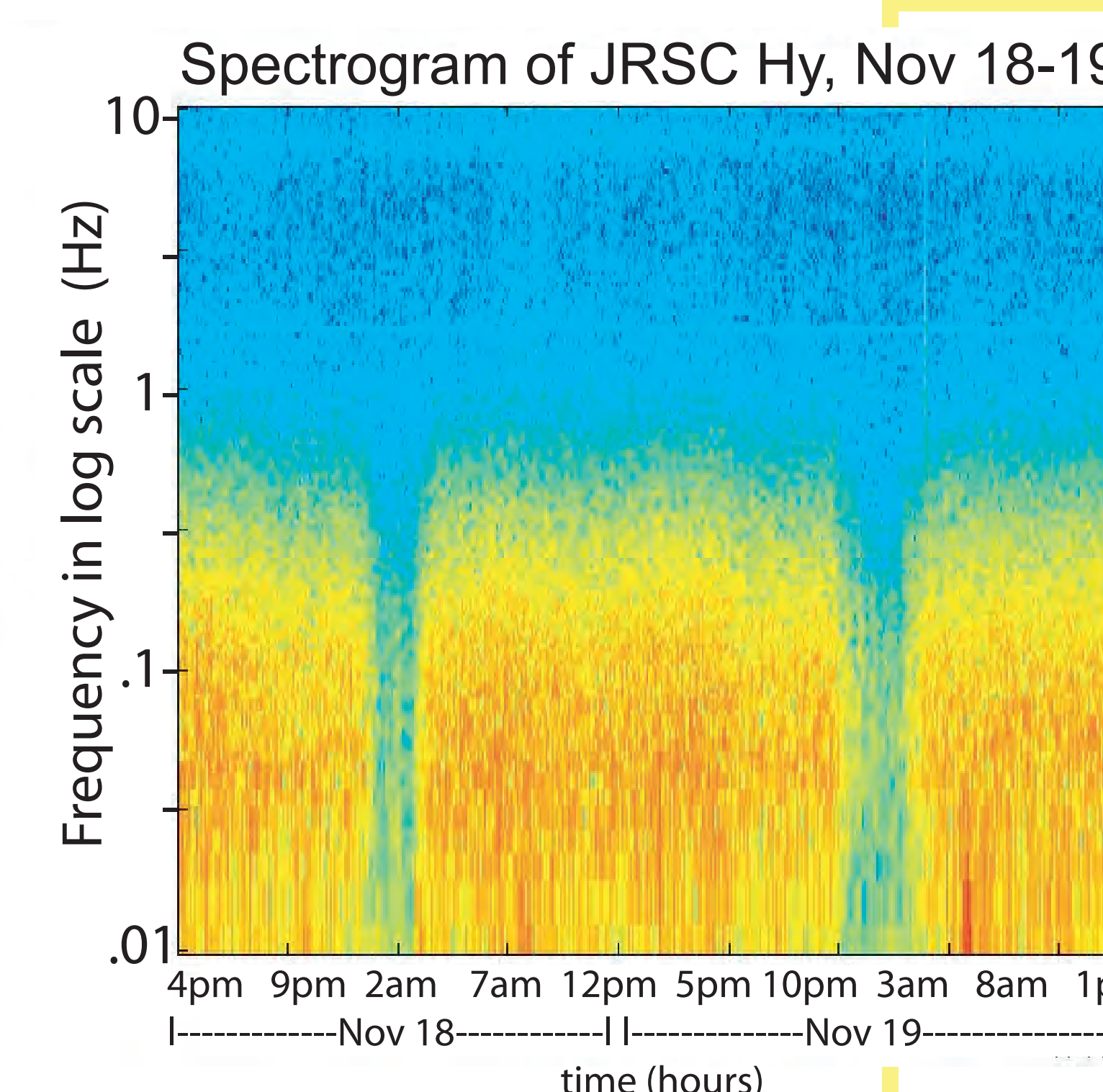
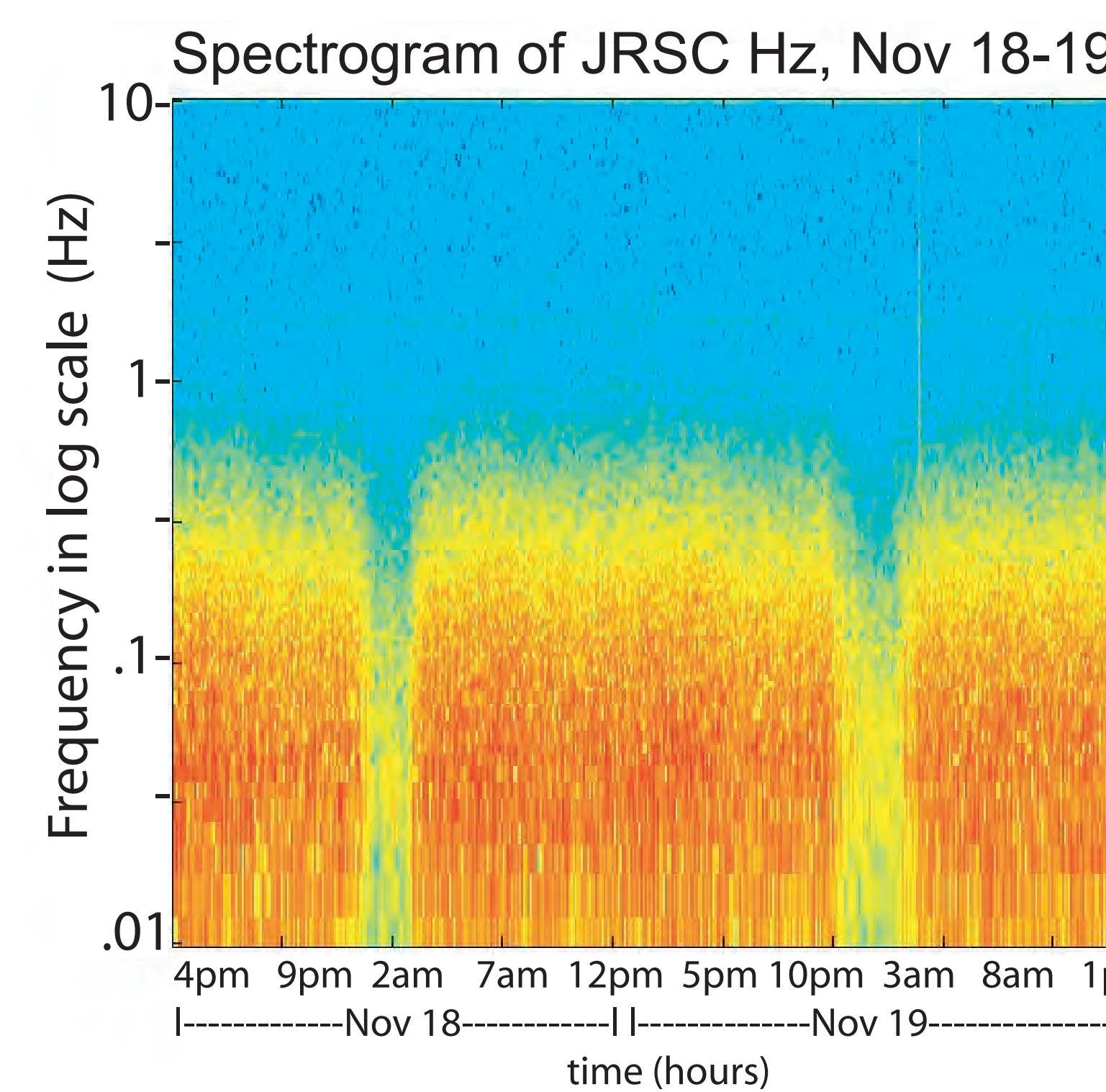


2 days time-series, 40 Hz, low-cut filtered 1000s. Note quiet periods when Bay Area Rapid Transit electric train (BART) is inactive, 2am-4am daily.

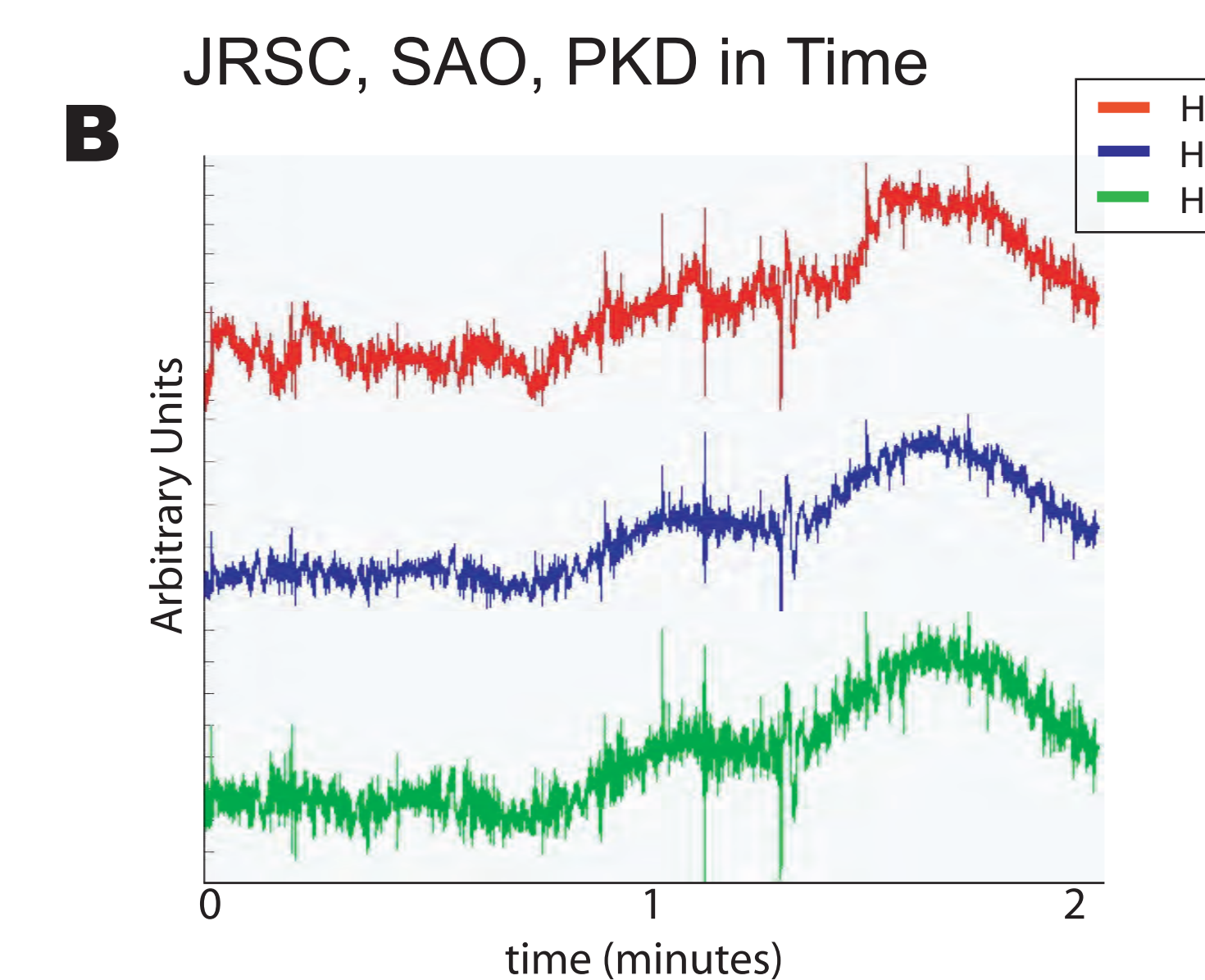
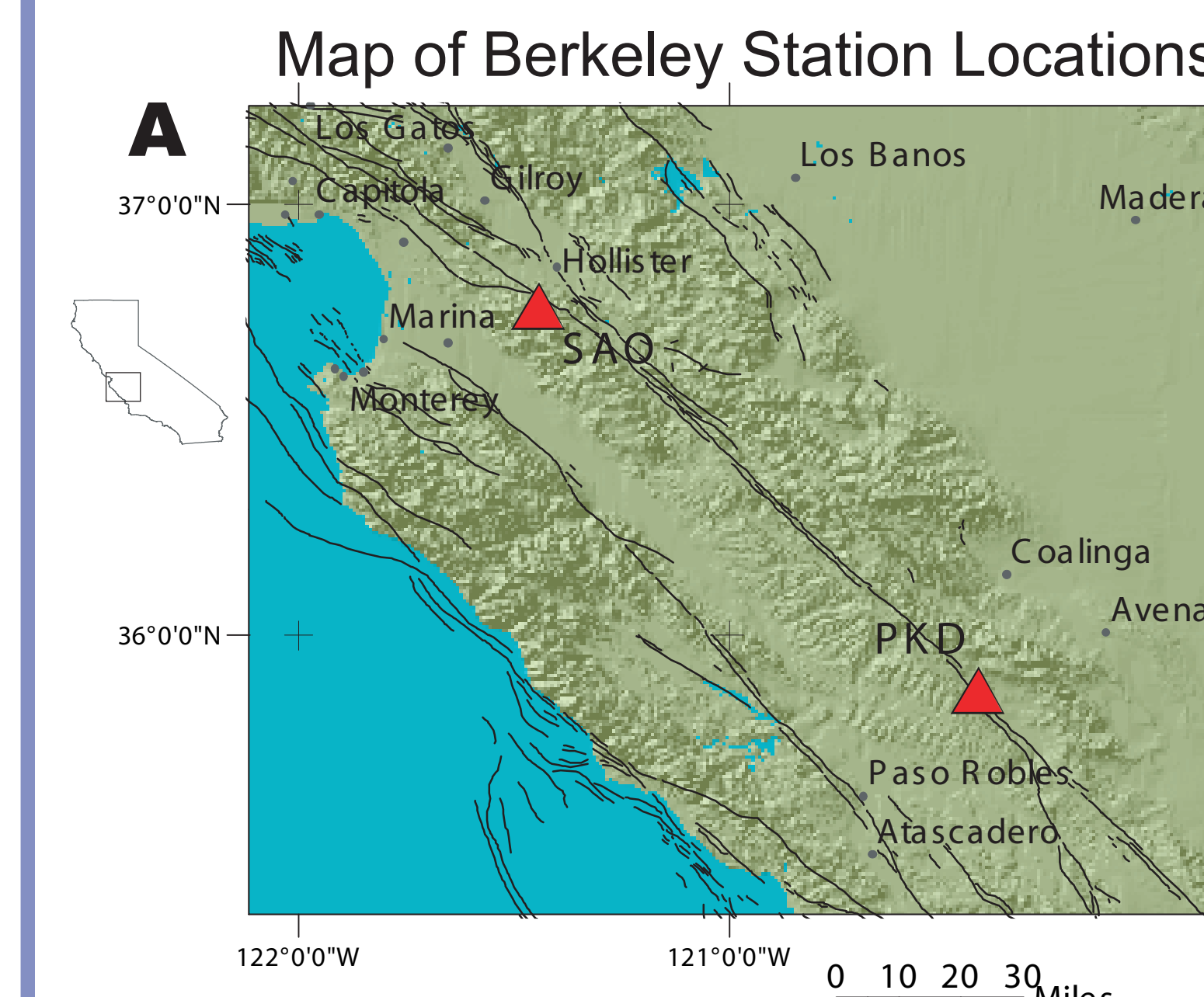
Magnetic Channels Spectrograms and Power Spectras

Spectrogram data is for two continuous days at 40 Hz. Spectrograms exhibit:
-- BART quiet periods for 2 hours each day on spectrograms.
-- Schumann Resonance at 7 Hz on Channels Hx, Hy

Power spectra show comparison of signal levels with BART on and off. Note:
-- Peak at Schumann resonance at 7 Hz in spectra both signals
-- Signals converge in higher frequency range; BART is unimportant above ~ 2 Hz



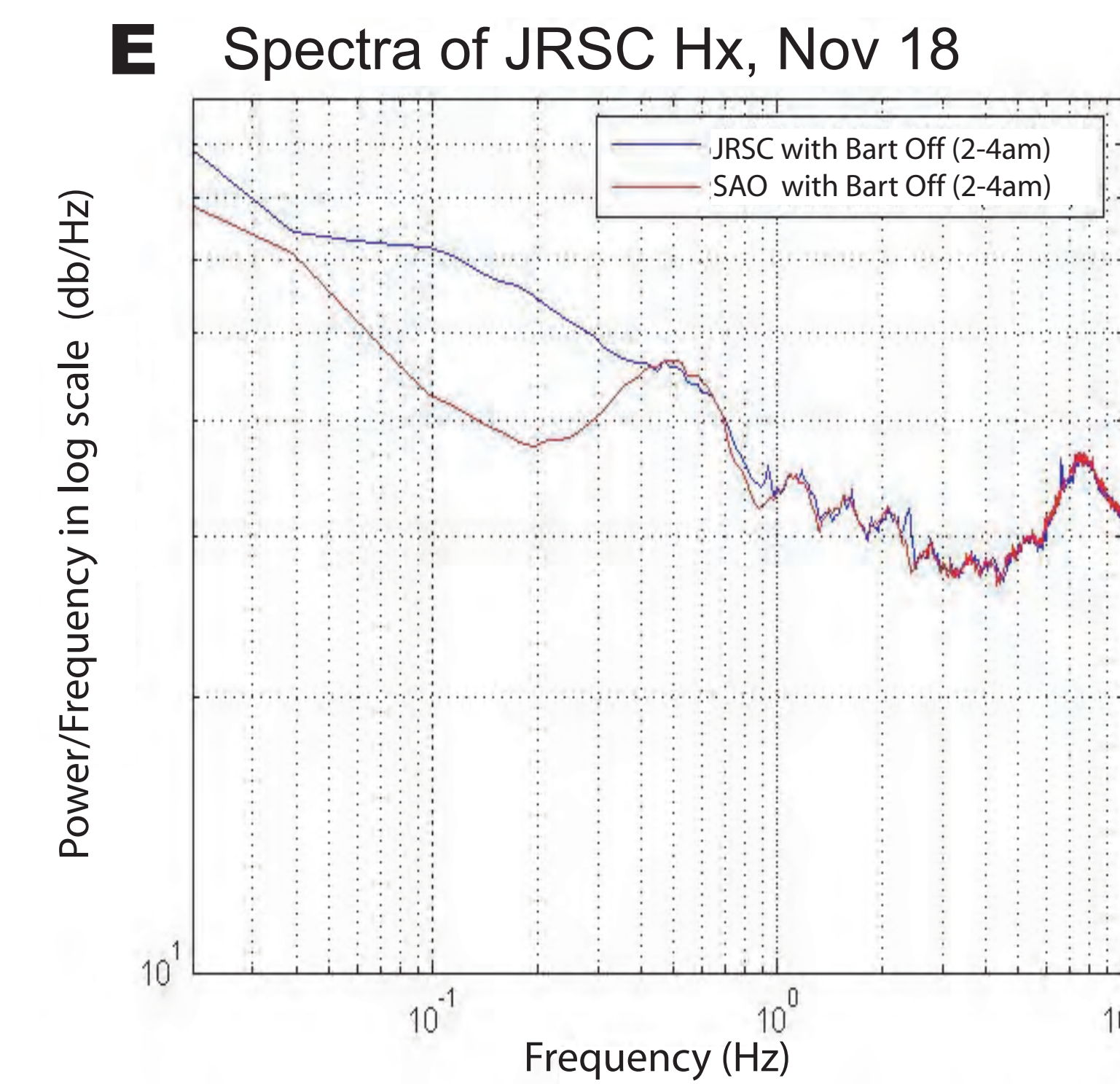
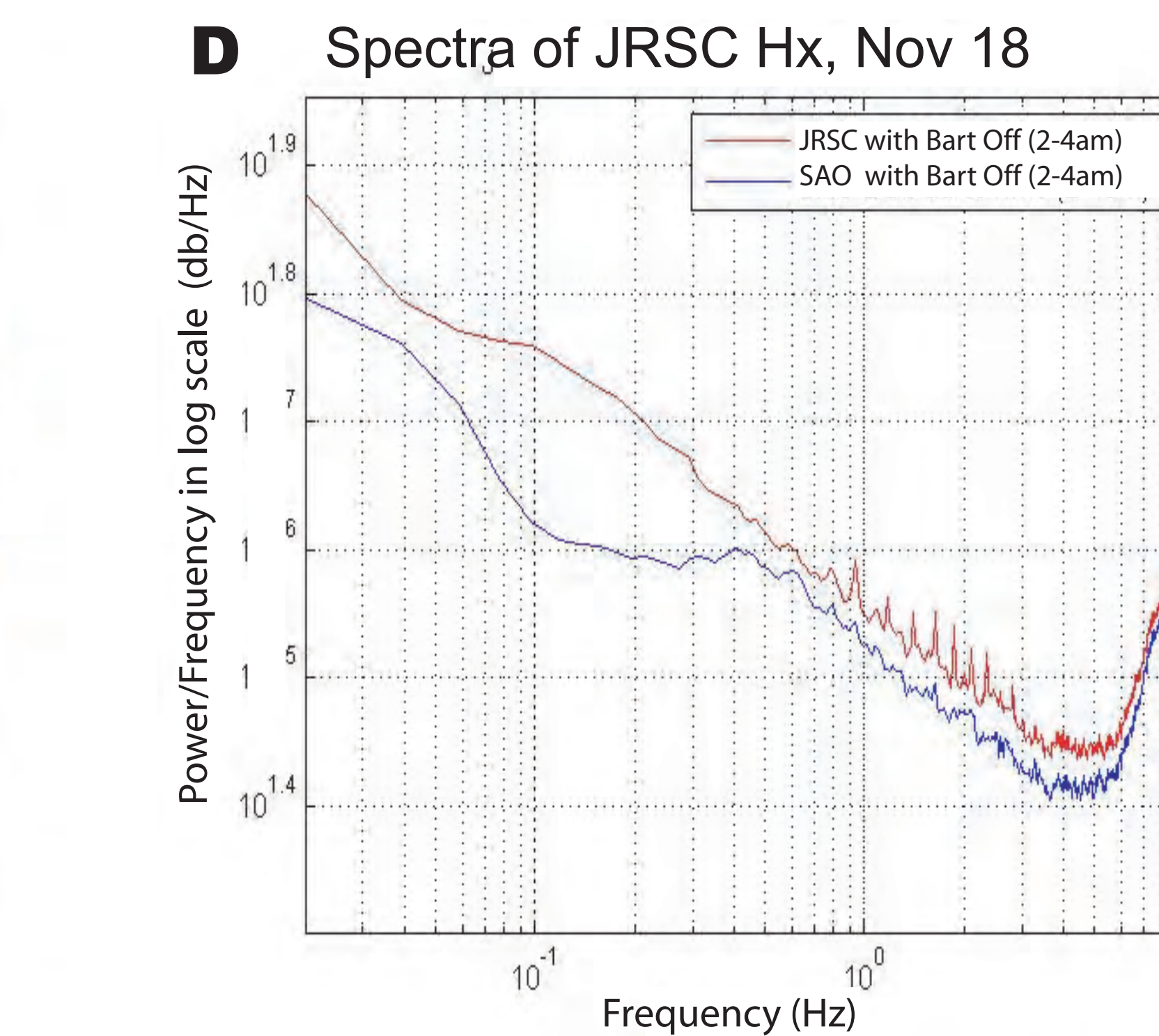
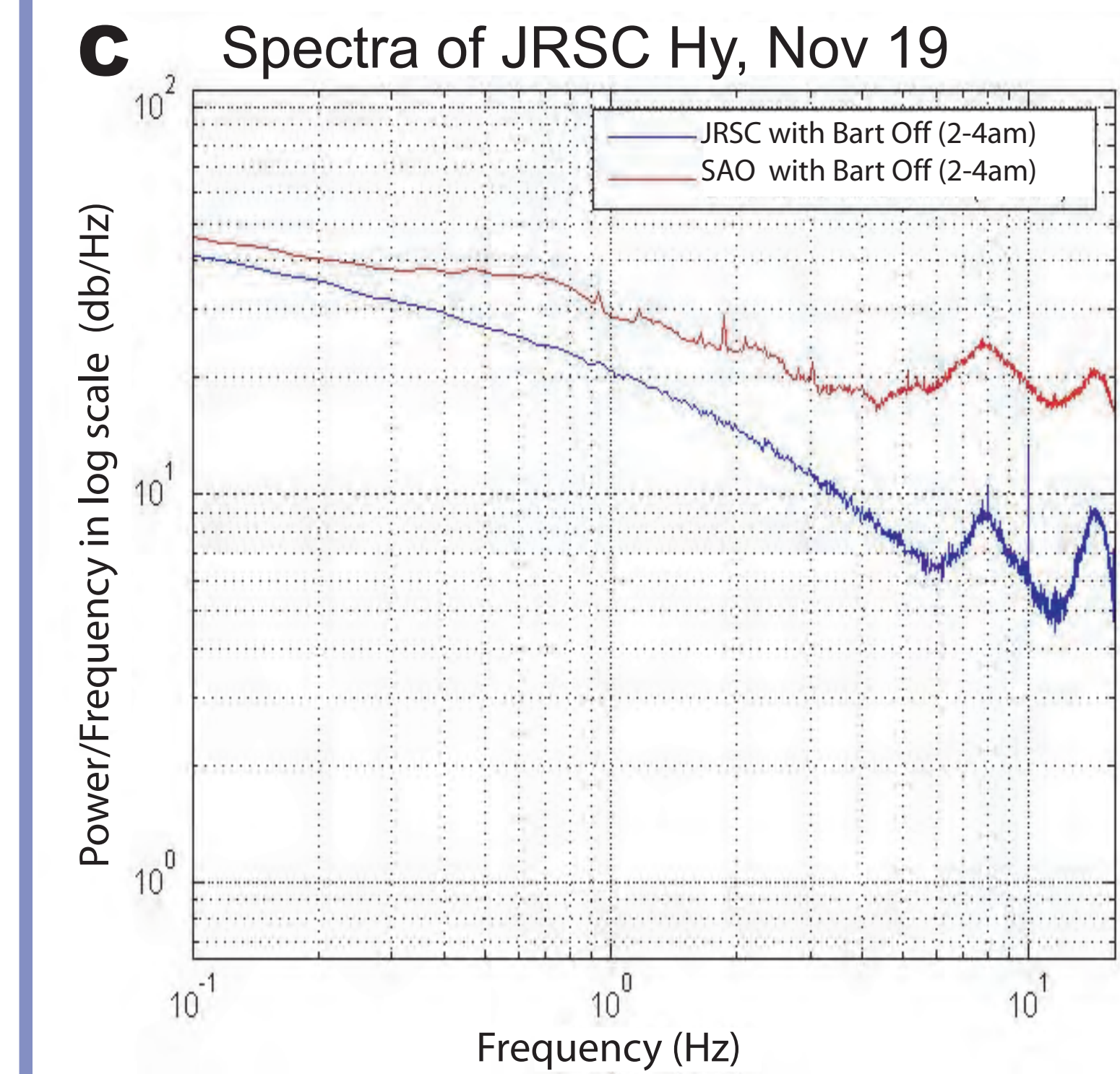
4 SPATIAL ANALYSIS: Comparison with established sites at Hollister and Parkfield



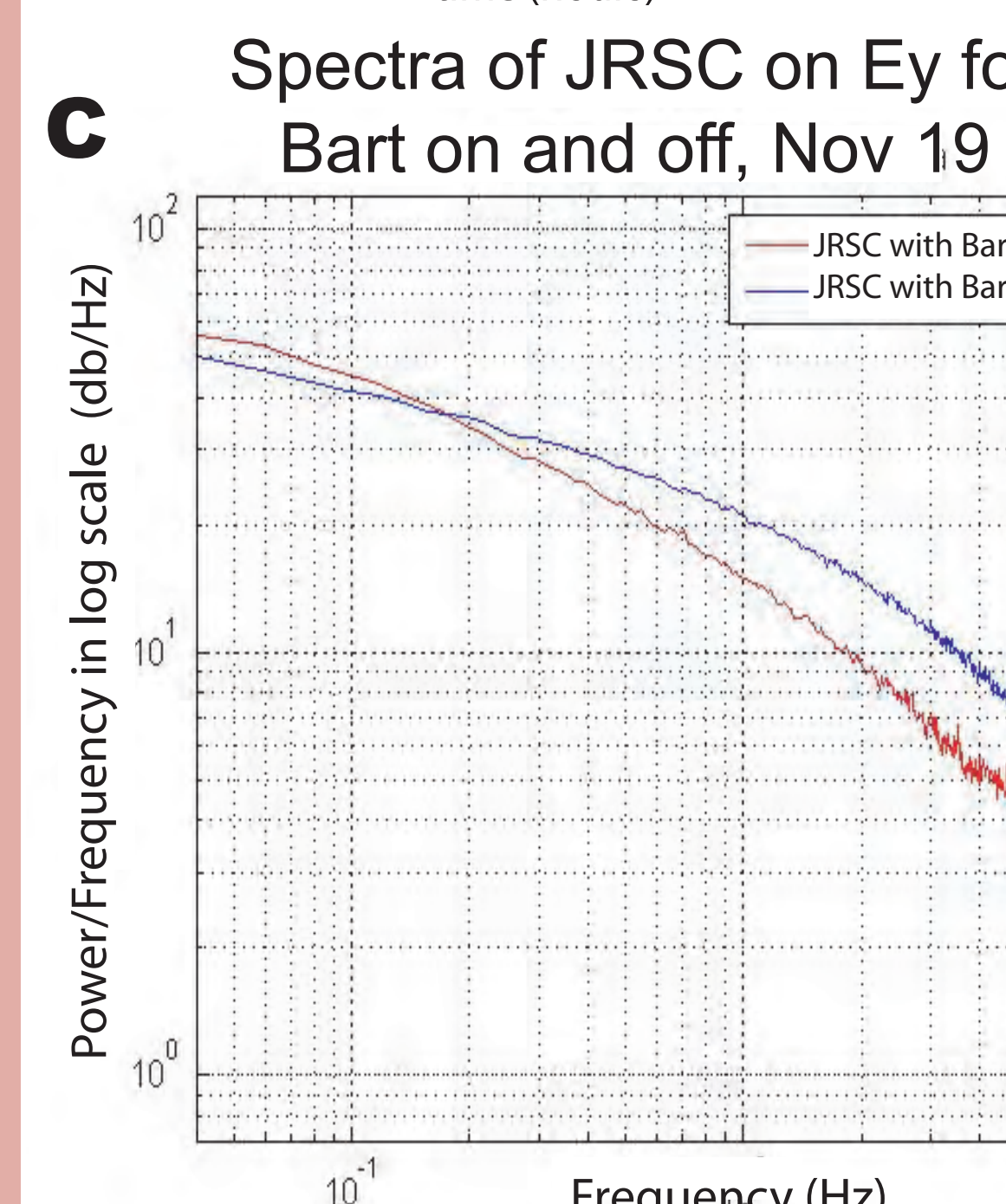
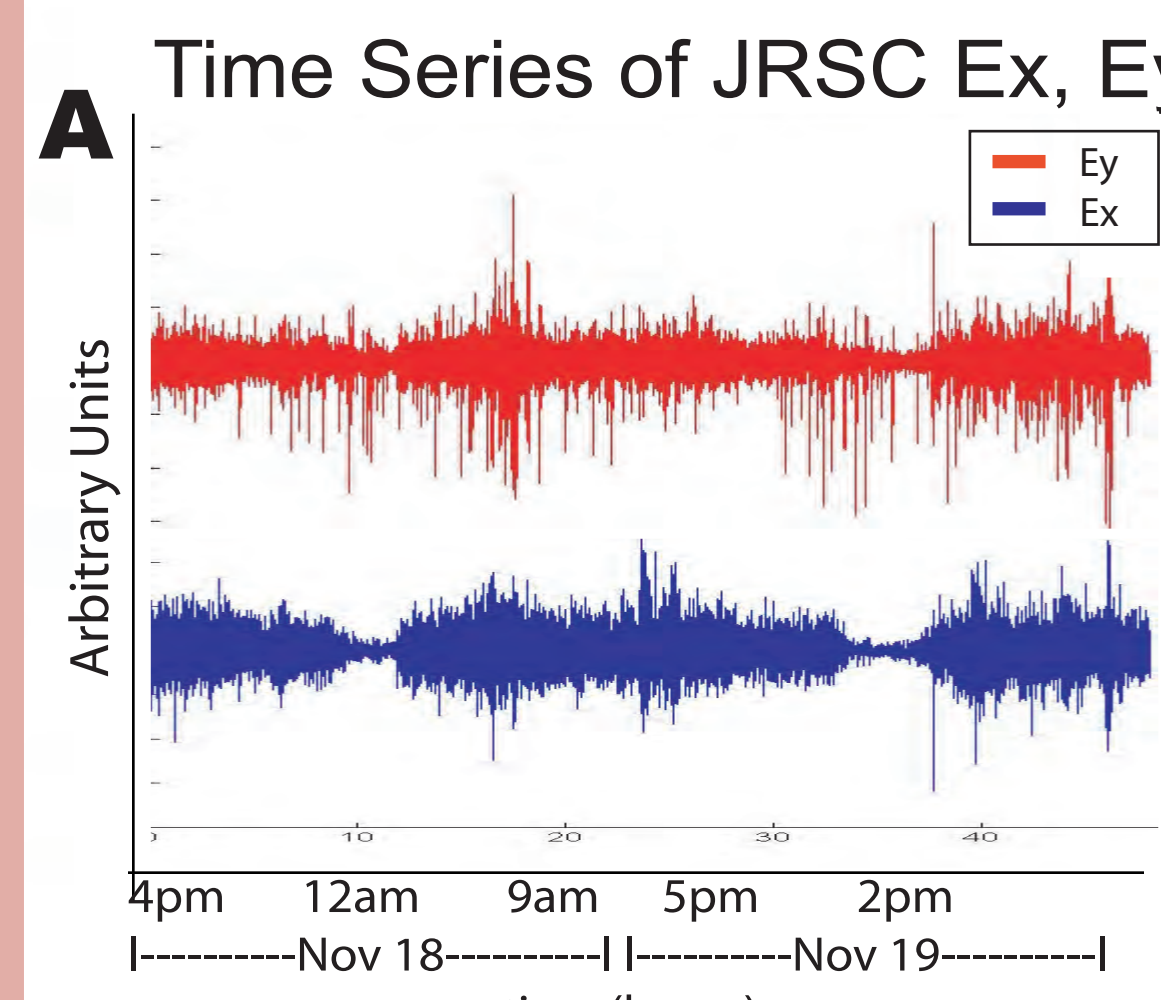
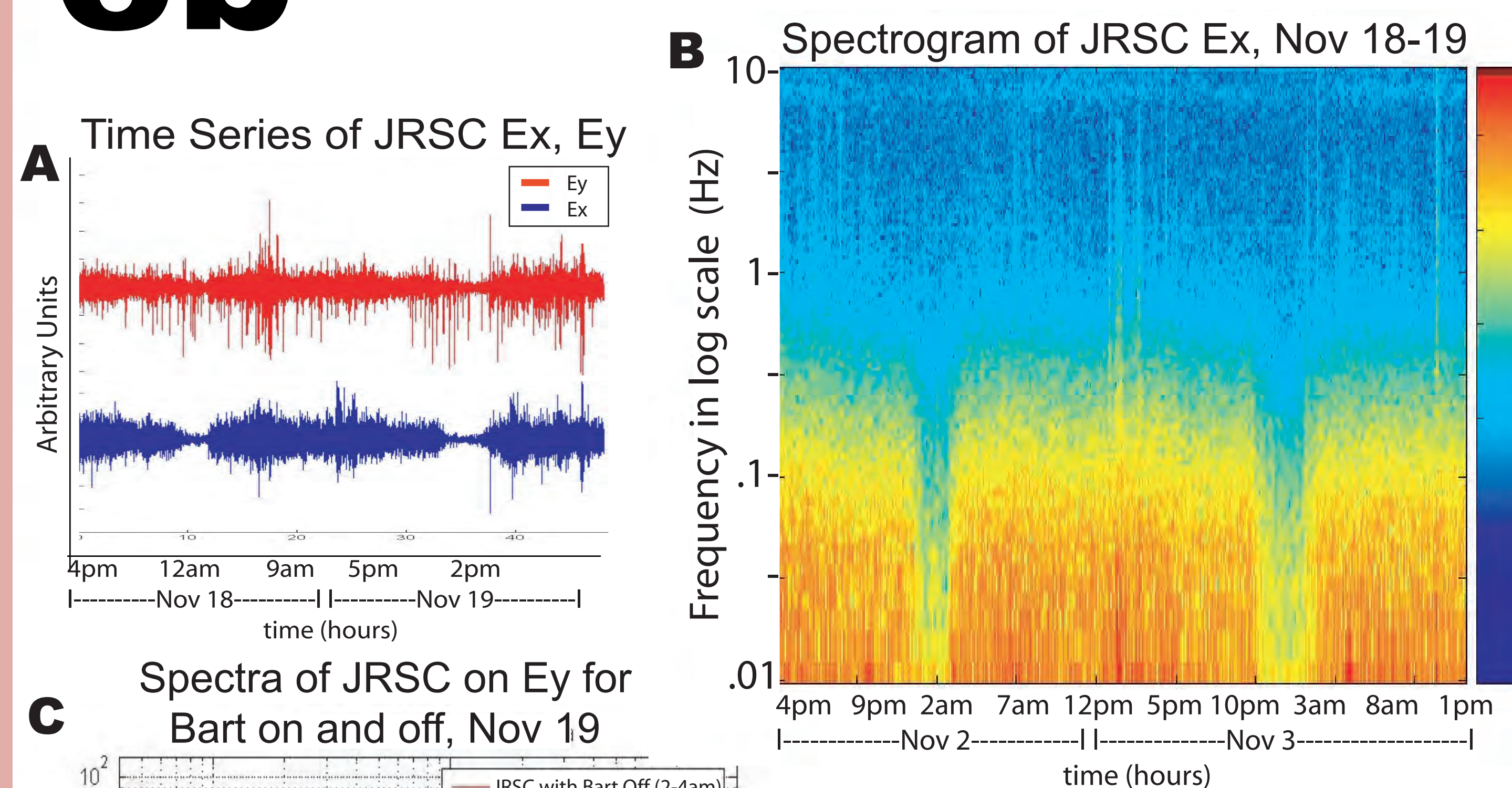
Comparing JRSC data with data from Berkeley stations allows for corroboration of data and the study of spatial distribution of signals.

Figure A. Berkeley EM stations. Also shown are faults (black lines) & earthquake epicenters (circles) colored & scaled by magnitude. Red triangles = existing BDSN reference stations at Hollister (SAO) & Parkfield (PKD).

Figure B. Time Series of JRSC, SAO, PKD for two-minutes of 40Hz data. Note increased signal noise on JRSC due to local conditions. Figure C, D, E: Power Spectra for JRSC and SAO. Spectra show Schumann Response at 7Hz.



3b Electric Channels



Comparing JRSC data with data from Berkeley stations allows for corroboration of data and the study of spatial distribution of signals.

Figure A. Time Series for Ex and Ey, 40 Hz. Quiet times are when BART is inactive. Figure B. Spectrogram is for two days, 40 Hz. Schumann Resonance is at 7 Hz. Quiet periods correspond to BART inactivity. Figure C. Power spectra show comparison of signal levels for JRSC and PKD. Note Schumann resonance at 7 Hz in spectra.