JET NOISE BEAMFORMING WITH SEVERAL TECHNIQUES

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ABSTRACT

Advanced techniques can enhance beamforming results. Deconvolution methods can improve low frequency resolution and reduce sidelobes. Matrix analysis approaches can separate statistically independent sources. This paper presents the results of applying 3D CLEAN-SC, DAMAS, TIDY, and eigenvalue cancellation to cage array data for turbofan engine jet noise from the NASA Engine Validation of Noise and Emission Reduction program.

1 INTRODUCTION AND TEST SETUP

The NASA EVNERT Program [1] included several phased arrays. One of these, a cage array for jet noise, was tested with a mixed flow and a separate flow nozzle fitted to a TECH977 turbofan engine. Separate flow results are given here for 87% power.

The traversing cage array had 105 XCQ-125B-093-15A Kulite pressure transducers mounted on a hoop structure with a diameter of 4.6 m and a length of 4.4 m, as shown in Fig. 1a). Measurements were made in three traverse positions. The results here are from the forward position. Data were acquired at 50 kHz using two Datamax II digital recorders.

The 3D beamforming grid has 16 transverse planes separated by 0.5 m, with each plane consisting of 35×35 points with a spacing of 0.1 m. The total number of points is 19,600.

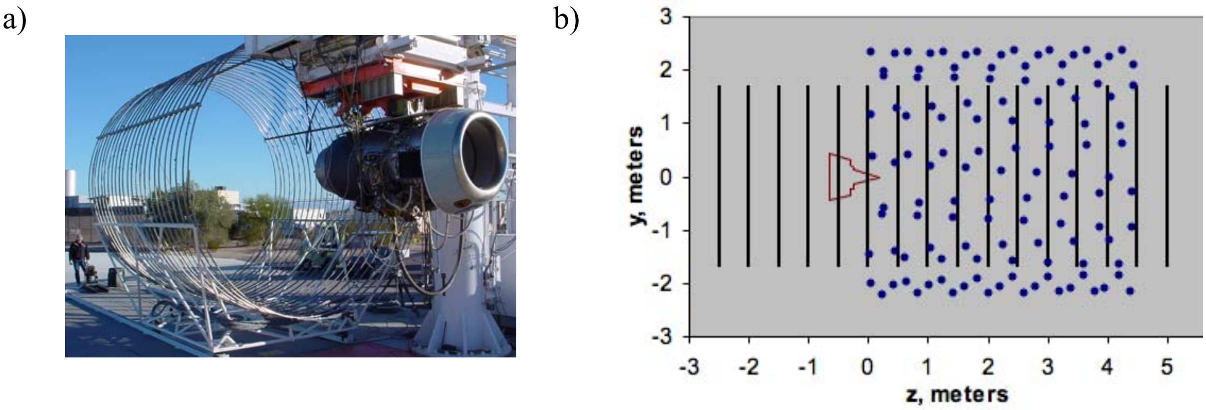

Fig. 1. Test setup, a), and 3D beamforming grid, b). Results are given on the 16 transverse planes.

2 RESULTS

2.1 Conventional Beamforming

Conventional beamforming results for a 24.42 Hz band centered at 244.14 Hz are given in Fig. 2. Each panel represents one transverse plane. The primary and secondary nozzles are indicated by the green circles. The diagonal green curves in the corners of the plots represent the diameter of the cage array. The resolution is poor at this low frequency, especially in the axial direction. This creates the appearance of noise sources as much as 2.5 m forward of the jet nozzle. Prominent sidelobes can be seen as spots from the jet plume.

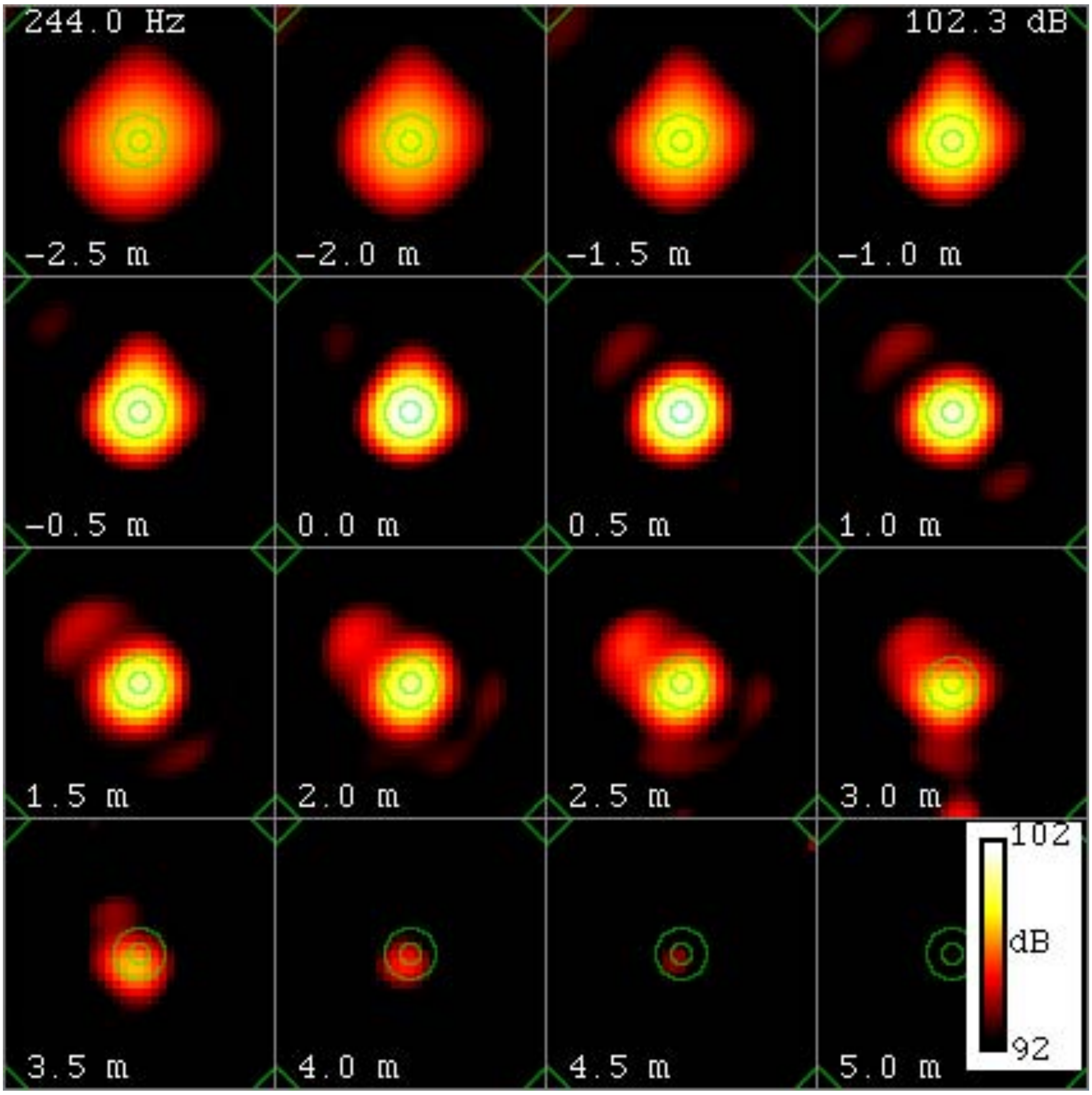

Fig. 2. Conventional beamforming results.

2.2 DAMAS

DAMAS [2] results for 200 iterations on the 3D grid are given in Fig. 3. Ring sources representing one or both of the jet shear layers can be seen clearly. The source in the upper portion of the plane at -1 m is believed to be real: possibly a feature of the test stand. The origin of the sources at -2.5 m is not known, but the turbofan engine has no shortage of noise mechanisms. The jet noise begins at the nozzle, as expected.

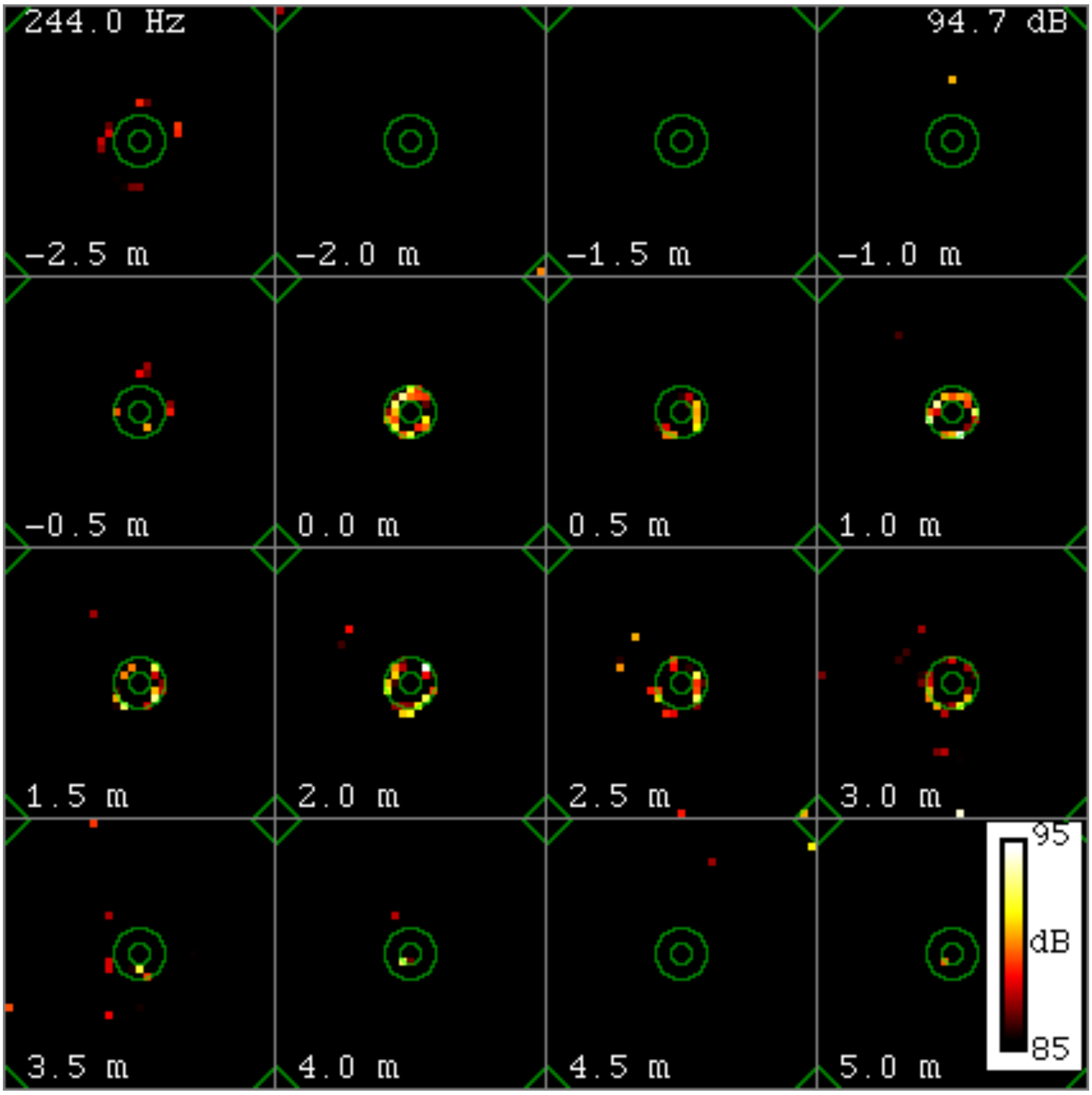

Fig. 3. DAMAS beamforming results.

2.3 CLEAN-SC

CLEAN-SC [3] results are shown in Fig. 4. The test stand source does not appear at -1 m, but there is a spot at -0.5 m. Most of the jet noise appears on the jet axis. This contrasts with the DAMAS results, which shows no jet noise on the axis.

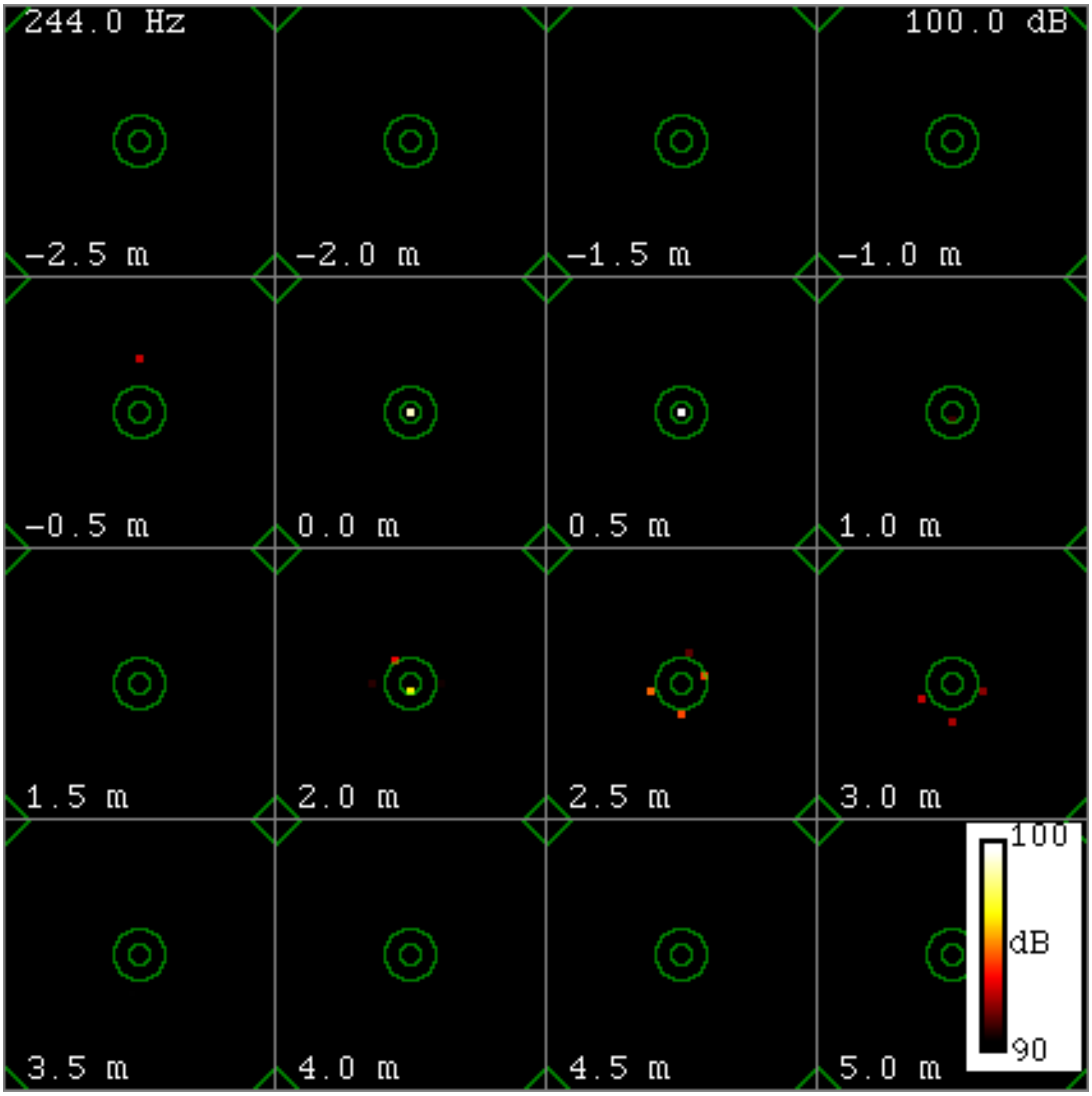

Fig. 4. CLEAN-SC results.

2.4 TIDY

TIDY [4] results are given in Fig. 5. Jet noise sources are seen on both the axis and the shear layers, combining elements found by both DAMAS and CLEAN-SC.

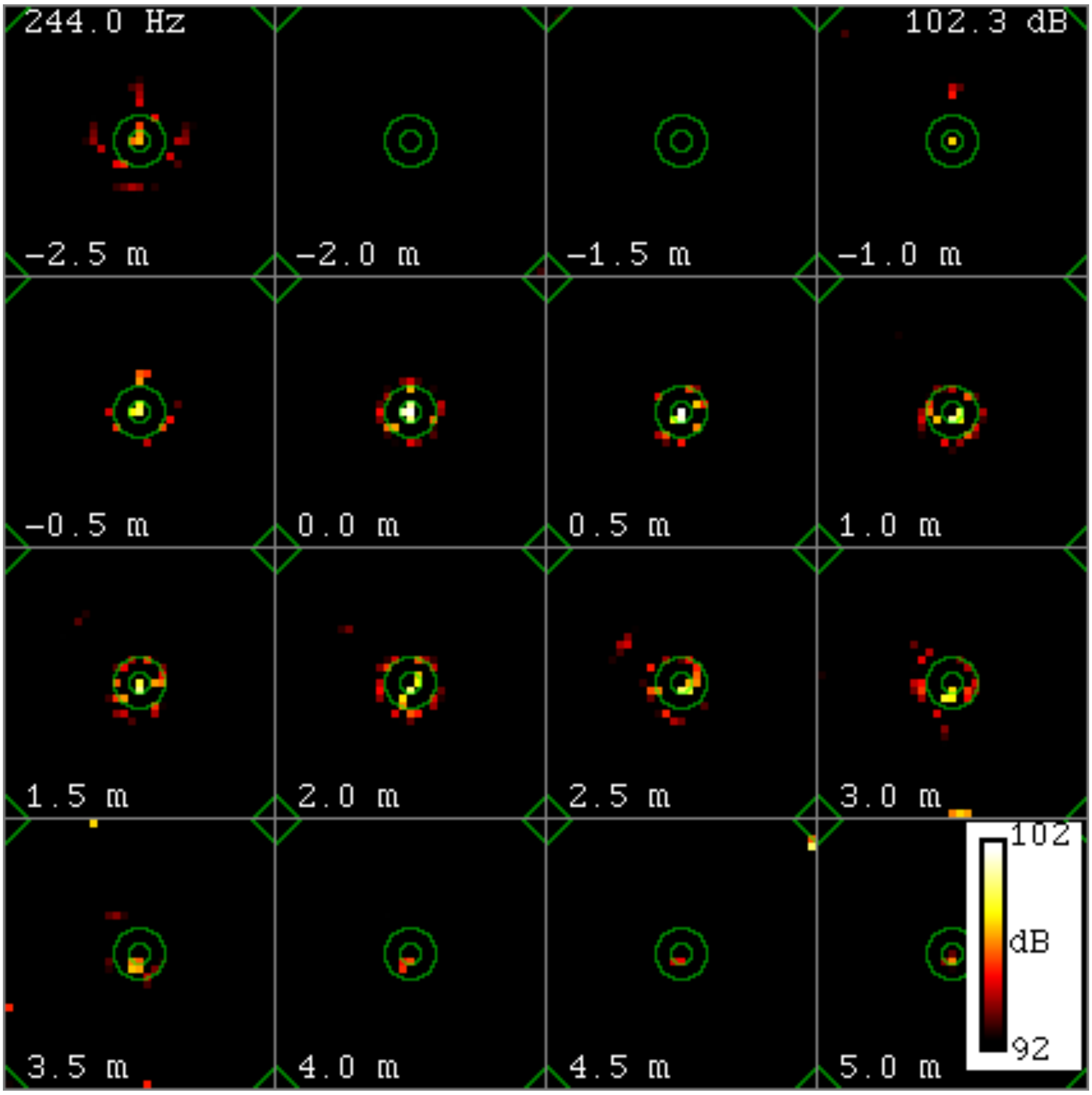

Fig. 5 TIDY results.

2.5 Eigenvalue cancellation

Combining TIDY and eigenvalue cancellation [5] to delete the first eigenvalue of the cross spectral matrix (CSM) gives the results shown in Fig. 6. Comparing Fig. 5 and Fig. 6, removing the first eigenvalue appears to have removed sources on and near the jet axis downstream of 0.5 m, enhancing the appearance of sources on the jet centerline at the nozzle and farther from the axis for z = 1.5 – 3.0 m. The results from z = 3.5 – 5.0 m have been removed to save space.

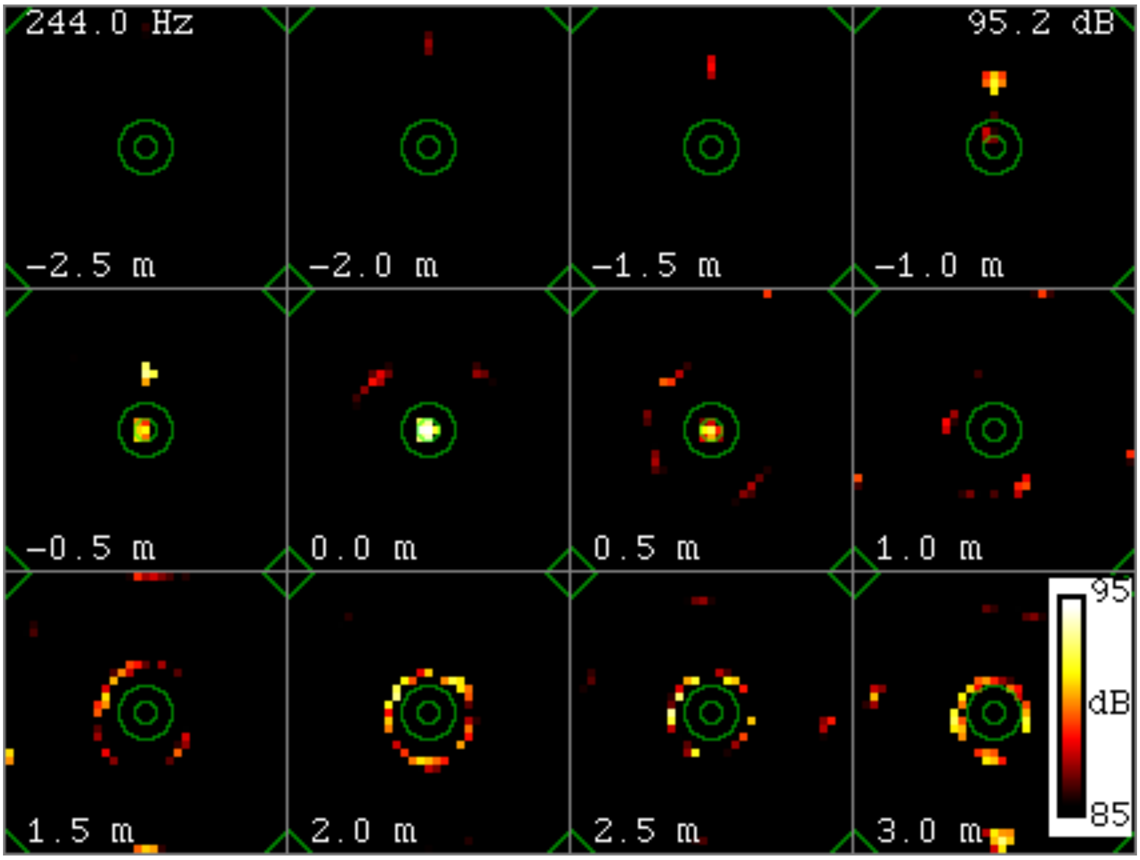

Fig. 6 TIDY applied with the first eigenvalue of the CSM deleted. Results for 3.5 – 5 m removed.

3 CONCLUSIONS

Cage array beamforming of jet noise at low frequency is feasible. Advanced techniques are required to image the structure of the shear layer noise. In the case tested, CLEAN-SC located jet noise sources on the axis, DAMAS placed them on a ring near the outer nozzle lip line, and TIDY found sources in both locations.

REFERENCES

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