The Magnetic Field in Star-Forming Regions of Perseus Molecular Cloud

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Abstract

We present magnetic field strength maps in the star-forming regions, including IC348, L1448, L1455, NGC1333, and PerB1, of Perseus molecular cloud. The angular dispersion is calculated from the 850 μm linear polarization maps as part of B-fields In STar-forming Region Observations (BISTRO) survey. The velocity dispersion is estimated from spectral lines of $C^{18}O$ and N_2H^+. The result shows that the magnetic field strength is higher at the core regions. Furthermore, we compare the magnetic field strength with volume density and find that they follow the expected power law. The mass-to-flux ratio in most of the regions is found to be less than 1, suggesting magnetically supercritical.

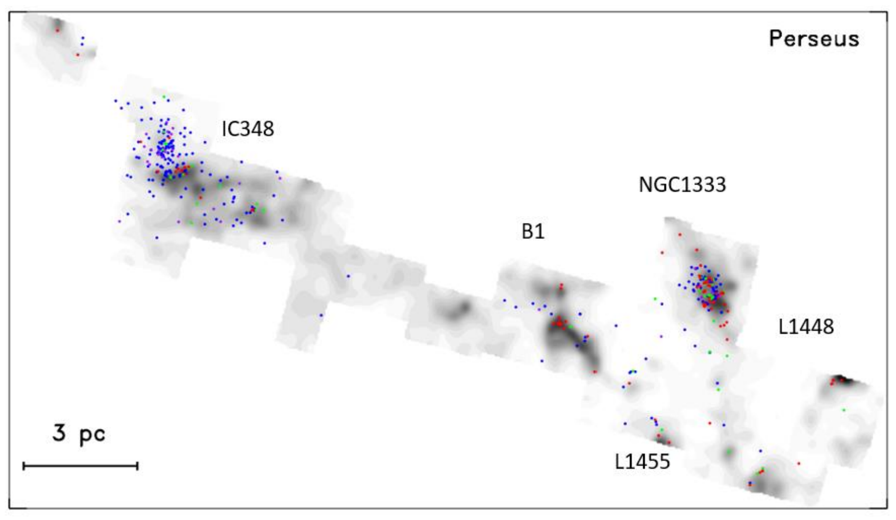


Figure 1. The maps of YSO in the Perseus molecular cloud from Neal J. Evans II et al. (2009) : red (I), green (flat), blue (II), and purple (III)

Magnetic Field Strength

The **Davis–Chandrasekhar–Fermi (DCF) method** (Davis 1951; Chandrasekhar & Fermi 1953) is widely used to assess the plane-of-sky magnetic field strength, which assumes that the local perturbations of the large-scale magnetic field is due to the turbulence.

$$B_{pos} = Q\sqrt{4\pi\rho}\,\frac{\sigma_v}{\sigma_\theta} \approx 9.3\sqrt{n(H_2)}\,\frac{\Delta V}{\sigma_\theta}$$

- Q=0.5 is a correction factor (Ostriker et al. 2001)
- $n(H2)$ is the hydrogen volume density
- σ_θ is the angular dispersion
- ΔV is the FWHM of the nonthermal spectral line

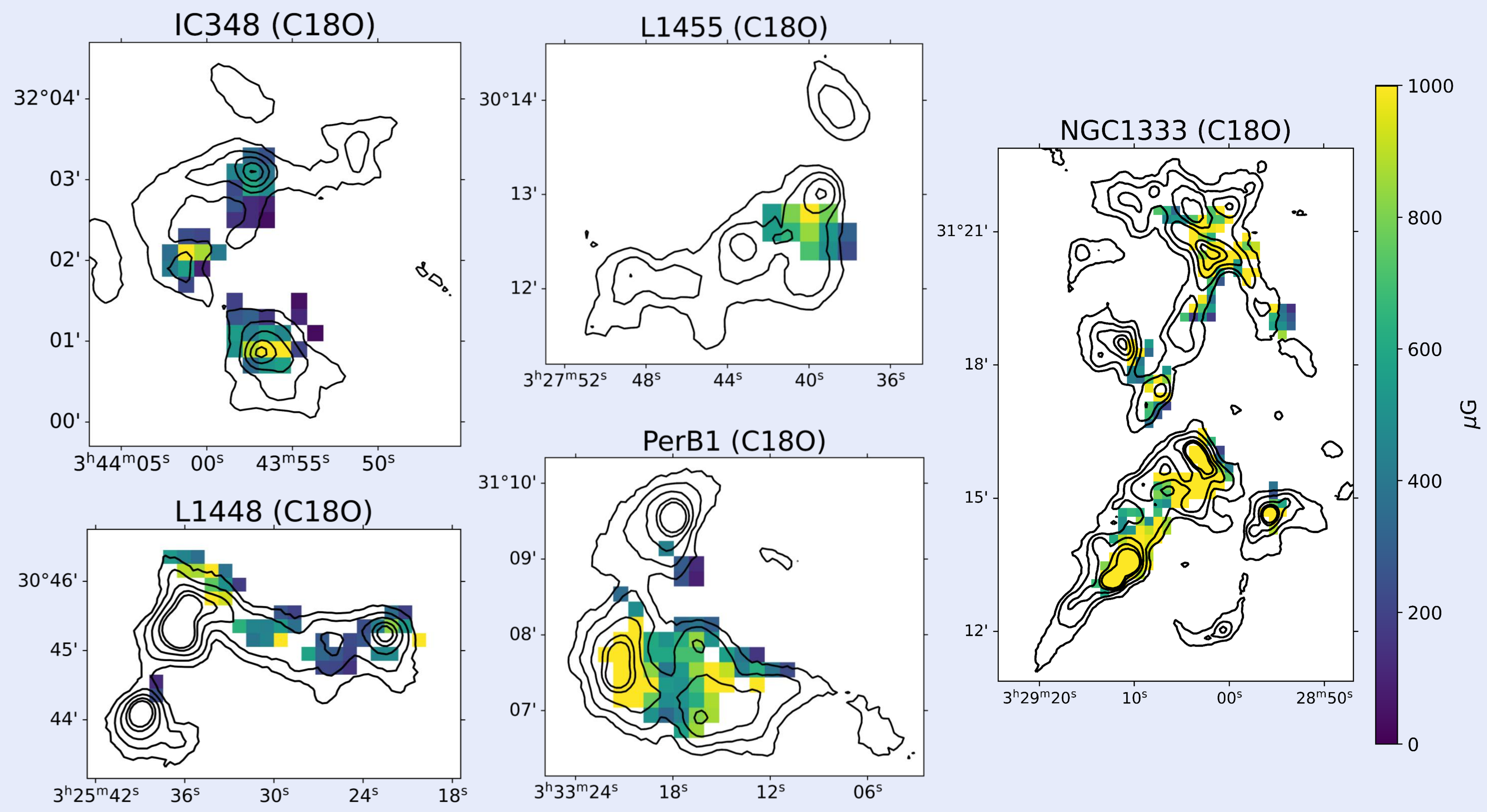
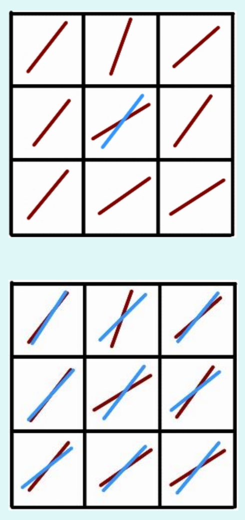


Figure 2. The magnetic field strength maps of star-forming regions calculated by DCF method.

Angular Dispersion

We first use "unsharp method" to create smooth polarization angle maps. Then, we estimate the angular dispersions within the 3x3 pixel box by two different methods (Pattle et al. 2017, Hwang et al. 2021).



$$\sigma_{\theta,P} = \sqrt{\frac{\sum_{i=1}^{N}\left(\Delta\theta_i - \overline{\Delta\theta_i}\right)^2}{N}} \;;\; \sigma_{\theta,H} = \sqrt{\frac{\sum_{i=1}^{N}\left(\theta_i - \bar{\theta}_i\right)^2}{N}}$$

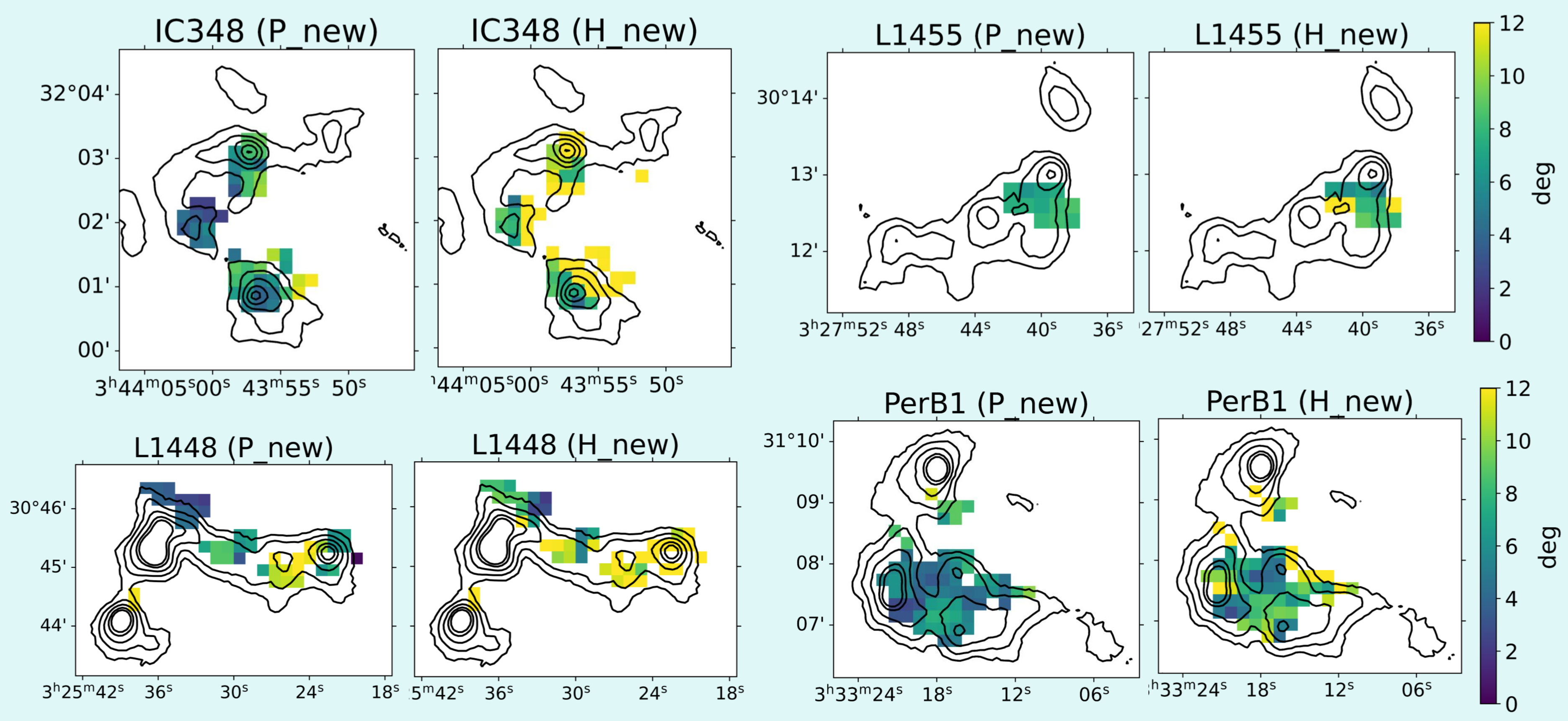


Figure 3. The comparison of angular dispersion maps calculated from different methods.

Velocity Dispersion

The FWHM of the nonthermal spectral line is obtained from the molecular spectral linewidth maps of $C^{18}O$ and N_2H^+.

$$\Delta V = 2\sqrt{2}\ln 2\,\sigma_v \;;\; \Delta V_{non}^2 = \Delta V_{tot}^2 - \frac{kT_k}{m_{molecule}} 8\ln 2$$

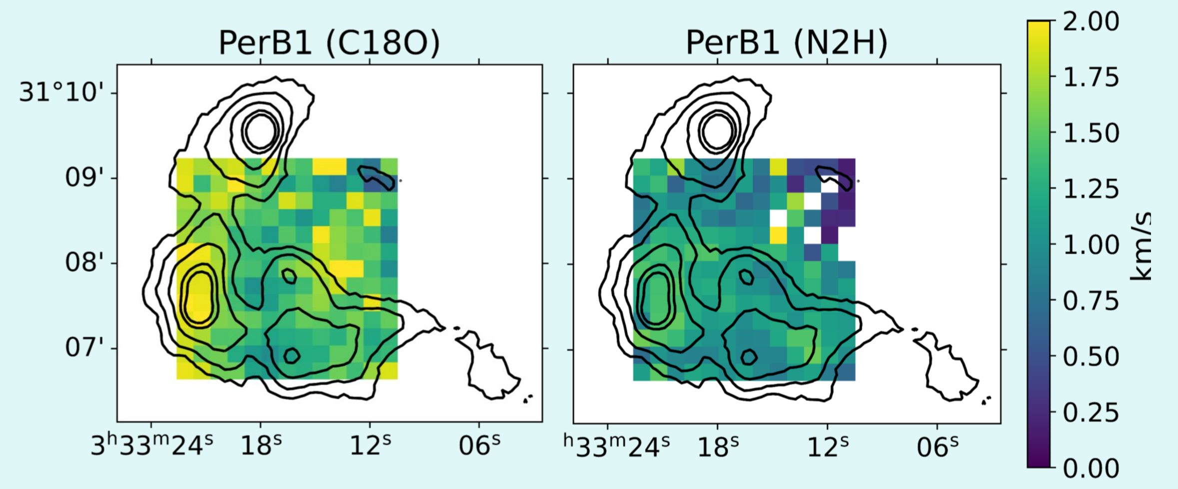


Figure 4. The comparison of FWHM maps calculated from $C^{18}O$ and N_2H^+ spectral lines.

Column and Volume Density

The column density is calculated from the dust continuum emission:

$$N_{H_2} = \frac{S_v^{beam}}{\Omega_A\,\mu_{H_2}\,m_H\,\kappa_v\,B_v(T)}$$

The temperatures are obtained from other research, and the depths are assumed to be the same as the widths of the filaments.

Mass-to-Flux Ratio

The mass-to-flux ratio (Crutcher, 2004): $\lambda \equiv \frac{(M/\Phi)_{obs}}{(M/\Phi)_{crit}} = 7.6\times10^{-21}\frac{N(H_2)}{B}$

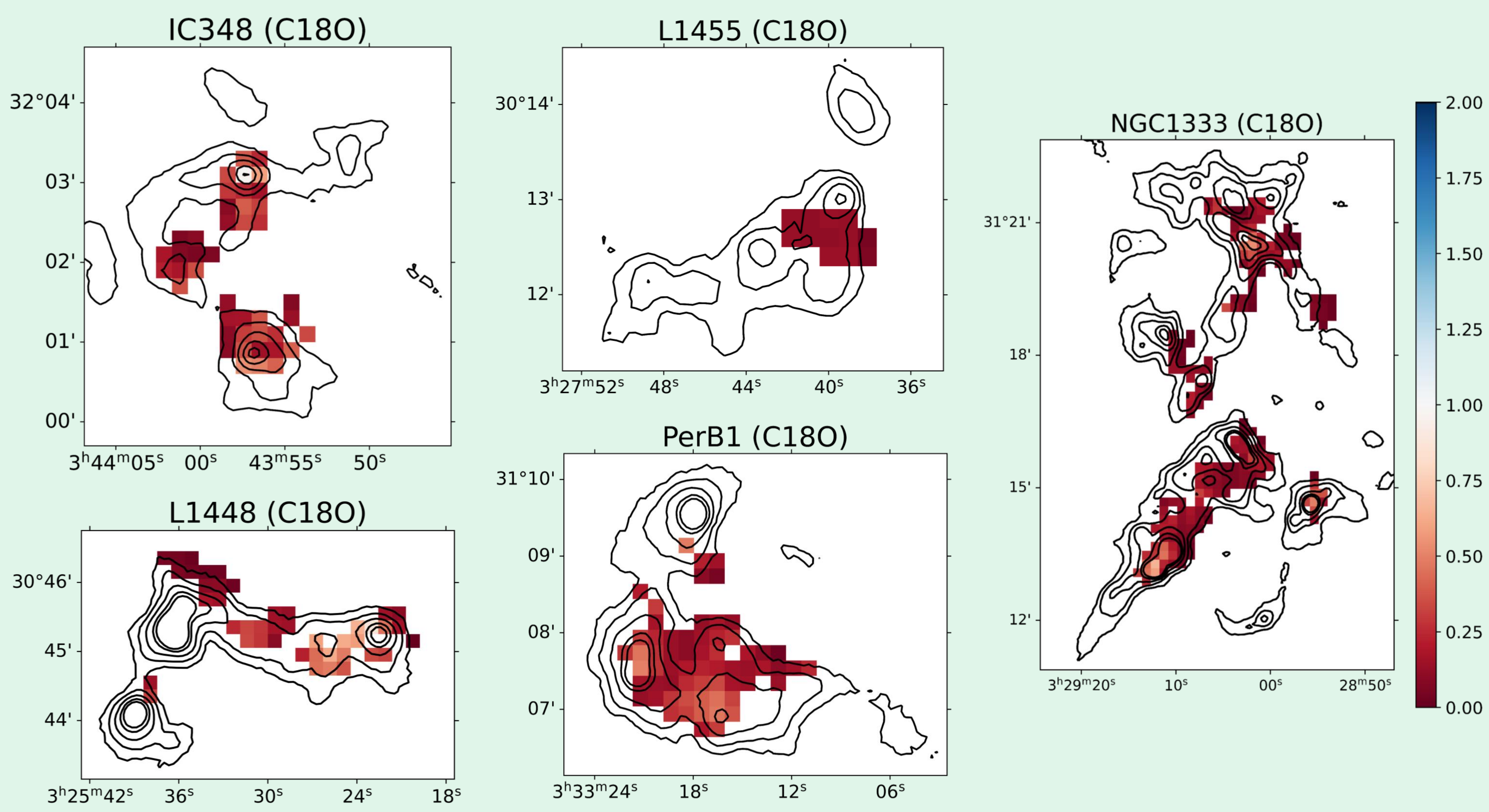


Figure 5. The mass-to-flux ratio of star-forming regions.

B-n relation

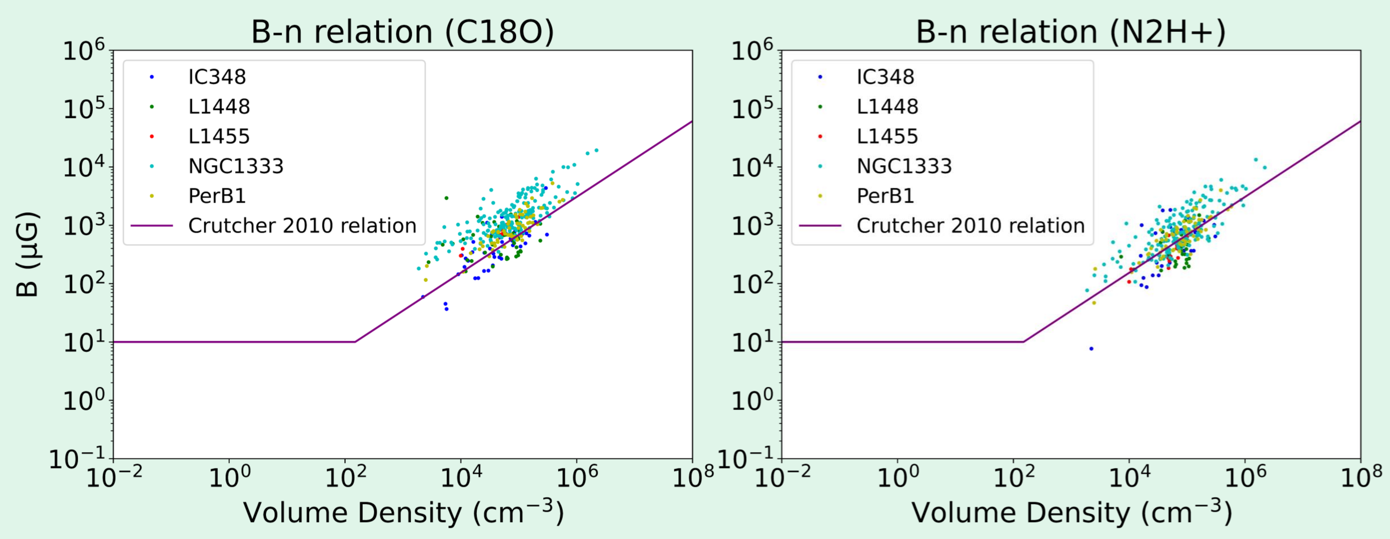


Figure 6. The magnetic field density relation.

Reference

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