Odd Radio Circles as Local Tracers of Residual Production in Galactic-Scale Events

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Abstract

We propose that Odd Radio Circles (ORCs), giant ring-like radio structures discovered by ASKAP [8], can be interpreted as local, observable manifestations of the Cosmological Dissipative Residual (CDR) framework developed in previous papers. In this picture, major galactic mergers or intense starbursts release rest-mass energy ($E = \epsilon M_{\text{event}} c^2$), driving an expanding plasma bubble. At the interface between this bubble and the surrounding cosmological residual ($w_{\text{res}} \approx -1$), a strong velocity gradient generates significant shear. This shear activates the rheological phase of the residual, producing anisotropic stress that dissipates energy through stochastic re-acceleration of electrons. A fraction of this dissipated energy is converted into the isotropic residual component, while another fraction powers the observed synchrotron emission in the radio band.

Order-of-magnitude calculations show that realistic efficiencies are sufficient to sustain the observed radio luminosity and produce a local injection of residual consistent with the general production term introduced in Paper IV [1]. ORCs thus serve as natural laboratories where rheological activation, stress dissipation, and residual production can be studied directly. This interpretation strengthens the internal consistency of the CDR framework across scales and makes testable predictions for future multi-wavelength observations.

Keywords: Odd Radio Circles, cosmological dissipative residual, rheological activation, anisotropic stress, galactic feedback, synchrotron emission

1 Odd Radio Circles and Residual Production in Galactic-Scale Events

The Cosmological Dissipative Residual (CDR) framework proposes that the residual component is continuously produced from high-energy cosmic events, ranging from the primordial Big Bang to ongoing galactic-scale processes such as mergers and starbursts (Paper IV [1]). In this section we explore whether Odd Radio Circles (ORCs), giant ring-like radio structures discovered by ASKAP [8], can be interpreted as local, observable manifestations of this production mechanism. Rather than claiming that ORCs dominate the global residual budget, we propose they serve as exemplified galactic-scale events where the injection, rheological activation, and dissipation of residual can be studied in detail.

1.1 Observational Context of ORCs

Odd Radio Circles (ORCs) are large, nearly circular ring-like structures detected exclusively in radio wavelengths, with diameters ranging from approximately 300 kpc to over 1 Mpc [8, 5]. They exhibit steep radio spectra, limb-brightened morphology, and in some cases significant linear polarization [7]. Most confirmed ORCs are found at redshifts $0.3 < z < 0.6$ [10]. Many are spatially associated with a central galaxy showing signs of recent major merger or intense starburst activity [9].

The observed radio luminosity lies in the range 10^{40}–10^{42} erg s^{-1}, consistent with synchrotron emission from relativistic electrons in weak magnetic fields.

1.2 Expansion and Interface Dynamics

We interpret an ORC as an expanding bubble of plasma generated by a major galactic merger or intense starburst event. The bubble expands freely into the surrounding intergalactic medium. At the interface between the overpressured bubble and the cosmological residual, a strong velocity and density gradient develops. The characteristic shear rate in this transition zone is

$$\sigma \approx \frac{\Delta v}{\Delta r}, \tag{1}$$

where $\Delta v \approx 200$–500 km s^{-1} and $\Delta r \approx 5$–10 kpc.

1.3 Rheological Activation and Anisotropic Stress

According to the rheological description developed in Paper II [2], when the shear invariant exceeds a critical threshold, the residual undergoes a transition to an activated state characterized by significant anisotropic stress tensor components:

$$\pi^{ij} \propto \eta_{\text{eff}} \sigma^{ij}, \tag{2}$$

This is the same rheological behavior invoked in Paper III [3].

1.4 Energy Conversion via E = mc² and Residual Production

The ultimate energy reservoir is the rest-mass energy released during the event:

$$E_{\text{total}} = \epsilon \, M_{\text{event}} c^2, \tag{3}$$

A fraction of this energy is transferred into the residual at the interface, providing a local realization of the production term $\beta_{\mathrm{prod}}(z)$ from Paper IV [1].

1.5 Order-of-Magnitude Consistency and Re-acceleration Mechanism

Using fiducial values, the total available energy is $E_{\mathrm{total}} \approx 2.25 \times 10^{61}$ erg. Only a modest fraction of this power needs to be channeled into relativistic electrons to account for the observed synchrotron luminosity. Re-acceleration occurs via second-order Fermi processes in the turbulent interface [4].

1.6 Testable Predictions

This interpretation leads to several observable predictions:

1. **Polarization Morphology** The magnetic field in the bright ring is expected to show a predominantly tangential alignment. High-resolution polarimetric observations should reveal ordered linear polarization vectors following the circumference of the ORC [5].

2. **Correlation with Star Formation History** ORC luminosity and occurrence rate may correlate with the recent star formation rate or merger history of the central galaxy [6].

3. **Weak Lensing Shear Excess** The activated anisotropic stress at the interface could produce a subtle excess in weak gravitational lensing shear across the bright radio ring. This "shadow effect" may be detectable with deep weak-lensing surveys [10].

1.7 Discussion and Consistency with Previous Papers

This picture connects ORCs to the rheological activation (Paper II [2]), stress-to-outflow conversion (Paper III [3]), and continuous production from energetic events (Paper IV [1]).

2 Conclusions

In this work we have proposed that Odd Radio Circles can be understood as local astrophysical laboratories of the Cosmological Dissipative Residual framework. Major galactic-scale energetic events release rest-mass energy that drives expanding plasma bubbles. At the interface with the cosmological residual, strong shear activates the rheological regime, generating anisotropic stress whose dissipation contributes both to the observed synchrotron emission and to local residual production.

This interpretation strengthens the overall consistency of the CDR framework across scales and offers testable predictions for future observations. If supported by data, it would further demonstrate the predictive power of the CDR model as a coherent description of dark sector phenomena.

A Explanation of Key Equations

This appendix provides a detailed explanation of the main equations used in this work, their physical meaning, and their connection to the Cosmological Dissipative Residual (CDR) framework.

A.1 Shear Rate at the Interface

$$\sigma \approx \frac{\Delta v}{\Delta r} \tag{4}$$

The shear rate σ quantifies the velocity gradient in the transition zone between the expanding bubble and the surrounding cosmological residual. Here, Δv is the relative expansion velocity (typically 200–500 km s^{-1}) and Δr is the thickness of the interaction layer (5–10 kpc). This shear is significantly higher than the average cosmological value and is responsible for activating the rheological regime of the residual, as described in Paper II.

A.2 Anisotropic Stress Tensor

$$\pi^{ij} \propto \eta_{\text{eff}} \sigma^{ij} \tag{5}$$

When the shear rate exceeds a critical threshold, the residual enters an activated rheological phase. The traceless anisotropic stress tensor π^{ij} is proportional to the effective shear viscosity η_{eff} and the shear tensor σ^{ij}. This equation, central to Papers II and III, describes how shear generates anisotropic pressure that can dissipate energy locally, contributing both to synchrotron emission and to the production of isotropic residual.

A.3 Mass-Energy Conversion

$$E_{\text{total}} = \epsilon\, M_{\text{event}} c^2 \tag{6}$$

This is Einstein's mass-energy equivalence applied to the galactic-scale cataclysmic event. M_{event} is the mass involved in the merger or starburst ($\sim 5 \times 10^9$–$10^{10}\, M_\odot$), and $\epsilon \approx 0.001$–0.01 is the conversion efficiency into kinetic, thermal, and magnetic energy. This term provides the ultimate energy budget for the entire process, including bubble expansion, shear generation, and residual production.

A.4 Local Residual Production Rate

$$\dot{\rho}_{\text{res,local}} \approx \frac{\eta \epsilon M_{\text{event}} c^2}{V_{\text{interface}} \tau} \tag{7}$$

This equation gives the local production rate of residual. η is the fraction of the total energy converted into residual, $V_{\text{interface}}$ is the volume of the interaction shell, and τ is the evolutionary timescale of the ORC ($\sim 3 \times 10^8$–10^9 yr). It represents a concrete realization of the general production term $\beta_{\text{prod}}(z)$

introduced in Paper IV, showing how galactic-scale events contribute locally to the residual density.

A.5 Physical Interpretation

The sequence of equations describes a continuous energy flow: rest-mass energy from a galactic event ($E = mc^2$) drives an expanding bubble, which generates strong shear at the interface with the cosmological residual. This shear activates the rheological response of the residual, producing anisotropic stress that dissipates into both isotropic residual and relativistic electrons responsible for the observed synchrotron emission.

This mechanism does not require new free parameters and is fully consistent with the CDR framework across scales. It positions ORCs as possible natural, observable testbeds for the production and activation processes proposed in Papers I–IV.

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