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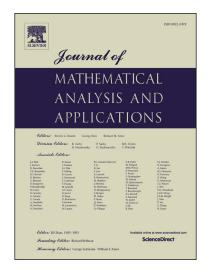
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### **ACCEPTED MANUSCRIPT**

# Li–Yau type and Souplet–Zhang type gradient estimates of a parabolic equation for the V-Laplacian

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#### Abstract

In this paper, we study a parabolic equation concerning V-Laplacian on complete Riemannian manifold M:

$$(\Delta_V - q(x,t) - \partial_t)u(x,t) = A(u(x,t))$$

on  $M \times [0, T]$ , where V is a vector field on M and  $\Delta_V \star := \Delta \star + \langle V, \nabla \star \rangle$ . We give a gradient estimate of Li-Yau type for positive solutions of this equation. As corollary, we obtain a new gradient estimate in the case that  $A(u) = au \log u$ . We also prove a Souplet–Zhang type gradient estimate for positive bounded solutions of this equation. As corollary, we obtain a gradient estimate for positive bounded solution of

$$(\Delta_V - q(x,t) - \partial_t)u(x,t) = a(u(x,t))^{\beta}, \quad \beta > 1.$$

Keywords: Gradient estimate, Parabolic equation, Positive solution. 2010~MSC: 35B45, 35K55.

#### 1. Introduction

In the seminal paper [14], P. Li and S.T. Yau studied following heat equation

$$(\Delta - q(x,t) - \partial_t)u(x,t) = 0$$

on a complete Riemannian manifold. They derived the gradient estimate for positive solutions of the above equation. Precisely, they proved

**Theorem A.** Let  $M^n$  be a complete manifold with boundary  $\partial M$ . Assume  $p \in M$  and let  $B_{2R}(p)$  be a geodesic ball of radius 2R around p which does not

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