ISSN 0974 - 9373

Vol. 18 No.1 (2014) **Journal of International Academy of Physical Sciences** pp. 59- 66

Propagation of Blast Waves Generated by Intense Flares

S. N. Ojha
Department of Mathematics
S. C. College, Ballia, Uttar Pradesh

Awaneesh Jee Srivastava
Department of Mathematics
SRMGPC, Lucknow. U. P.
Email id- awaneeshcancerian@gmail.com

(Received Dec 25, 2013)

Abstract : In this paper we discussed the propagation of blast waves generated by intense flares in stellar atmosphere. The effects due to pressure of magnetic field, self-gravitation and radiation heat flux are discussed. The numerical solutions for the flow behind the shock have been obtained in presence of self-gravitation, weak and strong magnetic field separately.

Key Words: Blast waves, intense flares, stellar atmosphere and self - gravitation.

Mathematics Subject Classification: 2010-76L05.

1. Introduction

The theory of blast waves and related flows has attracted a renewed interest in connection with astrophysical phenomenon. The blast wave conceivably driven by solar flares are observed to propagate into the interplanetary medium.[Parker[1], Hundhausen[2], Cox[3] , Dryer[4,5] , Maxwell & Dryer[6]]. Supernova remants of intermediate age are basically constituted by a blast flow on an interstellar scale initially driven by the supernova ejecta and interstellar gas there by heated up and compressed.

Taylor[7], Carrus etal.[8] Ragers[9] and Sedov[10] and Chevalier[11], have accumulated an extensive literature on self similar models of phenomena for the propagation of shock waves in gas dynamics and in the formation of stars and supernova explosions. Elliot[12] has discussed the explosion problem in non- gravitating and self- gravitating gaseous models. Ojha[13] extended the problem of Elliot taking into account the effects of magnetic field. The point explosion problem, produced on account of instantaneous release of energy in an inhomogeneous self- gravitating gaseous medium, has been studied by Ojha and Onkar[14]. Summers and Whitworth have discussed qualitative analysis of self- similar solution to the problem of unsteady spherical symmetric motion of self-gravitating gas. Ojha[15] have considered the effect of gravitation and magnetic field both on the propagation of shock waves in a heat conducting medium and concluded that the adiabatic exponent for a heat conducting gas plays an important role on the propagation of shock waves for a self- gravitating model of stellar bodies.

Parkar constructed a blast wave model consisting of strong spherical shock wave driven out by a propelling contact surface moving into a quiet solar wind region and obtained numerical solutions by a similarity method. Here our aim is to extend the problem of the blast wave propagation produced by intense flares in stellar atmosphere including the effects of the presence of magnetic field, self- gravitation and radiation heat flux. In particular, numerical solutions have been obtained for the flow behind the shock taking into account the effects of gravitation and presence of magnetic field separately. The effect of high and low Alfven velocity have been discussed.

2. Basic Equations

The fundamental equations governing the motion of self- gravitating, radiating fluid in spherical symmetry including the effects of presence of magnetic field are[14]

(2.1) $$\frac{\partial \rho}{\partial t}+u\frac{\partial \rho}{\partial r}+\partial\left(\frac{\partial u}{\partial r}+\frac{2u}{r}\right)=0$$

(2.2) $$\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial r}+\frac{1}{\rho}\frac{\partial p}{\partial r}+\frac{h}{\rho}\frac{\partial h}{\partial r}+\frac{Gm}{r^2}=0$$

(2.3) $$\frac{\partial h}{\partial t}+u\frac{\partial h}{\partial r}+h\frac{\partial u}{\partial r}+\frac{hu}{r}=0$$

(2.4) $$\frac{\partial p}{\partial t}+u\frac{\partial p}{\partial r}+\gamma p\left(\frac{\partial u}{\partial r}+\frac{2u}{r}\right)+\frac{1}{\partial r^2}\frac{\partial}{\partial r}\left(qr^2\right)=0$$

(2.5) $$\frac{dq}{dr} = 4\mu^{*} aT^{4}, where \mu^{*} = \mu_0 \rho^{\alpha'} T^{\beta'}$$

(2.6) $$\frac{\partial m}{\partial r} = 4\pi r^2 \rho$$

where $\rho, u, p, h, q, m, r, t, \gamma$ and T are the density, velocity, pressure, magnetic field, radiation, mass contained in sphere of a radius r, time and ratio of specific heats of the gas and temperature respectively. G represents the gravitational constant.

Introduce a similarity variable $\eta = \frac{r}{R(t)}$, and take the solutions of the fundamental equations in the form,

(2.7) $$p = p_0 R^{-2n} f_1(\eta)$$

(2.8) $$\rho = \rho_0 \varphi_1(\eta)$$

(2.9) $$u = R^{-n} \phi_1(\eta)$$

(2.10) $$h = H_0 R^{-n} g_1(\eta)$$

(2.11) $$m = m_0 R^{\frac{-4n}{3}} M_1(\eta)$$

(2.12) $$q = \rho_0 R^{-3n} W_1(\eta)$$

where $f_1, \varphi_1, \phi_1, g_1 M_1$ and W_1 are the functions of η only.

In view of equations (2.7-2.12), the fundamental equations (2.1) – (2.6) takes the forms

(2.13) $$(\phi_1 - A\eta)\varphi' + \varphi_1(\phi_1' + \frac{2\phi}{\eta}) = 0$$

(2.14) $$-A(n\varphi_1 + \varphi_1'\eta) + (\varphi_1\varphi_1' + \frac{p_0}{\rho_0}\frac{f_1'}{\phi_1}) + \frac{H_0^2 g_1' g_1}{\rho_0 \phi_1} + \frac{Gm_0}{\eta^2} M_1 R^{\frac{2n}{3}-1} = 0$$

(2.15) $$-A(\eta g_1^{'} + ng_1) + (\phi_1 g_1^{'} + g_1\phi_1^{'}) + \frac{g_1\phi_1}{\eta} = 0$$

(2.16) $$-A(2nf_1 + \eta f_1^{'}) + \gamma f_1(\frac{2\phi_1}{\eta} + \phi_1^{'}) + (W_1^{'} + \frac{2W_1}{\eta}) + \phi_1 f_1^{'} = 0$$

(2.17) $$W_1^{'} = \frac{4\mu_0 a}{\Gamma^{(\beta+4)^{'}}} \frac{p_0^{(\beta+4)^{'}} \rho_0^{(\alpha^{'}-\beta-5)^{'}}}{R^{(2n\beta^{'}+5n-1)}} f_1^{(\beta^{'}+4)} \varphi_1^{(\alpha^{'}-\beta^{'}-5)}$$

(2.18) $$M_1^{'} = \frac{4\pi\rho_0}{m_0}\varphi_1\eta^2 R^{\frac{9+4n}{3}}$$

(2.19) $$Gm0 = \frac{-6}{R^{2n-1}3\varphi_1^2\eta^2}(\frac{a_0^2 f_1}{\gamma} + \frac{V_H^2 g_1^2}{2}), \text{ where}$$

(2.20) $$R^n \frac{dR}{dt} = A = \text{constant.}$$

It is clear that the solutions are compatible with the equations if n = 3/2, $\alpha^{'} - \beta^{'} - 5 = 0$ and $2n\beta^{'} + 5n - 1 = 0$.

The equations (2.13-2.19) can be reduced to a non-dimensional form by substituting

(2.21) $$f_1(\eta) = \frac{A^2}{a_0^2} f(\eta)$$

(2.22) $$\varphi_1(\eta) = \varphi(\eta)$$

(2.23) $$\phi_1(\eta) = A\phi(\eta)$$

(2.24) $$W_1(\eta) = \frac{A^3}{a_0^2} W(\eta)$$

(2.25) $$M_1(\eta) = A^2 M(\eta)$$

(2.26) $$g_1(\eta) = \frac{A}{V_H} g(\eta)$$

where $a_0^2 = \frac{\gamma p_0}{\rho_0}, a_0 =$ velocity of sound in front of the blast wave and

(2.27) $$V_H^2 = \frac{H_0^2}{\rho_0}, V_H = \text{Alfven velocity.}$$

Putting (2.21-2.26) in equations (2.13) to (2.19) we have,

(2.28) $$\varphi'(\phi - \eta) + \varphi(\phi' + \frac{2\phi}{\eta}) = 0$$

(2.29) $$\phi'(\phi - \eta) - \frac{3}{2}\phi + \frac{1}{\gamma}\frac{f'}{\varphi} + \frac{gg'}{\varphi} + \frac{GM}{\eta^2} = 0$$

(2.30) $$g'(\phi - \eta) + (\phi - \frac{3}{2})g + \frac{g\phi}{\eta} = 0$$

(2.31) $$3f + \eta f' + \frac{\gamma f \varphi'}{\varphi}(\phi - \eta) - \phi f' - (W' + \frac{2W}{\eta}) = 0$$

(2.32) $$W' = N\varphi f^{\frac{11}{6}}, N = \frac{A^{\frac{2}{3}}}{a_0^{\frac{2}{3}}} \frac{4a\mu_0 p_0^{\frac{11}{6}}}{\Gamma^{\frac{11}{6}}}$$

(2.34) $$M' = \mu\varphi\eta^2, \mu = \frac{3}{V^2}$$

(2.34) $$Gm0 = \frac{-6}{\mu\varphi^2\eta^2}(\frac{f}{\gamma} + \frac{g^2}{2}) \quad .$$

3. Boundary Conditions

The shock conditions across a shock wave in presence of magnetic field and in absence of radiation heat flux are:

(3.1) $$\rho(U-u)=\rho_0 U$$

(3.2) $$H(U-u)=H_0 U$$

(3.3) $$p+\frac{1}{2}H^2+\rho(U-u)^2 = p_0+\frac{1}{2}H_0^2+\rho_0 U^2$$

(3.4) $$\frac{1}{2}(U-u)^2+\frac{\gamma p}{\rho(\gamma-1)}+\frac{H^2}{\rho}=\frac{1}{2}U^2+\frac{\gamma p_0}{\rho_0(\gamma-1)}+\frac{H_0^2}{\rho_0}$$

where U is shock velocity and quantities with zero suffix and without suffix are the values of the quantities just ahead and just behind the shock wave.

Writing

(3.5) $$\frac{\rho}{\rho_0}=\frac{1}{\beta}$$

(3.6) $$u=(1-\beta)U$$

(3.7) $$H=\frac{H_0}{\beta}$$

(3.8) $$p=p_0+\rho_0(1-\beta)U^2+\frac{1}{2}\frac{H_0^2}{\beta^2}(\beta^2-1)$$

where

(3.9) $$U^2=2a_0^2\{\frac{1}{\beta(\gamma+1)-(\gamma-1)}\}+V_H^2\{\frac{(1+\beta)((\gamma+1)\beta^2-2)}{\beta^3((\gamma+1)\beta-(\gamma-1))}\}$$

For strong shock,

(3.10) $$\frac{\rho}{\rho_0}=(\frac{\gamma+1}{\gamma-1})$$

(3.11) $$\frac{u}{U}=\frac{2}{\gamma+1}$$

(3.12) $$\frac{p}{p_0}=\frac{2\gamma}{\gamma+1}\frac{U^2}{a_0^2}$$

(3.13) $$\frac{H}{H_0}=(\frac{\gamma+1}{\gamma-1})U \, .$$

Using above similarity solutions, we have

(3.14) $$\varphi(1)=\frac{\gamma+1}{\gamma-1}$$

(3.15) $$\phi(1)=\frac{2}{\gamma+1}$$

(3.16) $$f(1)=\frac{2\gamma}{\gamma+1}$$

(3.17) $$g(1)=\frac{V_H}{A}(\frac{\gamma+1}{\gamma-1})$$

Conclusions

Equations (2.28-2.34) with initial conditions (3.14-3.17) can be integrated numerically to study the combined effect of the presence of self gravitation, magnetic field and radiation heat flux. Here our aim is to discuss the effects of magnetic field and gravitation on the flow behind the shock wave separately.

References

1. E. N. Parker; *Interplanetary Dynamical Processes*, Ny Wiley, 1963

2. A. J. Hundhausen*; Coronal Expansion and solar wind*, Berlin Spinger Verlog , 1972.

3. D. P. Cox ;Diffuse matter from Star forming regions to active Galaxies, *Ap. J.,* **178**(1972) 159.

4. M. Dryer; Space Plasma Physics: The study of Solar- system Plasmas, *Space Sci. Rev.,* **15**(1974) 403.

5. M. Dryer; Study of travelling inter Planetary phenomena, *Space Sci. Rev.*, **17** (1975) 277.

6. A. Maxwell and M. Dryer; Measurement on Shock wave generated by solar flare, *Nature,* **300** (1982) 237-239.

7. G. I. Taylor; Theory and applications of Viscous fluids flows, *Proc. Roy. Soc. London A*, **201** (1950) 1975.

8. P. A. Carrus.et al; Self- Similar MHD Shock waves for a rotating atmosphere under the force of Gravitation, *Astrophys. J.* **113** (1951) 496.

9. M. H. Rogers; An introduction to theory and models of CMES, Shocks,and energetic particles, *Astrophys. J.,***125** (1957) 478.

10. L. I. Sedov; *Similarity and Dimensional Methods in Mechanics*, Academic Press, New York , 1959

11. R. A. Chevalier;The Evolution of Supernova Remmants spherically symmetric models*, Ap. J.*, **188 (**1974) 501-516.

12. L. A. Elliot;Similarity methods in radiation hydrodynamics, *Proc. Roy. Soc.*, **258A** (1960) 287-301.

13. S. N. Ojha; Foundations of radiation hydrodynamics, *Acta Physica Hungarica*, **31**(4) (1972) 375.

14. S. N. Ojha. and Onkar Nath; Magneto gas dynamic cylindrical Shock wave model in an optically thin atmosphere, *Astrophys Space Sci.*, **135** (1987)175-185.

15. S. N. Ojha ; Propogation of spherical MHD Shock-waves in self –gravitating gas, *Astrophys. Space Sci.,* **168** (1990) 13-21.