LIST OF CALLS SUITED TO THE MAORI TRUMPET.

Officers.
Sergeants.
Fall in.
Men's dinner call.
Sergeants' dinner call.
Fatigue.
Picquet.
Orders.
Sick call.
Salute for guard.
Alarm.
Charge.
Fire, and Cease fire.
Extend, and Close.
General salute.

ART. XXIII.—*On Temporary Stars.*

By MARTIN CHAPMAN.

[*Read before the Wellington Philosophical Society, 6th September,* 1905.]

THE appearance of a so-called temporary star is always an event of great importance to all interested in astronomy and its kindred sciences. The event apparently involves a catastrophe of such colossal magnitude that it almost transcends our powers of imagination fully to realise it. A star which perhaps to our view is so insignificant as to be visible only in a powerful telescope—say, of the tenth or twelfth magnitude, or perhaps not visible at all—suddenly increases in splendour until it shines as a third- or second- or indeed even first-magnitude star. If our sun were to increase in heat- and light-giving activity in a similar proportion there can be no doubt that all planets would be rendered red- or white-hot, if they were not dissipated into vapour.

After this enormous development of light and heat the new star in a few days or weeks shows manifest signs of waning. This waning proceeds so rapidly that at the end of a few months the star is no longer visible to the naked eye, and can only be perceived through powerful telescopes. Its final appearance is also remarkable: it presents the appearance of a planetary nebula—that is, it appears to be a nebula of no great intensity of light, having a minute disc like a planet; but the fact that it has any visible disc is a proof of its colossal dimensions. No "Nova" has, so far as I am aware, yet shown an appreciable parallax: it follows that to have any disc visible to us its diameter must exceed that of the earth's orbit.

That such a vastly colossal globe of glowing matter should part with its heat in a few months is at first sight exceedingly surprising, and has led to the suggestion being made that the actual quantity of matter heated must be very small. How otherwise, it may be asked, can it be? A body like the sun is unaltered, so far as we can tell, after thousands or millions of years of cooling. How long, then, ought a body take to cool which can shine as a star of the first magnitude though so far distant as to have no measurable parallax ?

I have to consider this question, and show that the rapid cooling of a "Nova" is a necessary consequence of the added heat, from whatever cause due, and will take place though the body be equal in mass to, or greater than, the sun.

Consider a star of dimensions and mass comparable with those of the sun, and assume, as is generally supposed, that the whole is in a state which may be termed gaseous—that is, the temperature is so high that every part responds to increase and diminution of pressure in the same manner as a gas does. It is not necessary to assume that the ratio of expansion to increment of heat follows the law of gases. I make the assumption of the gaseous nature of a "Nova" because, first, there can be but little doubt that a "Nova" at least is in this state, and, secondly, because my arguments have no application to a solid or non-gaseous star. Assuming, then, the star to behave as a gas, we may also assume that at any moment it has such dimensions that an equilibrium exists between the tendency to expand and that to shrink. Each particle will at that moment be solicited by two forces—one the attraction of the mass, which tends to draw the particle towards the centre, the other the expansive force due to the high temperature of the gaseous mass. These opposing forces must exactly neutralise each other to produce an equilibrium. If there is any disturbance of that equilibrium the particle will move towards or away from the centre according as the gravitation or the expansion due to heat is in excess. In the case of the sun the equilibrium is being disturbed from moment to moment by the continuous radiation away of heat.

Consider the effect on a particle: Heat is radiated away, the amount of heat available to balance gravitation is diminished; but by the hypothesis the heat before radiation was exactly sufficient to balance gravitation; there is therefore after radiation an unbalanced tendency towards the centre, and the particle must take up a new position nearer the centre. This must also be true of every other particle of the sun's mass: in other words, the whole mass must shrink through loss of heat radiated away. So far this accords with our experience: a gaseous body—*e.g.*, steam—contracts as it parts with its heat.

Now, at first impression it might be supposed that, heat having been parted with, the sun's temperature would be lowered. It would be so if the volume remained constant, but this is not so; as shown above, the volume diminishes, and the very fact that the volume diminishes is in itself a cause of the generation of heat. Each particle in moving to the centre obviously falls; in falling it gives out energy; that energy appears as heat.

To change the mode of statement: Each particle approaching the centre constitutes a compression of the whole mass, but the temperature of a gas rises when it is compressed: the temperature of the sun therefore rises. The extent to which it rises is governed by the circumstance that an equilibrium is again sought. But our particle, having fallen, is now nearer than it was to the centre; its gravitation is therefore increased; its tendency to continue to fall requires now a greater force to balance it: in other words, to preserve equilibrium the temperature must be higher than before. The additional temperature is derived, as pointed out, from the compression of the mass. Hence we have what may appear to some a paradoxical result—*i.e.*, that by abstracting heat from the sun (by radiation) the temperature is caused to rise and not to fall—contrary to our experience of cooling bodies. In reality there is no paradox. Part of the heat is due to the contraction.

There are two kinds of energy in the sun, one heat, the other energy of position or potential. If we take away some of the former we, so to speak, call for contribution from the latter, and that contribution is on a scale a little more liberal than necessary to merely compensate what is taken away. The abstraction of heat causes shrinkage, and the shrinkage causes the development of more heat than that abstracted. This is capable of exact calculation, it being known that a shrinkage of about one-eleventh of a mile will account for the radiation of the sun for a year, and (if the sun is gaseous throughout) still leave the sun a trace hotter at the end of the year than it was at the beginning.

The apparent (not real) paradox is exactly analogous to that arising in the case of a secondary body moving about its primary. Supposing a secondary were moving in a resisting medium, which at first sight might be supposed to diminish its velocity, the real observable effect would be that its velocity would be increased through its fall towards the primary. The evidence of a resisting medium, supposed to be furnished by Encke's Comet, is not that its velocity diminishes, but that it increases.

Now, I took the case of heat being abstracted because it is what is going on in the case of the sun, but the whole process above indicated is reversible.

Supposing, again, the star in momentary equilibrium kept so, as before, by gravitation tending to draw each particle to the centre, and the expansive force created by heat balancing gravitation. Now let heat be added: in the first case the subtraction of heat by radiation left gravity partly unbalanced; now the addition of heat leaves the expansive power partly unbalanced. Each particle must therefore move outwards, but in doing so it moves against gravitation work being done and heat absorbed ("rendered latent" was the old expression); but, as a compressed gas heats by the transformation of work into heat, so an expanding gas cools by the transformation of heat into work (both processes being made use of in our steam-engines, freezing-engines, &c.). The added heat then does work against gravity, and is all absorbed in doing so.

Now, if this were all, we should have simply expanded our sun at the original temperature. But when expanded to the extent referable to the added heat each particle is further from the centre than it was before heat was added; gravity is therefore diminished; and since, by the hypothesis, the amount of heat was previously exactly sufficient to balance gravity, there is now more than enough to do so, so that there is a residue of expansive power still left: more heat than that added will therefore be used up in expanding the body. This must be at the expense of the heat already possessed by the sun: in other words, the temperature will be lowered. This is the same apparent paradox, in an inverted form, that we had before: by putting heat into a gaseous star we lower its temperature.

We may put the results alongside each other thus:—

(1.) The body parts with heat by radiation: it *shrinks* in consequence, and the *temperature rises.* We may add, the potential falls to the exact extent of the heat radiated away, plus the added temperature.

(2.) The body has heat supplied to it: it *expands* in consequence, and the *temperature falls.* We may add, as before, the potential rises to the exact extent of the heat added, plus the latent heat of expansion.

Now, let us apply these considerations to a "Nova." Some cause which we can only conjecture occasions an enormous amount of heat to be added to a body. The only probable cause we can think of is a collision of some kind—it may be of two large bodies, or two meteor-streams, &c. If the body was already gaseous the above reasoning would apply at once. If it were not gaseous the added heat caused by the collision (in the case of a "Nova") is sufficient to make it so, and the reasoning will apply as soon as it is so. If the heat were due to collision, as is probable, the process of heating would be exceedingly rapid. If the colliding bodies were both gaseous the generation of the whole heat of collision would take a few hours only; but as the whole of that heat could not be converted in the same time into motion of expansion, because of the inertia of the mass to be moved, the temperature would rise enormously beyond what it would ultimately be on the establishment of an equilibrium. Hence it is quite in accordance with what we ought to expect if, on a collision between two bodies, the temperatuie should rise in a few hours or days so greatly that the joint mass would shine as a bright star. But this state of things could not be permanent, as the gravity of the mass would be insufficient to counteract the expansive force created by the enormous accession of heat. The mass would therefore expand, the rate of expansion being slow at first, increasing to a maximum, and finally dying out. The body would then be enormously diffused, but at a moderate temperature. The greater the velocity of the impact the lower would be the final temperature. A velocity can be assigned at which the body would be dissipated in infinite space, and the temperature exactly zero; but this velocity could not be acquired by the mutual attraction of the colliding bodies. With any velocity which we can admit as probable the final state of the mass would be a globe vast in proportion to the sum of the original volumes of the colliding bodies, with a moderate temperature. Such a body would present the appearance of a planetary nebula.

Before this final stage was reached there would be fluctuations. The outward velocity communicated to the gaseous atoms would cause the first expansion to go beyond equilibrium; indeed, the outward velocity at the position of equilibrium would be a maximum. Hence the body would be overexpanded and overcooled. It would then condense again, with a rise in temperature again overcompensated. This might, indeed would, be repeated many times, finally dying out. These pulsations appear to have been observed.

The consideration applied here to two colliding globes would equally apply to colliding flights of meteors, but the effects might not be so marked—the rise in temperature would be more gradual. They would also apply to the case of a sphere plunging into a vast hydrogen region, such as the spectroscope reveals to us.

ART. XXIV.—*Notes on a Meteoric Appearance.*

By MARTIN CHAPMAN.

[*Read before the Wellington Philosophical Society, 2nd August,* 1905.]

I THINK it as well to put on record a remarkable phenomenon which was observed by myself, with many others, on the evening of the 9th June. A party of us left Otaki by the evening