

**POTENTIAL MECHANISMS FOR THE FORMATION OF LAVA FLOW AURAS ON IO.** S. M. Baloga and L. S. Glaze, Proxemy Research (20528 Farcroft Lane, Laytonsville, MD 20882, steve@proxemy.com).

**Introduction:** Two kinds of interesting volcanic features on Io are the surface deposits from active plumes and the bright conforming borders of lobate lava flows. Often the plume deposits take the form of a bright annulus, as found at Prometheus. Bright features beside lava flows, referred to as *auras* [1, 2, 3], are found at numerous paterae, including Ra, Mbali, and Talos, and on plains such as Nemea Planum. A well-expressed aura is shown in Figures 1 and 2.

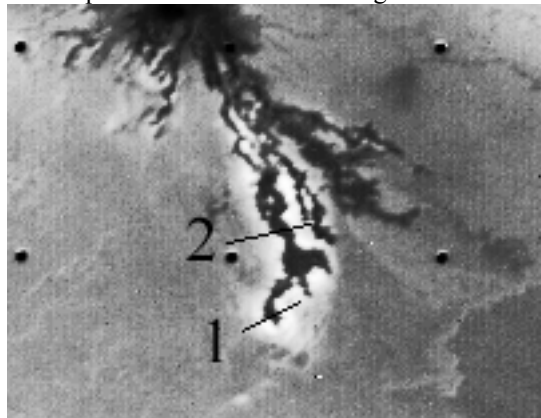


FIGURE 1. Voyager subspace (clear filter, #1639036) of Talos Patera lava flows with bright, collateral auras.

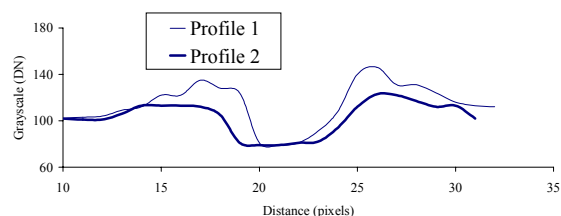


FIGURE 2. Typical transects showing how the aura brightness decays to background.

The auras were originally thought to be produced by regolith outgassing, with  $\text{SO}_2$  the most likely of a number of plausible compounds ranging from  $\text{H}_2\text{S}$  to  $\text{S}_8$ . Heat from a fresh lava flow liberated pre-existing volatiles from the flowbed at the margin of the flow. Subsequent transport above the surface to the final location in the aura deposit was described [e.g., 1] by an early form of the “stochastic-ballistic” theory discussed below. The original  $\text{SO}_2$  inference assumed the flows were composed of elemental sulfur and naive models of flow emplacement were used. Here we use an updated version of this model to explore the regolith outgassing hypothesis and two alternatives.

**Modeling Approach:** Glaze and Baloga [4] have refined the stochastic-ballistic theory for plumes on Io and applied it to the bright annular deposit at Prome-

theus. The model divides a plume into two spatial regions. The stochastic region is considered as a hemisphere near the vent with a radius that is small compared to the overall dimensions of the plume. Within this region, the random effects associated with collisions of particles, thermalization, and irregularities in vent conditions, dominate the dynamics. The theory assumes that the transport variables (e.g., energy, ejection angles) have probability distributions. Once particles leave the stochastic region, the randomizing influences on particle motions cease and the subsequent trajectories are ballistic. In effect, the probability distributions are quenched when the plume particles exit the stochastic region. Distributions of transport variables in the stochastic region become initial conditions for ballistic emplacement.

Here, we adapt the stochastic-ballistic model for application to auras and perform the same sequence of analyses as was done for the annuli. Specifically, we characterize the dimensions and brightness distributions for the auras, starting with those that are well-expressed and are relatively isolated from other complicating features. Next, these distributions and dimensions are related to constraints on the energy for ballistic transport. Finally, we use these energy distributions to develop compositional constraints.

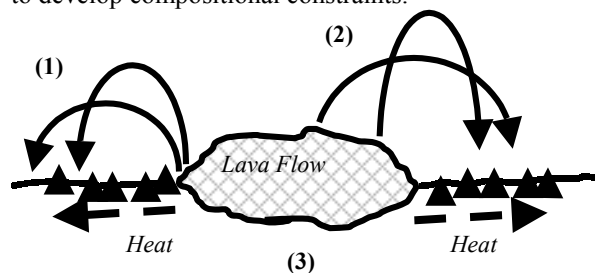


FIGURE 3. Models of aura formation: (1) Liberation of volatiles from the regolith immediately beside the flow (2) Stochastic-ballistic transport of volatiles from the surface of the flow itself (3) Heat propagation through the regolith and local liberation of volatiles.

Three plausible alternative hypotheses for the formation of auras are illustrated in Figure 3. In hypothesis (1), heat from the flow releases volatiles from the regolith beside the flow. The volatiles are then transported above the surface and are deposited to form the aura. In hypothesis (2), the volatiles are derived directly from the surface of the flow itself. Once liberated from the flow, they follow ballistic trajectories to the surface. In hypothesis (3), heat from the fresh flow propagates through the regolith, locally mobilizing the

volatiles throughout the entire lateral extent of the aura. Upon reaching the surface, volatiles condense immediately. No aerial transport is involved in this formation mechanism.

There are valid arguments that can be made for some form of sulfur, silicate, or ultramafic volcanism on Io [cf 5, 6, 7, 8, 9, 10, 11, 12, 13]. The lobate flows with bright auras usually have morphologic characteristics reminiscent of terrestrial basalts. However, we consider lava temperatures associated with all three plausible volcanism styles. Although current thinking favors high temperature volcanism, none of the three styles can be precluded by the present Io data.

**Case Study:** We have obtained the exact analytic surface distribution of particle deposition from a point source with a fixed energy. The areal density of surface particles for angular and energy distributions is readily obtained by integration. One important case for discriminating between competitive aura formation hypotheses is the nature of the areal deposit arising from a line source, e.g., the regolith adjacent to a lava flow. We have obtained this areal density by treating each point beside a flow as a miniature plume with an arbitrary ejection energy and angular distribution. The case we discuss here assumes the energy is fixed. For each source point, a cylindrically symmetric areal distribution is produced. In general, a given pixel in the aura receives a contribution from a source at the margin of the lava flow at any distance permissible by the exit energy. We have obtained the integrated areal density from a 'line source' by numerical integration and binned the results to be comparable to the spacecraft data. Typical cases are shown in Figures 4 and 5. All small scale fluctuations in the Figures are due to the finite binning and graphics smoothing.

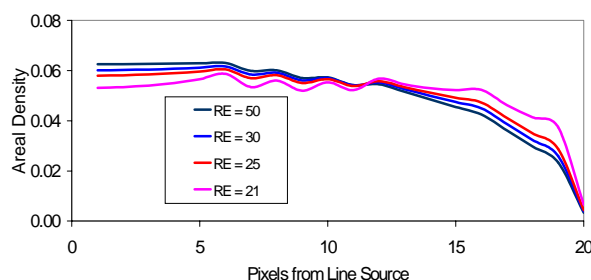


FIGURE 4. Areal density of particles in the aura from a linear source beside the flow margin (upper cone only).

In Figure 4 we have fixed the maximum distance that can be obtained by a ballistic trajectory and varied the total kinetic energy of emanation (RE values). All particles in this case are emitted with angles less than 45 deg from vertical. While the different energies produce different curves, the areal density in no way rep-

resents the type of decay observed in the actual aura brightness, shown in Figure 2. Thus, we preclude the possibility of a mean vertical gas flow out of the regolith beside the flow. It is also unlikely that we could reproduce actual aura distributions by superpositions of sources from the flow itself.

By contrast, Figure 5 shows the integrated areal density of the deposit when ejection angles are greater than 45 deg. As the angle of ejection grows, we begin to see the integrated areal density decay with distance from the margin of the flow. When the emission from each point source is almost isotropic (i.e.,  $r_{min}$  of 0 to 5), we see the decay in areal density that corresponds in character and in scale to actual aura brightness.

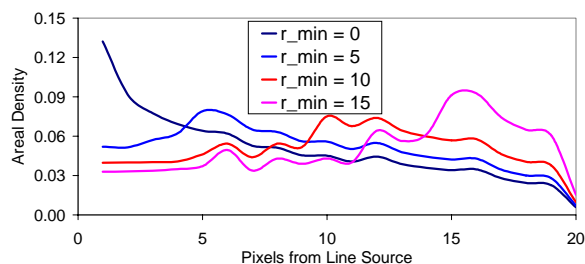


FIGURE 5. Areal density of particles in the aura from a linear source beside the flow margin (lower cone only).

We can thus match theoretical and observed aura brightness profiles and develop subsequent inferences about temperature of the volatile and composition. If aura materials are derived from the regolith, then the characteristic temperature for hypotheses (1) and (3) is expected to be the vaporization temperature of the aura material. If the aura materials are ejected directly from the flow, then the initial temperature for the stochastic-ballistic model would be that of the flow itself.

It is interesting and encouraging that constraints on the process of formation, temperatures and admissible compositions can be obtained by theory/data matching without resorting to much more complex hypotheses and emission distributions.

**References:** [1] Baloga SM (1982) *Proc Am Astr Soc.* [2] Baloga SM et al. (1983) *Proc Plan Geol PI Mtg.* [3] Baloga SM et al. (1983) *Proc LPSC XIV*, 35-36. [4] Glaze LS and Baloga SM (2000) *JGR*, 105, 17,579-17,588. [5] Williams DA, et al., (2000) *JGR*, 105, 1671-1684. [6] McEwen AS et al., (1998) *Science*, 281, 87-90. [7] McEwen AS et al., (1998) *Icarus*, 135, 181-219. [8] Keszthelyi L and Mc Ewen A, (1997) *GRL*, 24, 2463-2466. [9] Hapke B (1989) *Icarus*, 79, 56-74. [10] Carr MH (1986) *JGR*, 91, 3521-3532. [11] Pieri DC et al., (1984) *Icarus*, 60, 685-700. [12] McEwen AS and Soderblom LA (1983) *Icarus*, 55, 191-217. [13] Keiffer SW (1982) *Satellites of Jupiter*, ed., D Morrison, 647-723.