## Title
IR Radiation Characteristics of Rocket Exhaust Plumes Under Varying Motor Operating Conditions



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# IR Radiation Characteristics of Rocket Exhaust Plumes Under Varying Motor Operating Conditions

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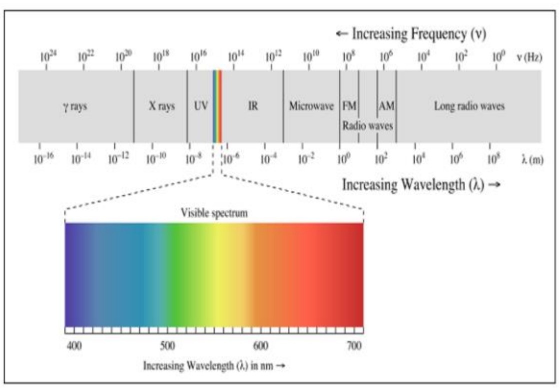
**Abstract** Rocket plumes are very interesting in many ways due to its distinguishable properties. Each rocket/missile has an IR signature from the exhaust plume, which can tell us a lot about the type of vehicle, motor stage, condition and much more. There are three main operating conditions: afterburning, chamber pressure, and minor changes in the oxidizer propellent. The IR irradiance in different bands of these plumes can tell us almost anything on the vehicle, which is why photonics comes in handy when analyzing plumes.

**Introduction** Rocket exhaust plumes are the main source we use as infrared radiation signatures to see or track flight vehicles. The IR signature contains distinct spectral information based on the bandwidths found. The two main bands are H2O in 2.7 band and CO2 in 4.3 band.




With the technology we have, we can only see bandwiths within a certain peramiter. The researchers of this paper decided to stick between 1.5-5.5 after careful consideration. They wanted to develop a model that predicts the IR spectral Radiation for each stage, which can be easily done with careful consideration. Once we figure out the signature of each stage, you can use that as a comparison later on when observing other rockets.

**Methods** For local spectral intensity of radiation, they used the regions below to calculate their model with a combination of fluid dynamics, which is not as relevant to this class.

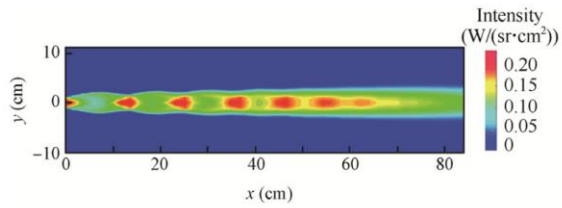
**Table 3** Spectral regions of main species.

| Emission mode | Spectral region (μm) |
|---|---|
| $H_2O$ | 2.70–2.95 (Bending vibration peak of OH and $H_2O$) |
| HCl | 3.24–4.12 (HCl or HCl-$H_2O$) |
| $CO_2$ | 4.20–4.45 (Asymmetric vibration peak of $CO_2$) |
| CO | 4.45–4.84 (Asymmetric vibration peak of CO) |

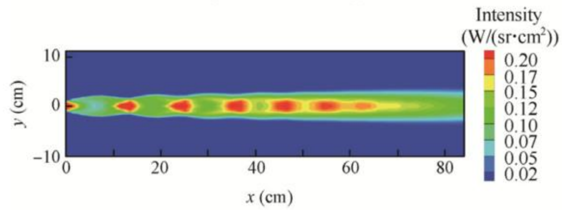
Taking a multi-component gas absorption coefficients and a multi-temperature model into mind they were able to a line by line method. They had to also assume the model was isotropic and isothermal to derive the intensity of each stage.

This was very similar to what we had to do in class. We have delt with many equations where we had to assume that something was isotropic. The only thing is that coming up with a model is way less straight forward than what we did all quarter. There are so many factors that you have to take into account when looking at a plume such as the afterburning phenomenon and other thermos gad dynamic parameters.

**Results and Conclusion** As far as the results they found, they were able to replicate an experimental IR image with their calculated IR values using their model.



(a) Experimental IR Image



(b) Calculated IR contour

They were able to calculate and reeducate almost every other stage of the rocket too. Overall they were able to develop and compute IR radiative signatures and further investigate the characteristics within a limited waveband. They determined that the afterburning effects increased the shape/ size of radiance images. The increase in chamber pressure in the vehicle also leads to an increase in IR irradiance intensity.

They also said that in future work they would study the same thing, but on IR radiance signatures at different flight altitudes, speeds, angles of attack, and observation angles.  This is actually what I did this past summer at my internship at Lockheed martin. These characteristics are very important in tracking vehicles, but when a vehicle launches, our observation will not be head on like they did in their calculations. That is why this model is just the basis of this idea. We need to add layers as we expand the research, which has come a long way since this article from 2016. Although it seems pretty math based, its all based on the principals of photonics starting with the bands we can track.

**Acknowledgement** This review was all based on the article from the title and the three authors listed below

NIU, Qinglin, et al. “IR Radiation Characteristics of Rocket Exhaust Plumes under Varying Motor Operating Conditions.” *Chinese Journal of Aeronautics*, Elsevier, 26 Apr. 2017, https://www.sciencedirect.com/science/article/pii/S1000936117300912.