

# 1 Introduction

## 2 Model

We follow the analytic model of a photoevaporated wind described in Henney & Arthur (1998).

The simplest assumption is that there is a static spherical distribution of gas about the central lowmass star. This gas is being evaporated and ionizing by the radiation coming from  $\theta_1 C$

- Radiacion ionizante que incide de manera paralela al proplyd.
- Se asume una geometria cilindrica con simetría en la coordenada  $\Phi$
- Frontera de ionizacion semiesferica
- El gas fotoionizado fluye de manera radial de la frontera de ionizacion

El flujo no es isotermico Las desexcitaciones colisionaes no son despreciables

### 2.1 Geometry

Si tomamos un marco de referencia cuyo cero se encuentre en el centro del proplyd, podemos definir una coordenada espacial adimensional  $R = r/r_0$  donde  $r_0$  es la distancia medida observacionalmente del centro del proplyd a la frontera de ionizacion

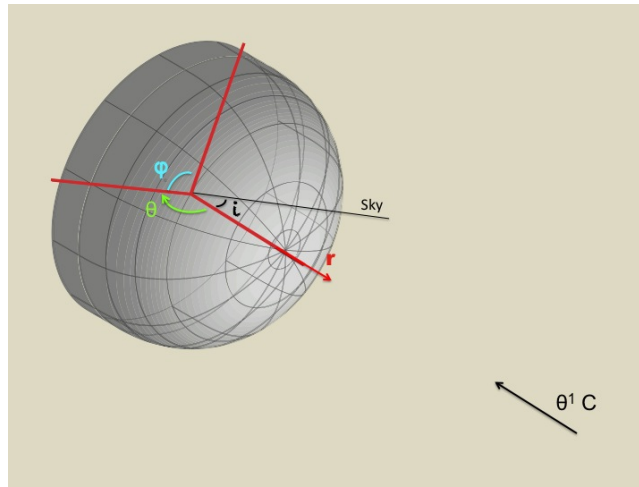


Figure 1: A sketched geometry of the model.

## 2.2 Radial Density Structure

As we mentioned above one way to develop models that take into account both, the radiative transfer and the hydrodynamics of the gas, is to introduce an approximate hydrodynamics in the radiative models that are available and such are stable. This is our case and the way to introduce the hydrodynamics of the gas is using the electron density structure that is a result of the hydrodynamic theoretical models.

We divide the proplyd flow into two zones:

- $r > r_0$ : An outer, fully ionized flow.
- $r < r_0$ : An inner, partially ionized flow.

This is equivalent to say that the behavior of the physical conditions are different in both zones. We suppose that the flow in the partially ionized zone, that corresponds to the thin ionization front, is a subsonic flow. This is accelerated to be a supersonic flow in the outer fully ionized zone. The boundary between them is exactly the sonic point. The conditions there, and in every point of the proplyd, are fixed by continuity, it means that the electron density change as the gas-phase velocity change and viceversa.

$$n_e(X) = \begin{cases} f_1(X) & 1 \geq X \geq 0.98 \\ f_2(X) & 0.02 \geq X \geq 0.98 \end{cases} \quad (1)$$

### 2.2.1 The outer zone

In the outer zone we assume an isothermal, supersonic, completely ionized flow. From mass conservation, in spherical geometry and in the steady state, radial velocity of the ionized gas,  $v(r)$ , satisfies the equation

$$\rho v r^2 = \text{cte} \quad (2)$$

### 2.2.2 The boundary

Because the gas velocity is the property that determines the behavior of other physical properties of the proplyd, the logical boundary between the regions is exactly the sonic point.

This point is also where the criterion of Stromgren for a density bounded region is met. That is, where the photoionization balance is broken and the recombination starts to overcome the photoionization.

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### 2.2.3 The inner zone

Partially ionized region: Density is function of sound speed

La ley de densidad usada para el gas completamente ionizado como función de la velocidad es

$$R = U^{(-1/2)} \exp\left(\frac{1}{4}(U^2 - 1)\right) \quad (3)$$

donde  $U(R) = v/c_0$  con  $v(R)$  la velocidad del gas y  $c_0(R)$  la velocidad del sonido. Y dentro de la frontera de ionización:

$$\rho(c_m) \quad (4)$$

En cada punto la ecuacion de continuidad, permite calcular la densidad:

$$\rho(R)v(R)R^2 = \rho(R_{\max})v(R_{\max})R_{\max}^2 \quad (5)$$

### 3 Results and Predictions

#### 3.1 Physical properties

- Electron Density: It has an almost constant increase reaching the maximum value in the i-front (after the sonic point) where the H is partially ionized. In this zone, the electron density reach the critical electron density for some ions, making the collisional deexcitation a process that need to take into account.

This is not important in the outer parts of the flow since they are highly ionized, which means that [O III] is the dominant coolant. The critical density of this ion is about  $1e6 \text{ cm}^{-3}$ , which is reached just near of the sonic point, that is, where the [O III] emission is less than the 10% of the total [O III] emission. (See

- Temperature: The electron temperature is almost constant in the outer zone. As we approuche to the He recombination front the Te increase reaching the maximum value just before the i-front, where the He is neutral and the H still fully ionized.

It is due for two reasons: The first one is that as the radiation field goes into the gas-phase of the proplyd, the less energy photons are absorbed. This cause a hardening of the radiation field increasing the mean electron kinetic energy. That is, increasing the photoelectric heating per recombination. The second one is the electron density increase. It causes collisional deexcitation of the main cooling lines.

#### 3.2 Ionization structure

#### 3.3 Emissivities

All the high ionization lines are all wholly outside the sonic point.

[Ne II], Ha, [N II] and [O II] have almost the 90% of their emission in the super-sonic zone and the 10% in the sub-sonic zone.

[S II] is about 70% outside the sonic point and 30% inside.

[O I] is about 20% outside and 80% inside the sonic point.

So if we take into account the full emission of the proplyd, and the sub-sonic zone is not well modelated, the effect of this should be not very important since it is only going to affect two lines. Nevertheless, if we want to compare the model predictions with observations that takes only a little aperture of the proplyd and it is near of the center (near the i-front), the sub-sonic zone will be very important.

There are a clear separation of 3 km/s (about 15%) between the median velocity of the [O III] 5007 and 4363 lines.

Discutir tambien la diferencia que hay entre la linea auroral y la nebular de [NII] para ver la importancia de las desexcitaciones colisionales. Una es mas afectada que la otra y por lo tanto conforme vamos a las zonas de mayor densidad la razon entre ellas debe ir cambiando, aumentando de hecho.

## 4 Conclusion

We will construct Cloudy models of a series of individual radial cuts from the center of the proplyd, at different angles  $\theta$  from the proplyd axis.

## References

HENNEY, W. J. & ARTHUR, S. J., 1998. Modeling the Brightness Profiles of the Orion Proplyds. *Astronomical Journal*, **116**, 322–335.