ISWA

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Molecular formation along the atmospheric mass loss of HD 209458 b and similar Hot Jupiters

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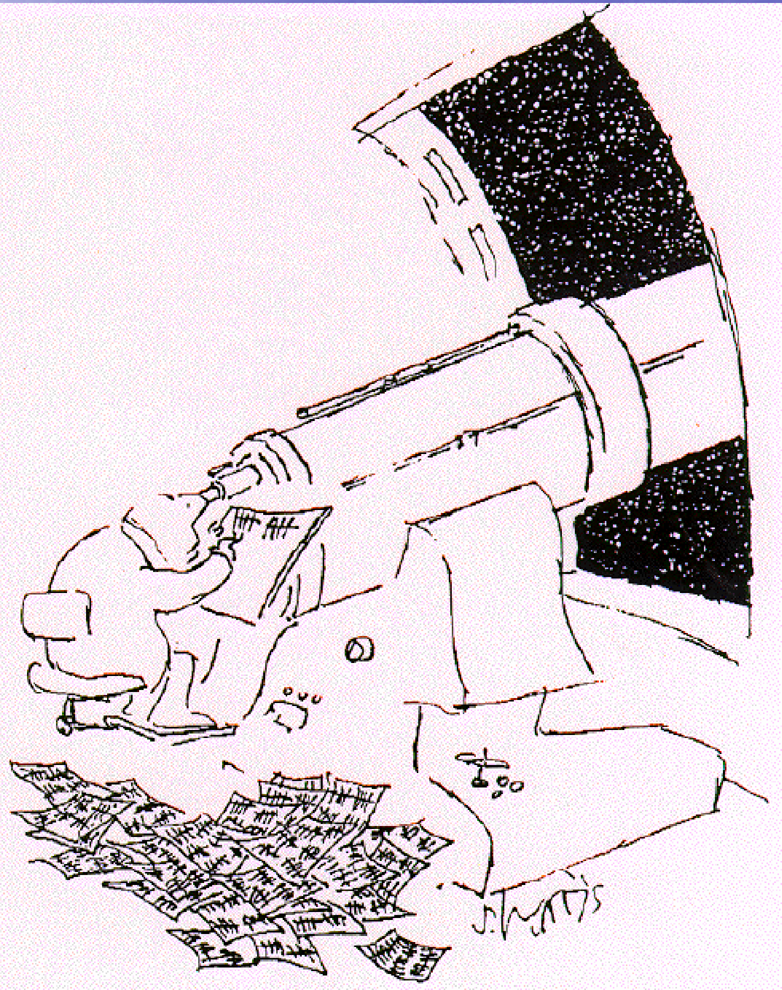
Since 1995...

- ~ 3400 planets discovered around main sequence stars (Schneider – **The Extrasolar Planets Encyclopaedia**)



How Many Known Extrasolar Planets?

"What's one and one and one and one and one and one and one and one and one and one and one?"

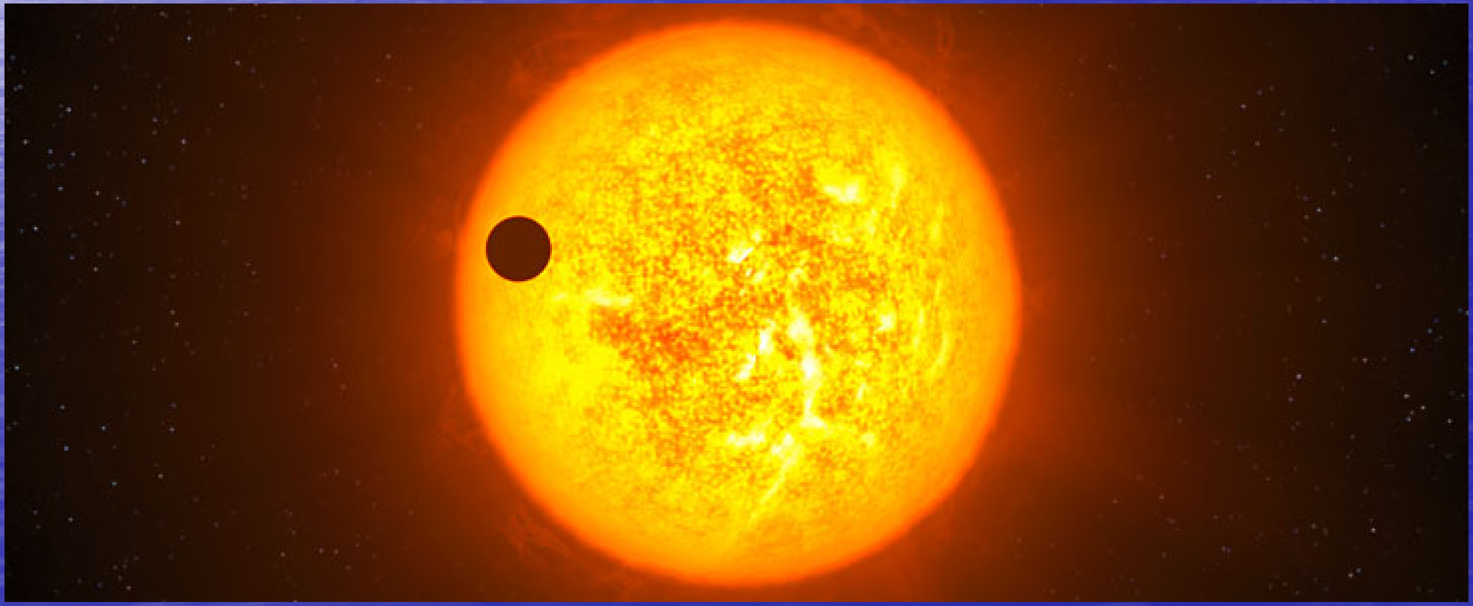
"I don't know," said Alice. "I lost count."

"She can't do addition," said the Red Queen.

Lewis Carrol,
Alice in Wonderland

Since 1995…

- Main methods: radial velocity and transit
- Gas Giants, Super-Earths, Mini-Neptunes…
- Some are Gas Giants orbit their host stars at distances < 0.1 AU ➔ Hot Jupiters !



Some Hot Jupiters are losing mass…

- Examples: HD209458 b (Osiris) and HD189733 b
- Rates at 10^9 to 10^{12} g s^{-1}
- Escape velocities up to 130 km s^{-1}

What about ***chemical reactions*** going on along the mass loss from Hot Jupiters?

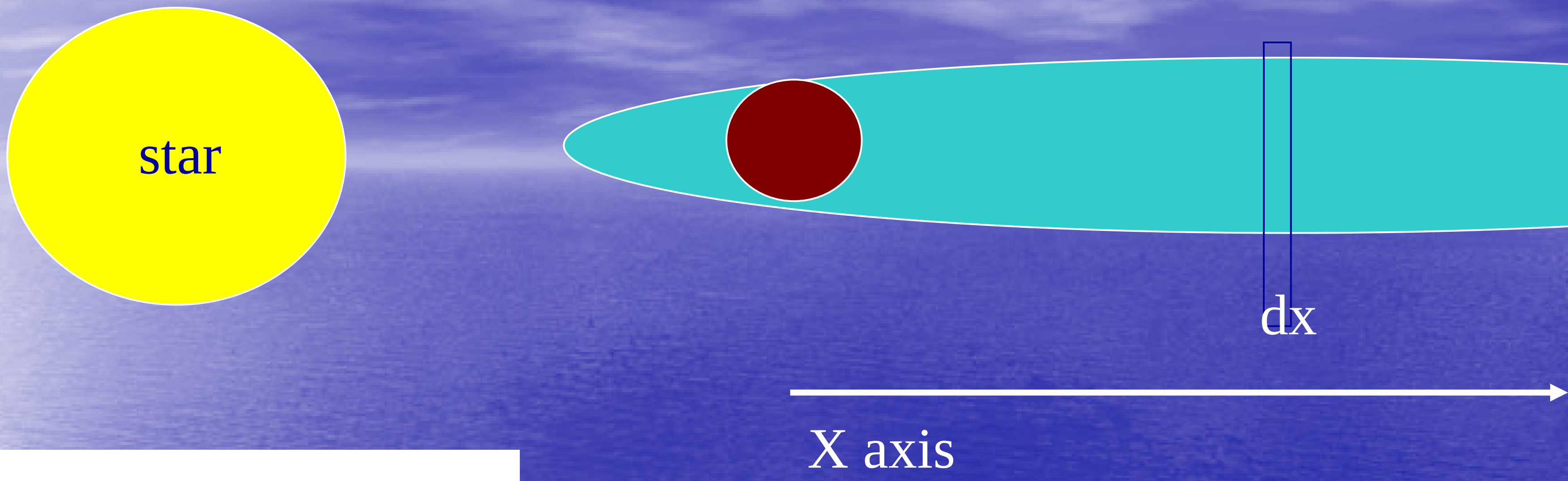
- Carbon chain molecules
- Main source of PAHs to the ISM: Carbon Rich AGB stars; but no detection (weak UV field)
- Considering a carbon-rich atmosphere of Hot Jupiter...
  – Could there be PAH formation along the mass loss?
  – what about simpler molecules like C2H2 ?
  – Which conditions would be necessary for this process to take place?
- Simple molecules with oxygen
  – Faster overall reaction rates

566 reactions from the UMIST database

- Involving 56 species containing H, C and O atoms
- Photoionization and photodissociation reactions also, with reaction constants corrected for the UV radiation flux from the star
- Network of hydrocarbon molecules up to benzene
- Simulations start where T < 2000 K

Species with H	Species with He	Species with C	Species with O	Species with H and C	Species with H and O	Species with C and O	Species with H, C and O
H^+ H^- H H_2^+ H_2 H_3^+	He^+ He	C^+ C^- C	O^+ O^- O	CH^+, CH, CH^-, CH_2^+, CH_2, CH_3^+, CH_3, CH_4^+, CH_4, C_2H^+, C_2H, C_2H^-, $C_2H_2^+$, C_2H_2, $C_2H_3^+$, C_2H_3, $C_2H_4^+$, C_2H_4, C_3H_2, $C_3H_3^+$, C_3H_3, $C_3H_4^+$, $C_4H_2^+$, $C_4H_3^+$, $C_5H_3^+$, $C_6H_5^+$ C_6H_6, $C_6H_6^+$, $C_6H_7^+$	OH^+ OH OH^- H_2O^+ H_2O H_3O^+	CO^+ CO CO_2^+ CO_2	HCO HCO^+ H_2CO

The Model



$$\frac{d}{dr}[\rho v(x_i)] = \sum \Omega_n$$

$$\rho = \rho(x)$$
$$v = v(x)$$
$$T = T(x)$$

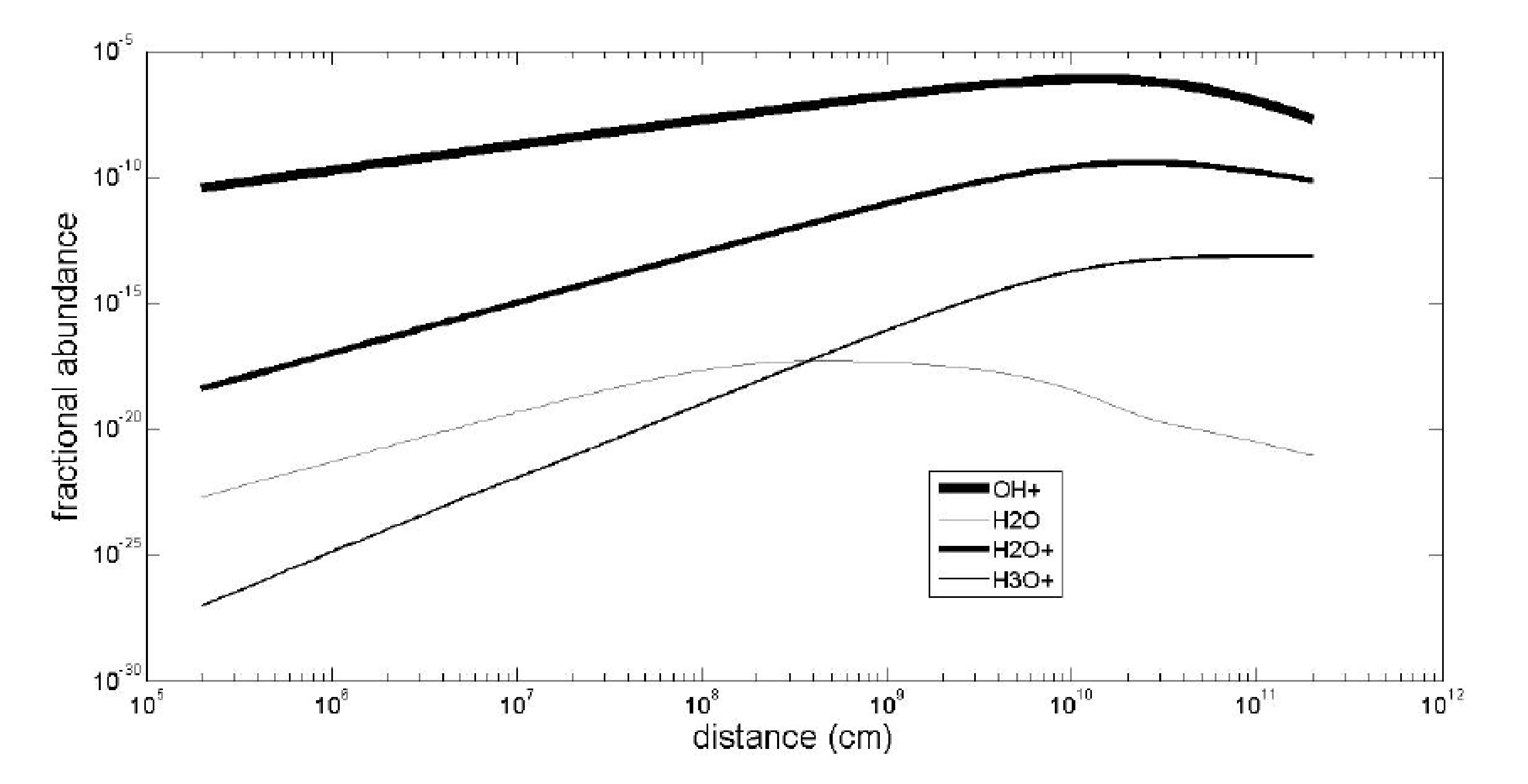
where ρ is the hydrogen number density (cm^{-3}), v is the radial velocity of the mass loss ($cm\ s^{-1}$), Ω_n is the reaction rate ($cm^{-3}\ s^{-1}$) of any reaction n (from the 566 reactions used) which produces or consumes the species i, and x_i is the abundance of the species i *relative to hydrogen*.

RESULTS:

- benzene formation along the mass loss of OSIRIS is not significant
- UV field from the star too Strong, affecting the abundance of precursor molecules in the chain reaction whch leads to benzene

$HCO^+ + C_2H_2 \rightarrow C_2H_3^+ + CO$ (1)
$C_2H_3^+ + C_2H_2 \rightarrow C_4H_3^+ + H_2$ (2)
$C_4H_3^+ + C_2H_2 \rightarrow c\text{-}C_6H_5^+ + h\nu$ (3)
$c\text{-}C_6H_5^+ + H_2 \rightarrow c\text{-}C_6H_7^+ + h\nu$ (4)
$c\text{-}C_6H_7^+ + e^- \rightarrow c\text{-}C_6H_6 + H$ (5)

- **But other species are produced with significant abundances, especially OH+ (total column density of 3 x 10^7 cm^-2**
- **OH+ could be a tracer of residual molecular hydrogen**



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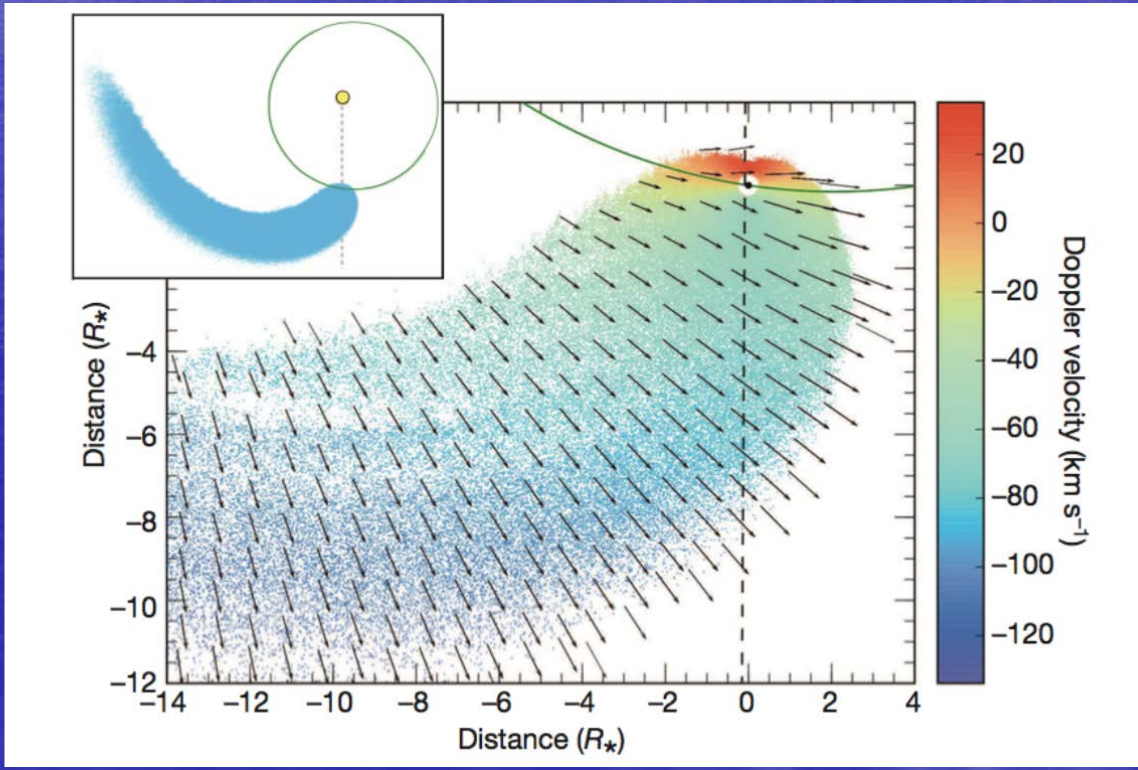
Next steps:

- **Observation of OH+ lines (SOFIA...)**
- **application of the program to the Hot Neptune GJ 436 b, which also loses mass and receives less intense UV radiation**



Ehrenreich et al. (2015)


THANK YOU !