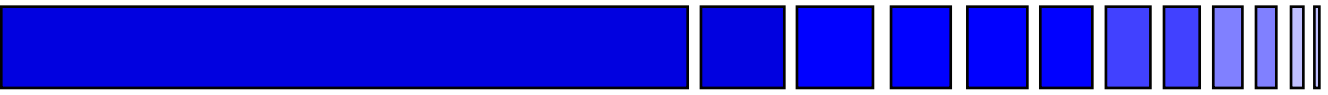
Observation of Interstellar H_3^+



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Kenneth H. Hinkle
National Optical Astronomy Observatories

Thomas R. Geballe
Joint Astronomy Centre

H_3^+ toward GL2136

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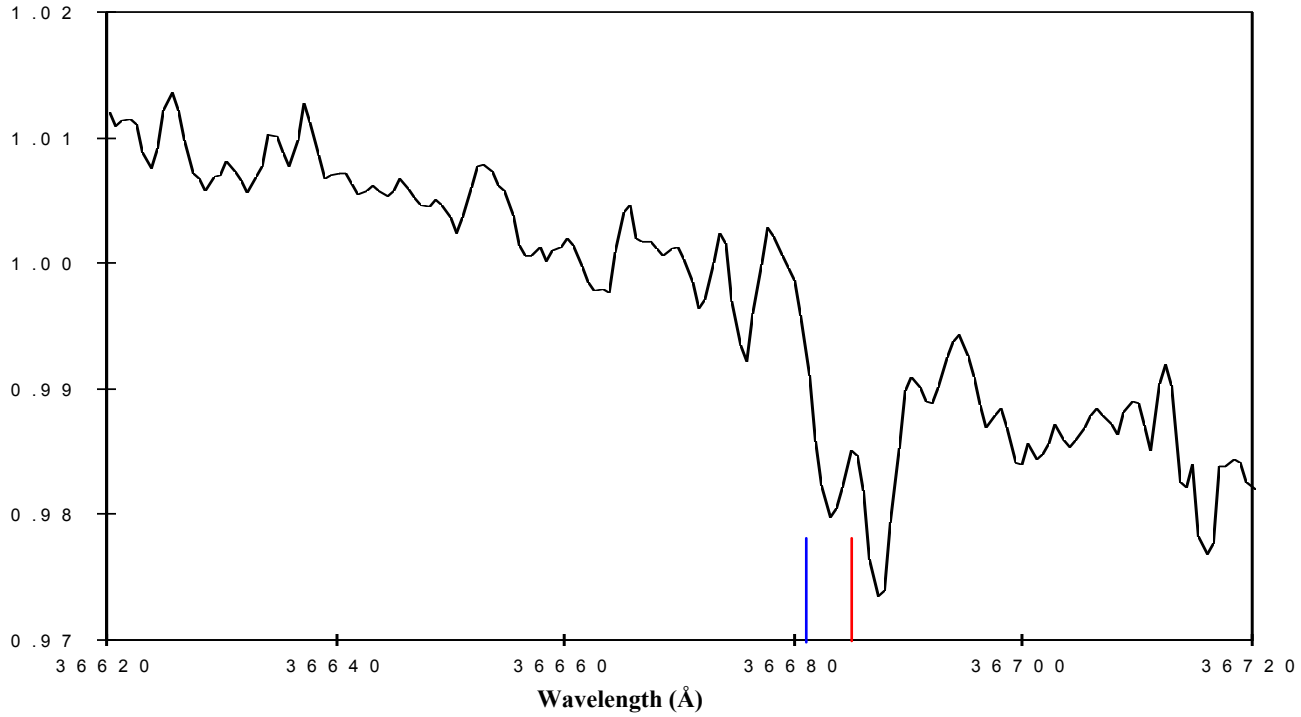

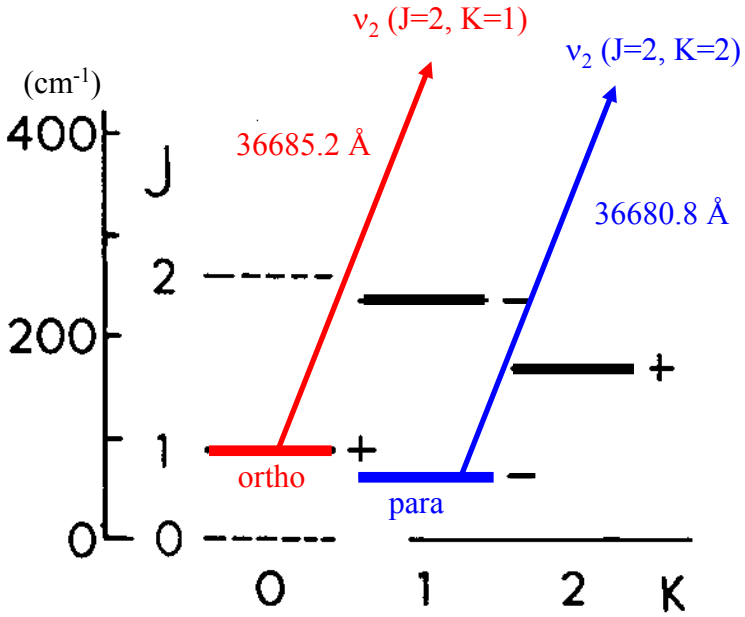

Column Density

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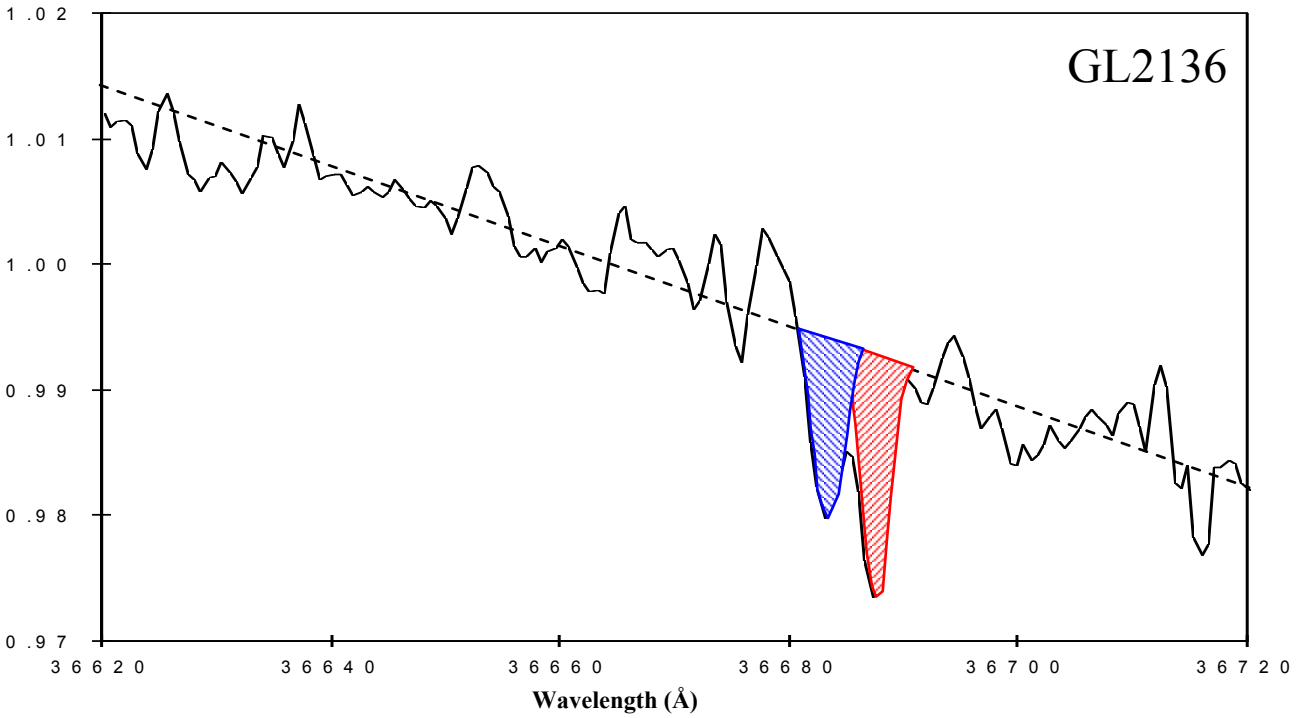

Peak Area ⇒ Column Density (N)

→ # molecules in 1 cm^2 cross section along line of sight

→ $\int$ [n = number density] dx

$N_{para} = 2.07 \pm 0.18 \times 10^{14}\ cm^{-2}$

$N_{ortho} = 1.60 \pm 0.11 \times 10^{14}\ cm^{-2}$

Doppler Shift

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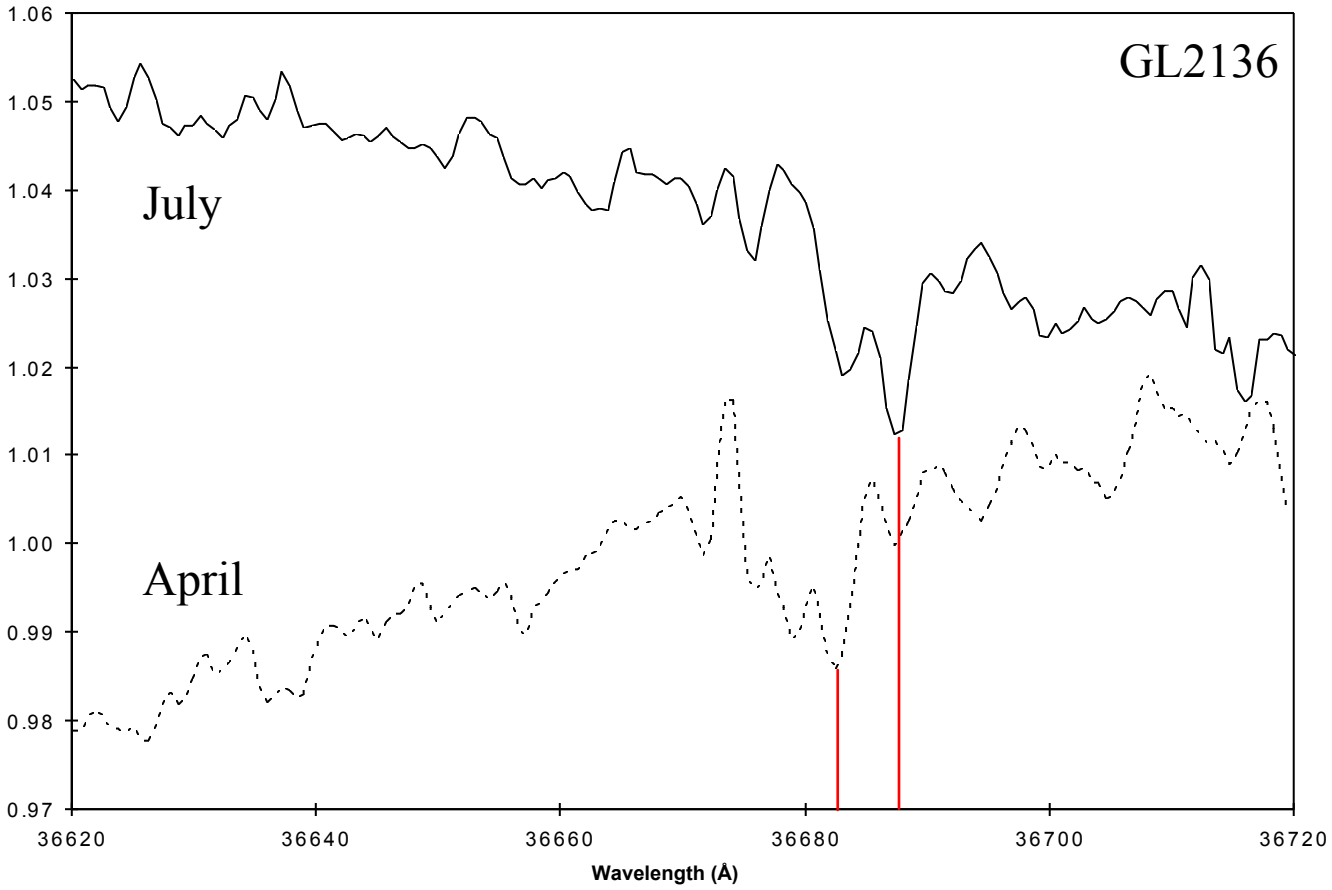
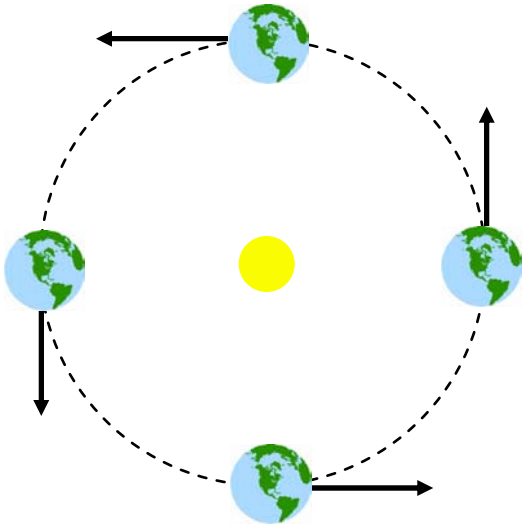
GL2136





Other Detections

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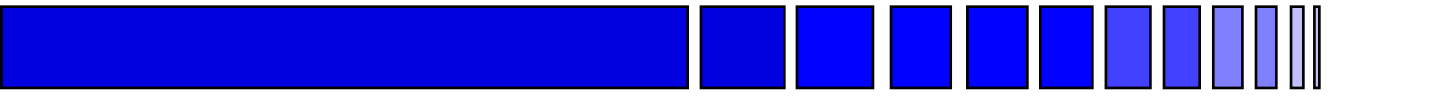

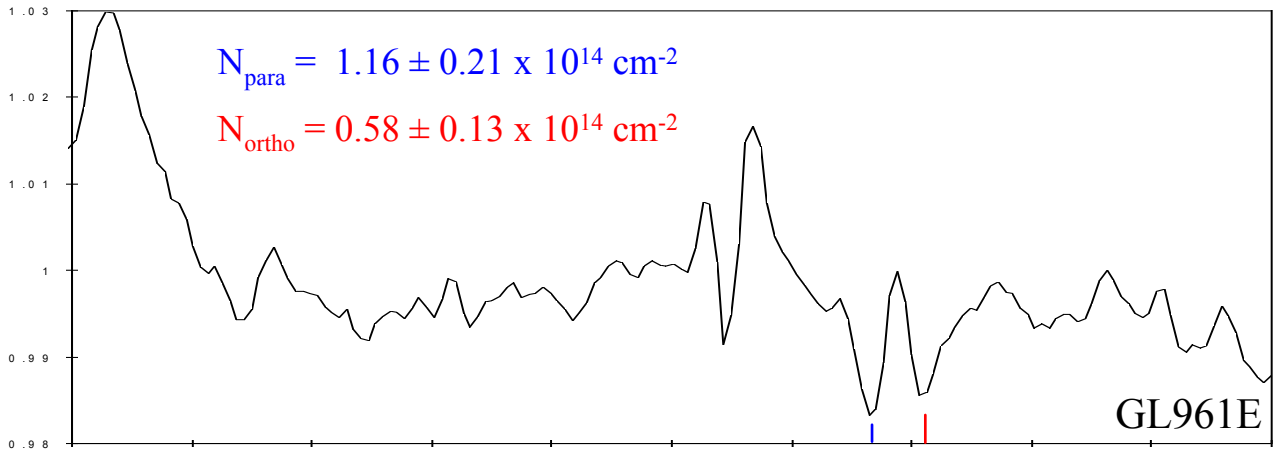

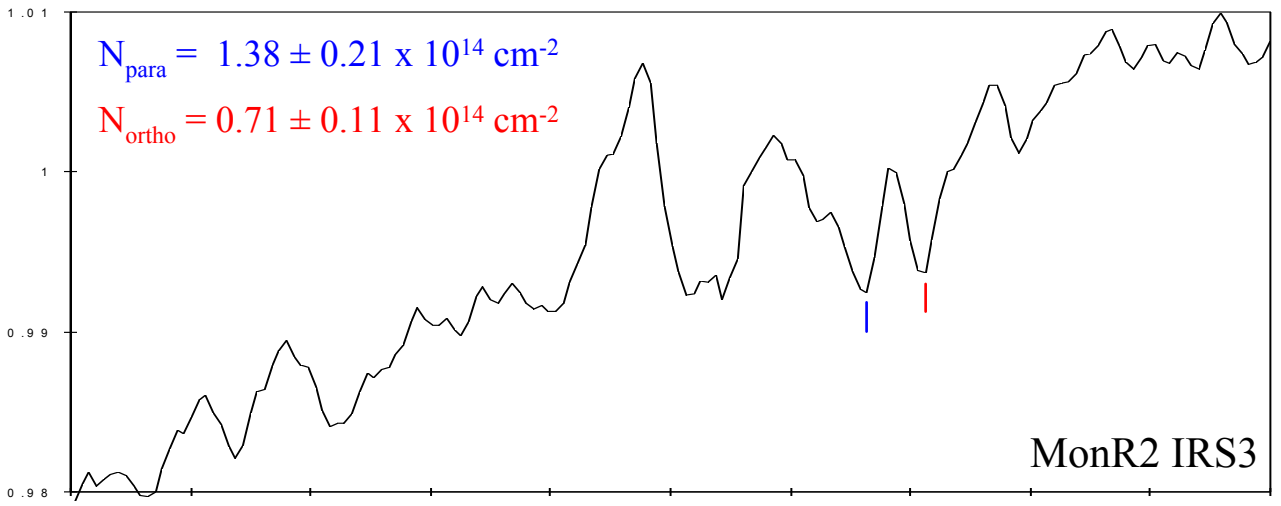

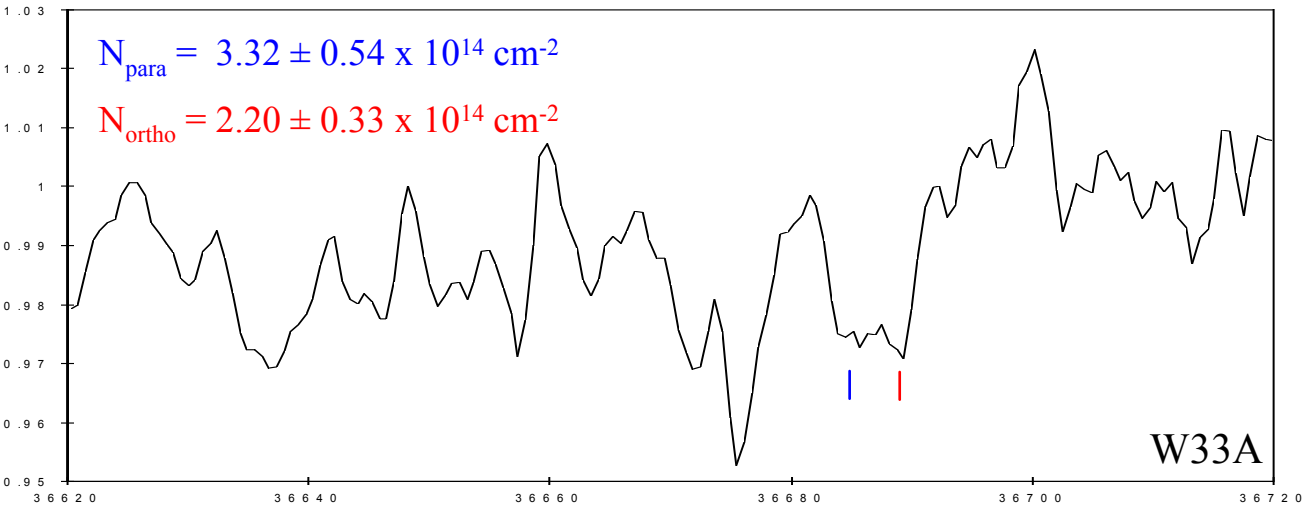

Monoceros R2

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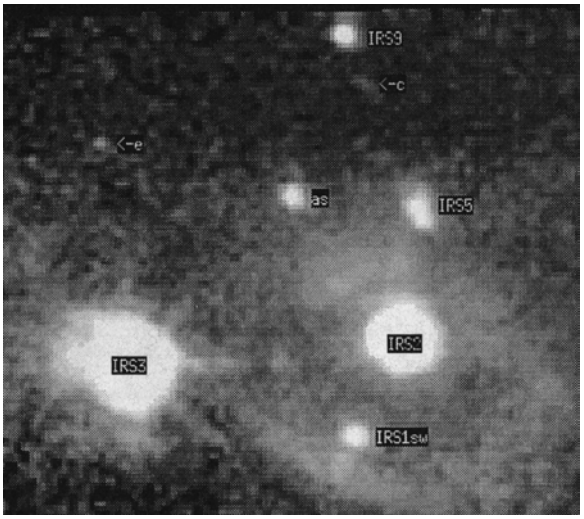

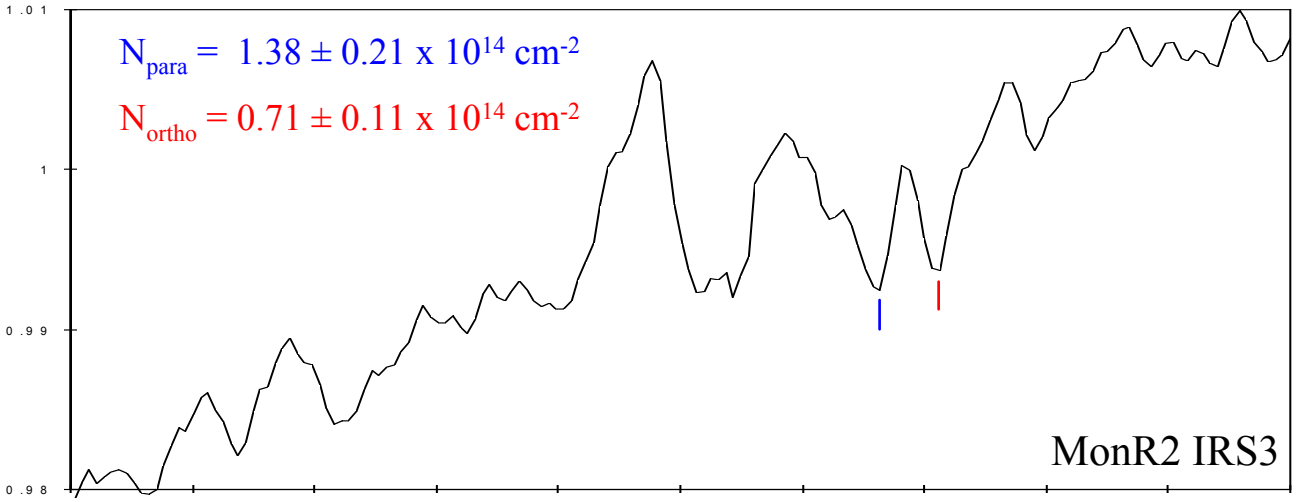

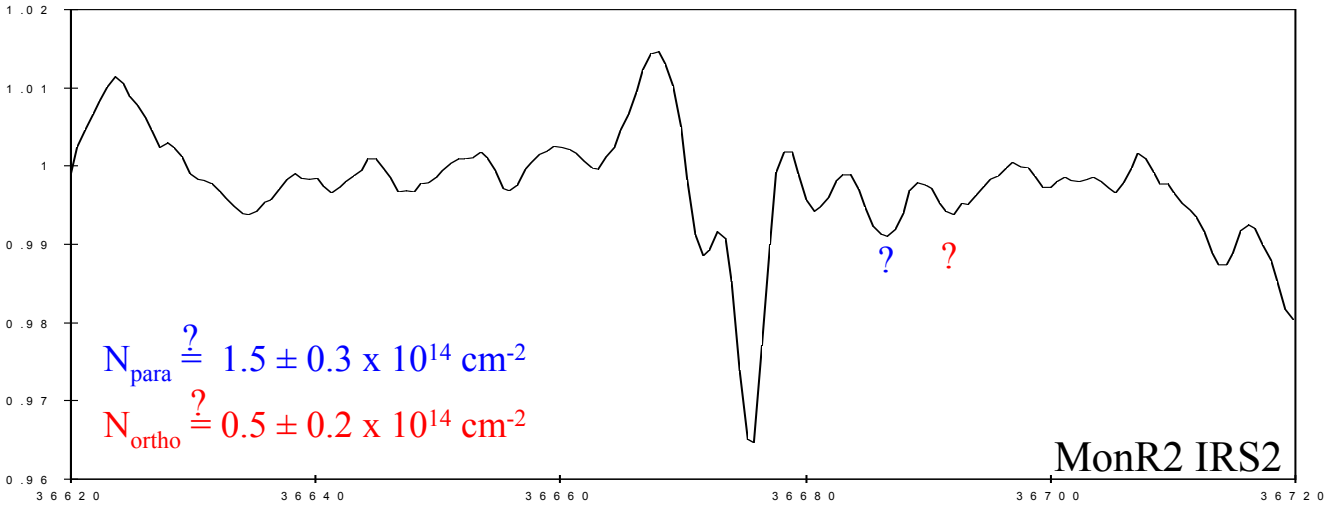

NGC 2024 IRS 2

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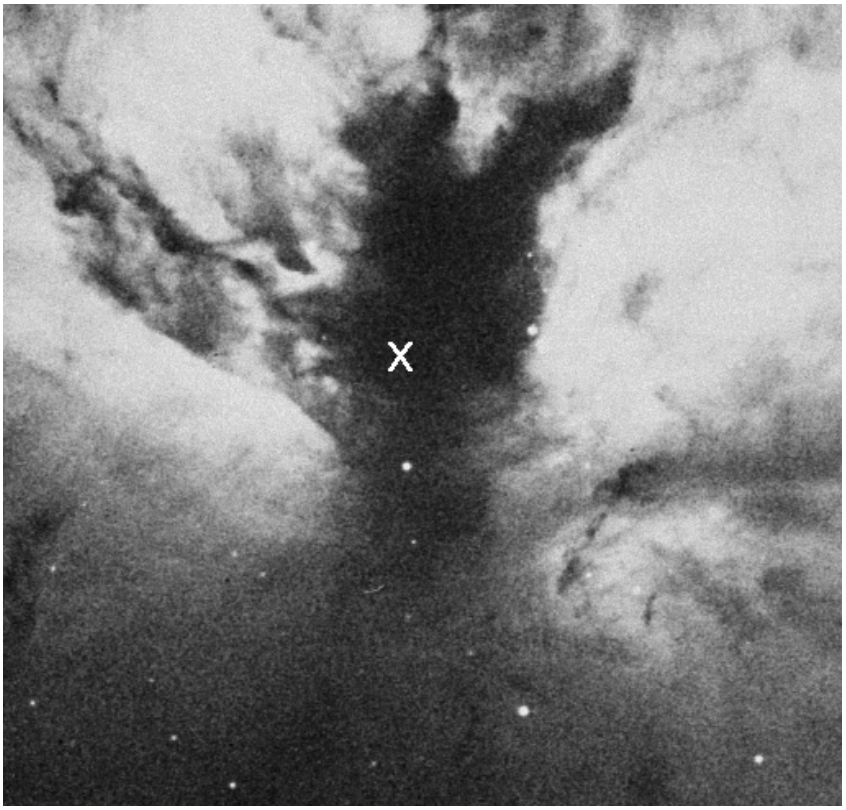
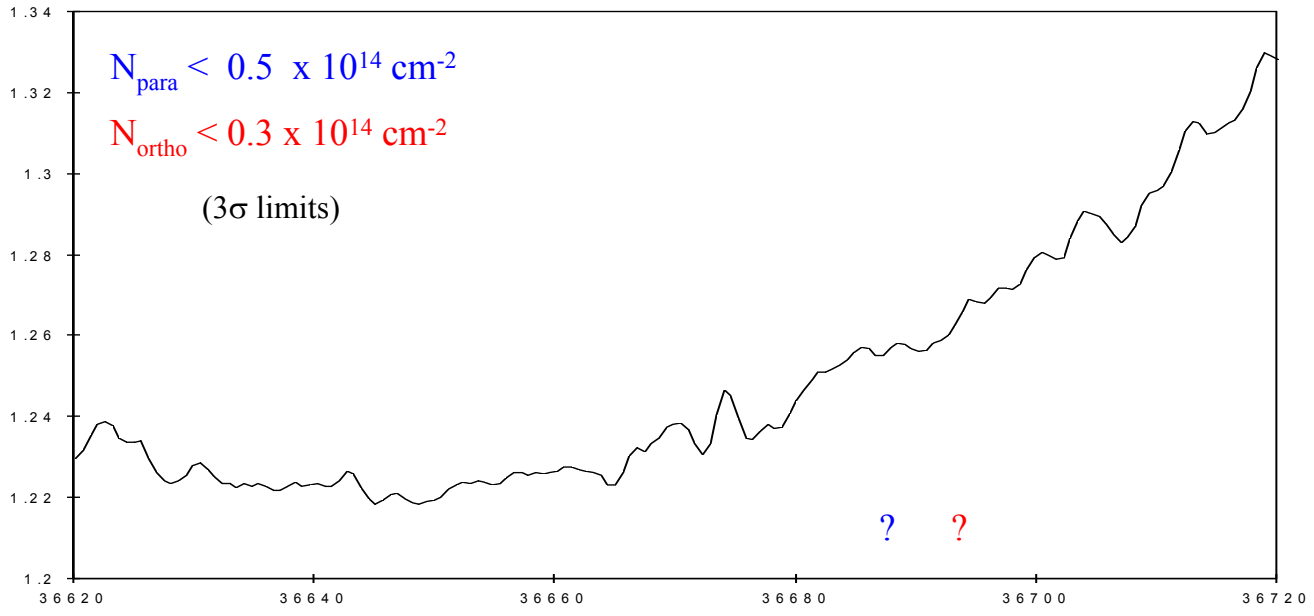


Palomar plate Klinglesmith & Hollis (1987)



H_3^+ Chemistry

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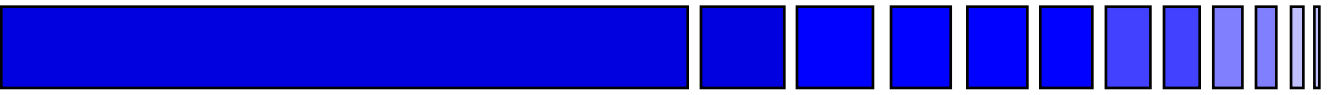

Formation Rate (Cosmic Ray Ionization)	=	Destruction Rate (Reaction with CO)
$\zeta\, n(H_2)$	-	$k\, n(H_3^+)\, n(CO)$

assumed constant
$\sim 10^{-17}\ s^{-1}$

$$\frac{\zeta}{k}\left[\frac{n(H_2)}{n(CO)}\right] - n(H_3^+)$$

→ Constant!
In all molecular clouds,
$n(H_3^+) \sim 3 \times 10^{-5}\ cm^{-3}$

measured
$\sim 2 \times 10^{-9}\ cm^3\ s^{-1}$

observed to be constant in many varied conditions
$\sim 6.7 \times 10^3$

Calculations

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Source	$N(H_3^+)$ [cm^{-2}]	$\frac{N(H_3^+)}{n(H_3^+)}$	$N(H_2)$ [cm^{-2}]	$\frac{N(H_2)}{N(H_3^+)} = \frac{n(H_2)}{n(H_3^+)}$	$n(H_2)$ [cm^{-3}]
GL2136	3.7×10^{14}	~4 pc	1.8×10^{23} (1)	4.9×10^{8}	1.5×10^{4}
W33A	5.5×10^{14}	~6 pc	2.8×10^{23} (1)	5.1×10^{8}	1.5×10^{4}
MonR2 IRS3	2.1×10^{14}	~2 pc			
GL961E	1.7×10^{14}	~2 pc			
MonR2 IRS2	2×10^{14}?	~2 pc?	4×10^{22}? (1)	2×10^{8}?	6×10^{3}?
NGC2024 IRS 2	$<0.8 \times 10^{14}$	<0.9 pc	3.5×10^{22} (2)	$>4.4 \times 10^{8}$	$>1.3 \times 10^{4}$

This work

$\div n(H_3^+)$ || 3×10^{-5}

Other observations

(1) Tielens et al. (1991)

(2) Lacy et al. (1994)

Temperatures

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$H_3^+ + H_2 \rightarrow H_2 + H_3^+$ ("proton transfer")

$\therefore$ H_3^+ is thermalized with H_2

$$\frac{N_{ortho}}{2\,N_{para}} = e^{-\frac{\Delta E}{kT}}$$

GL2136	$\longrightarrow$	35 ± 4 K
W33A	$\longrightarrow$	30 ± 6 K
MonR2 IRS3	$\longrightarrow$	24 ± 4 K
GL 961 E	$\longrightarrow$	24 ± 5 K
(MonR2 IRS2)	$\overset{?}{\longrightarrow}$	$(18 \pm 4$ K)

Future Work

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- Survey of other molecular clouds
- Variation of H_3^+ column density?
- Comparison with CO temperatures
- Observe H_2, CO, HCO^+ in absorption
- Comparison with models of interstellar chemistry