Cosmic Ray Ionisation

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What have Cosmic Rays ever done for us?

"Cosmic Rays ionise molecular clouds, which are threaded by magnetic fields, leading to magnetic support"

Cosmic rays ionise throughout the cloud (cf. UV)

Cosmic rays 'diffuse' into the cloud due to magnetic field

Cosmic rays heat the cloud

Magnetic field is turbulent (?)

Ionisation causes flux freezing, and hence magnetic support

star formation due to collapse, ambipolar diffusion

chemistry also driven by ionisation

What can we observe?

1. Cosmic Rays — CTA
2. Magnetic fields — ASKAP-POSSUM (small scales?)
3. Ionisation?
    1. we currently characterise the CRs as ζ ionisations per unit time per ISM atom
    2. $\zeta \approx 10^{-17}\,\mathrm{s}^{-1}$
    3. Can this really be characterised by a spatially uniform rate?

Tracking ionisation in the molecular ISM

CR ionisation produces H_3^+, which then drives chemistry through *ion-molecule reactions*

in particular, HCO^+ produced from CO in one step:

$H_3^+ + CO \rightarrow H_2 + HCO^+$

(so the HCO^+/CO ratio should trace ionisation rate ζ)

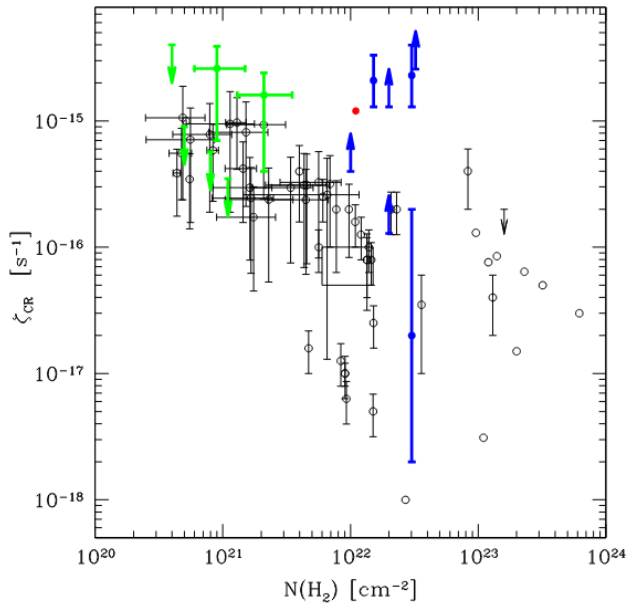

Figure: CR Ionisation in MCs from Gabici & Montmerle 2015

HCO^+/DCO^+

Guélin et al. (1977):
HCO^+/DCO^+ ratio can estimate the electron fraction in the cloud;
low electron fraction gives greater deuteration *(fractionation)*
$H_3^+ + HD \rightarrow H_2D^+ + H_2$
this process is slow;
destruction by electrons *(dissociative recombination)* is fast
Ideally: HCO^+ 1–0 (89 GHz), DCO^+ (72.04 GHz), CO (109–115 GHz)
(Caveat from Herbst et al. 2016: the relationship between HCO^+/DCO^+ and ζ gets broken by the ortho-to-para ratio of hydrogen for young systems and low ζ.)

Can we do this at Mopra? (Spoiler: No)

Can we do this at Mopra?

MOPRA-RX 76–115 GHz

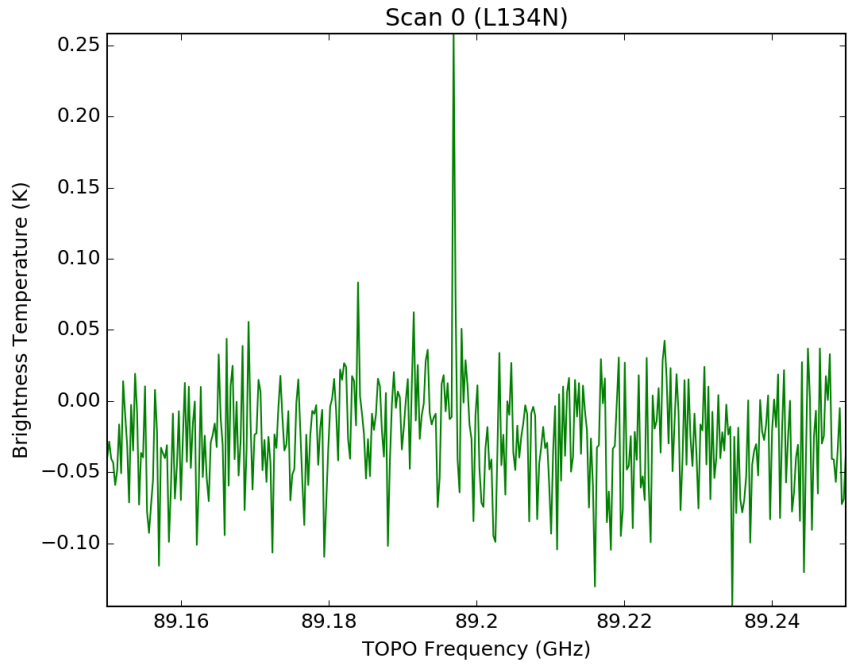

Figure: HCO^+ towards L134N

Probably Not.

For Mopra nerds: At 76 GHz LO, IF 4 power drops out of range, even with attenuator 0

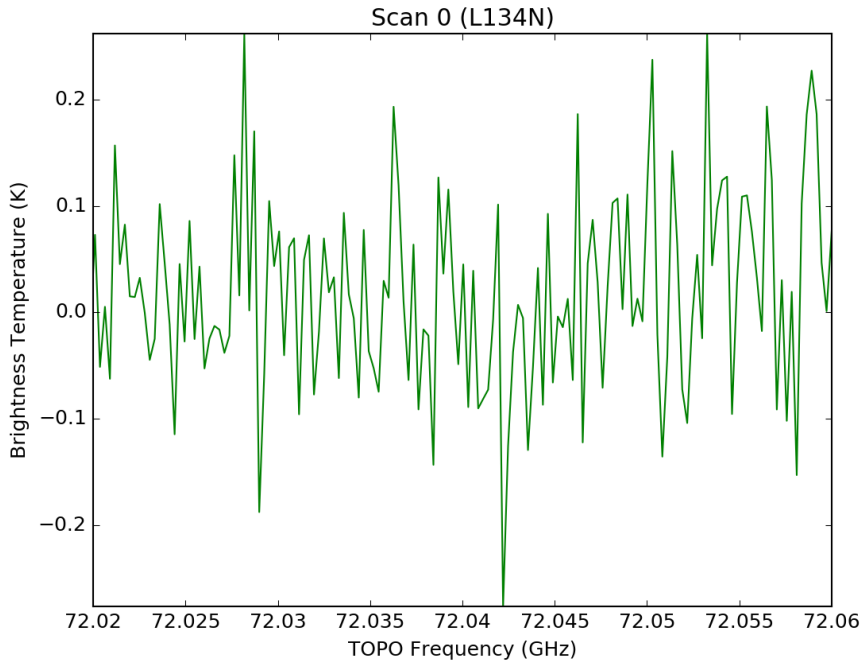

Figure: DCO^+ not detected towards L134N

If we integrated for an hour or two, would we get it?

Can we do it anywhere else?

IRAM 30 m; Nobeyama 45 m;
Nothing south of 36° N can do DCO^+
ATCA, ALMA only work $>\sim$86 GHz

What else can we do?

Gabici & Montmerle, 2015:
"[search] for chemical tracers of low energy CRs in MCs, alternative to HCO^+, DCO^+, and H_3^+"
DCN/HCN is referred to as a similar example of deuteration — but we can't get DCN either!
Could we do something with DNC, HNC, HCN…?

Could we get an HCO^+/DCO^+ machine?

We'd need a new RX on Mopra.
Or a new RX and resurfacing on ATCA
This would be the only telescope capable of tracing CR ionisation in the southern hemisphere(!)