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VIA VERITAS VITA

Prediction of Flux Density Maximum at 1 MHz

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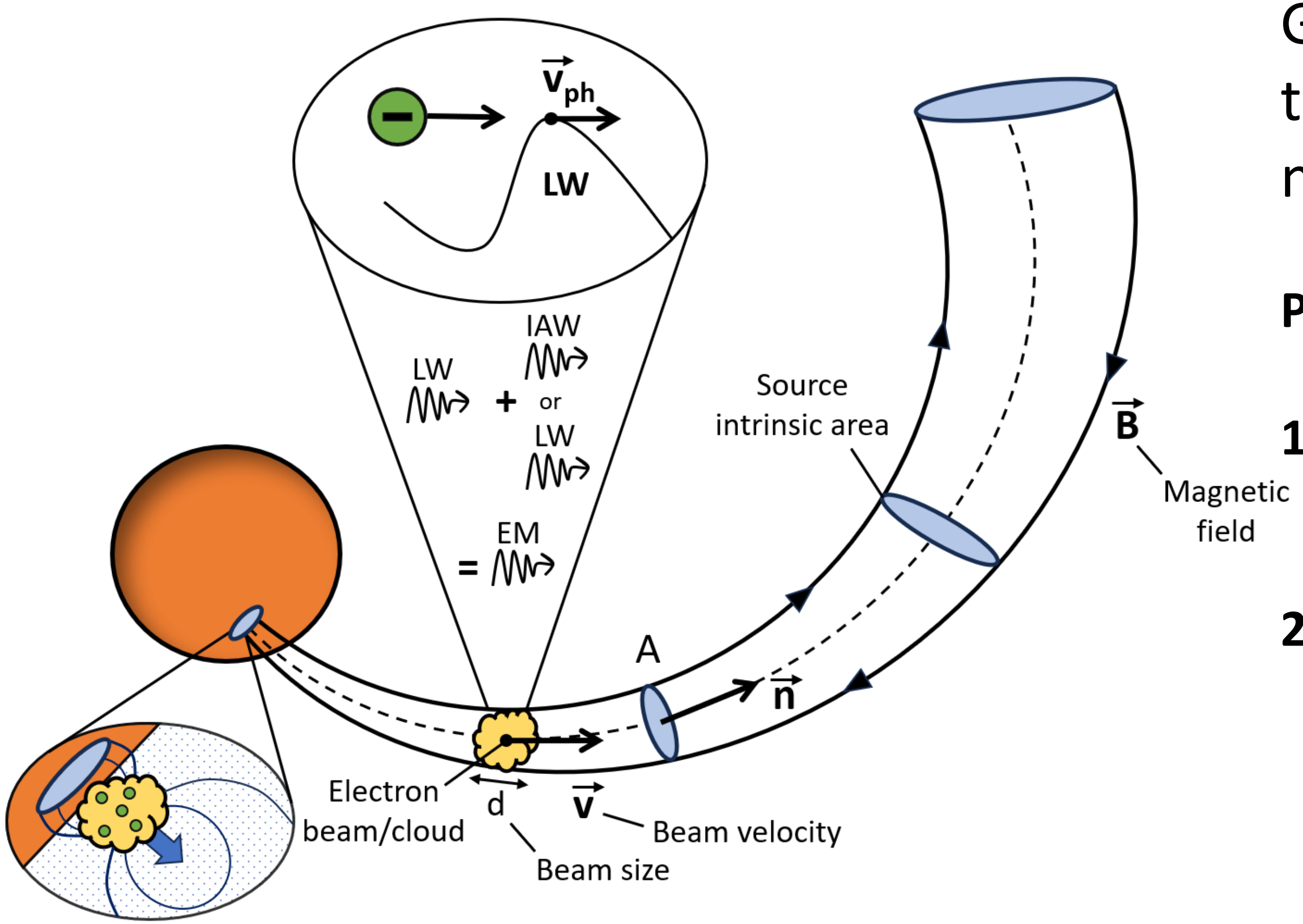
What is a Type III burst?

Impulsive radio frequency signals that exhibit a drifting pattern from high to low frequencies over time



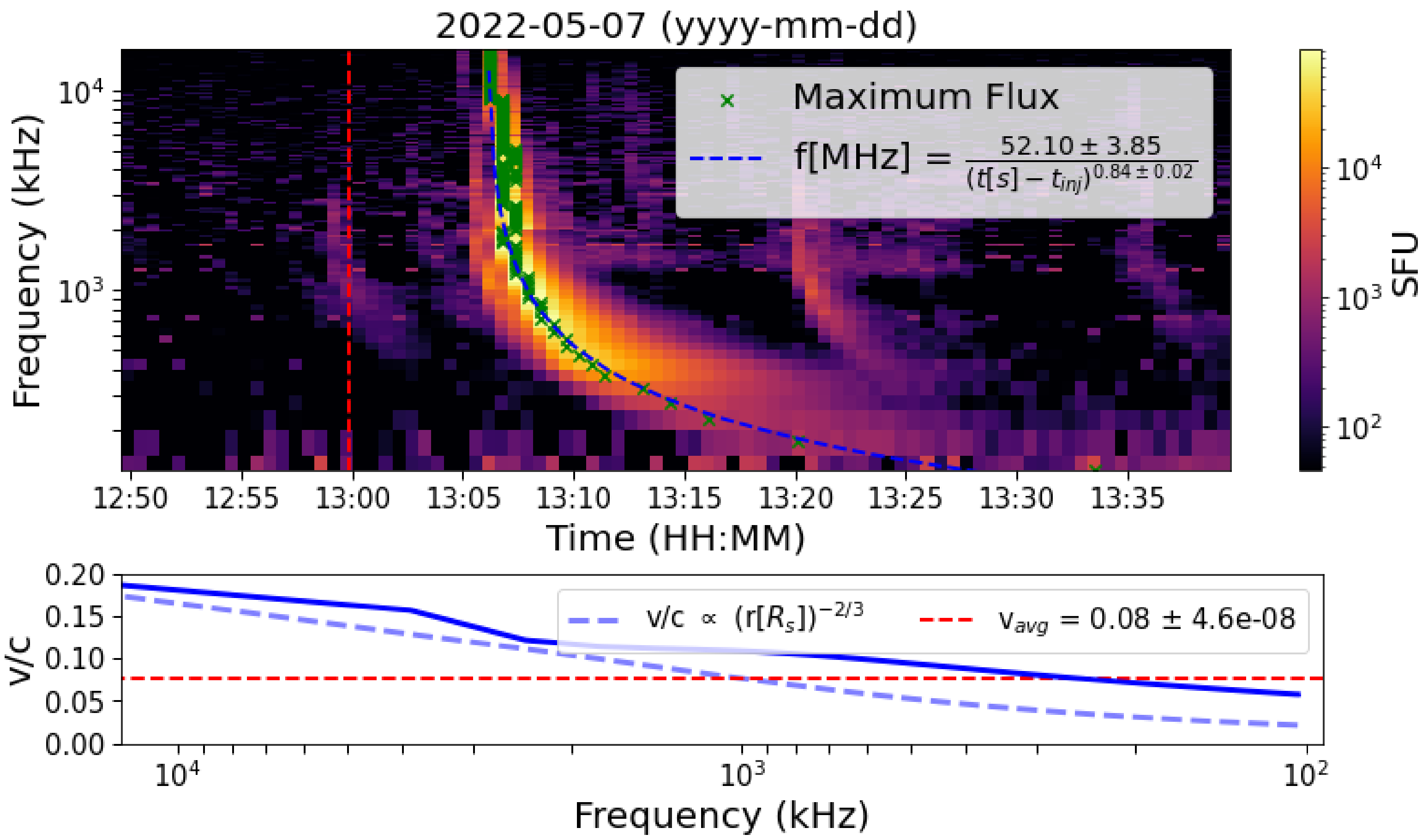
Generated by **accelerated electron beams** traveling through the solar system's plasma at nearly relativistic energies.

Process responsible for radio emission:

1. **Two-stream instability** leads to **production of Langmuir waves**

2. **Wave-wave interactions** between Langmuir waves and ion-sound waves/ oppositely propagating Langmuir waves **(fundamental emission/ harmonic emission)**

Methods and Observations



25 isolated type III radio bursts seen by STEREO, PSP and SolO were selected.

Background noise: spectrum 10 minutes before burst appears.

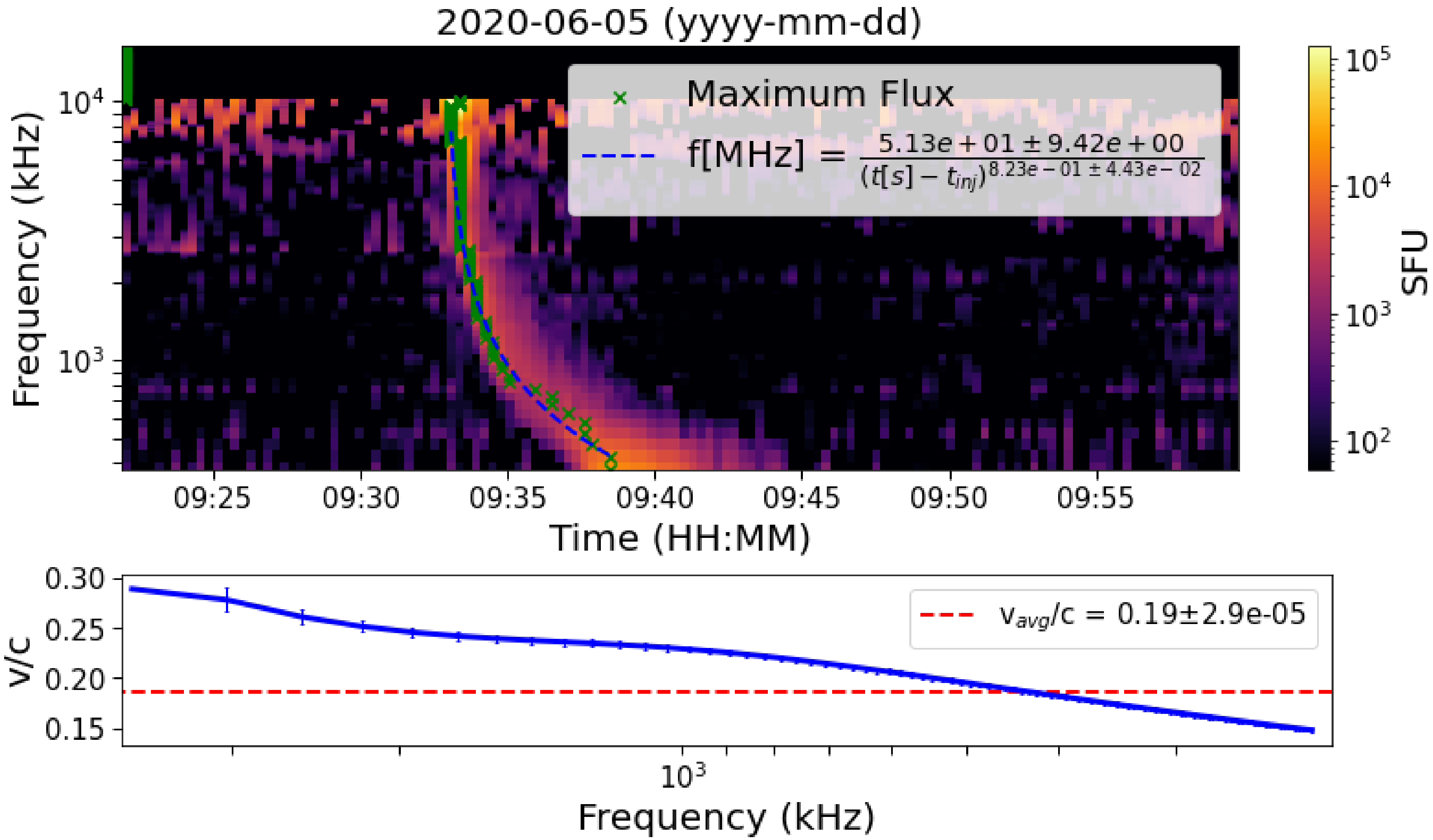
Fit for frequency as function of time **found using peak emission at each frequency**

Emitter's speed v/c of 0.1 ± 0.04 was. $r(f_{pe})$ found through interpolation, then velocity found by taking gradient with time

[Electron density model from **Kontar et al. (2019)** assumed throughout this work]

$$n(r) = 4.8 \times 10^9 \left(\frac{R_\odot}{r}\right)^{14} + 3 \times 10^8 \left(\frac{R_\odot}{r}\right)^{6} + 1.4 \times 10^6 \left(\frac{R_\odot}{r}\right)^{2.3} \text{ [cm}^{-3}\text{]}$$

SolO Data Coming Soon!



Modelling the interaction

Vedenov (1963); Drummond and Pines (1962): Quasi-linear (kinetic) equations for reduced field-aligned **electron distribution function** (f) and **spectral energy density of Langmuir waves** (W)

Ryutov and Sagdeev (1970); Mel'Nik et al. (1999): Smallness of τ_{qv} allows to use hydrodynamic description, with $f = f_0 + f_1 + \ldots$

$$\frac{\partial f}{\partial t} + v\frac{\partial f}{\partial x} = \frac{4\pi^2 e^2}{m^2}\frac{\partial}{\partial v}\frac{W}{v}\frac{\partial f}{\partial v} = \frac{\partial}{\partial v}D\frac{\partial f}{\partial v}$$

$$\frac{\partial W}{\partial t} = \frac{\pi \omega_{pe}}{n_p} v^2 W \frac{\partial f}{\partial v},$$

τ_{qv} = characteristic time of interaction ≈ $n_0 / \omega_{pe} n_b$

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(Mel'nik et al 1999) The **spectral energy density of the Langmuir waves** can be described by

$$W(v,x,t) = \frac{m_e}{\omega_{pe}} v^4 \left(1 - \frac{v}{u_0}\right) \frac{n(x,t)}{u_0}$$

m_e electron mass, ω_{pe} electron plasma frequency, u_0 maximum velocity in the electron beam

Retaining first order in *f*:

For linear diffusion, n(x,t)* is found to be**, for initial condition ***n(x,0) = n_b exp(-(x/d)^2)

(d is the size of electron cloud)

$$\frac{n(x,t)}{n_b} = \frac{d}{\sqrt{d^2+4D_{xx}t}} \exp\left(-\frac{\left(x-\frac{u_0 t}{2}\right)^2}{d^2+4D_{xx}t}\right)$$

with $D_{xx} = \frac{u_0}{4D_0}\left(\ln\frac{u_0}{v_{\min}} - 1\right)$ (where $D_0 = \pi \frac{\omega_{pe}}{u_0}\frac{n_b}{n_0}$)

Consider spectral emission at the spatial peak, $x \approx u_0 t/2$ **and near the spectral peak** $v \approx 4/5\, u_0$.

Peak in beam electron density given by:

$$n(x,t)|_{t=\frac{2x}{u_0}} = \frac{n_b}{\sqrt{1+\frac{2xu_0n_0}{\pi\omega_{pe}n_bd^2}}}$$

H-component of EM radiation **is saturated: consider spectral energy density (** W_H^{EM} **) to be proportional to energy of Langmuir waves (Melrose, 1980)**

Spectral flux density S_H of H -component at 1 AU given by

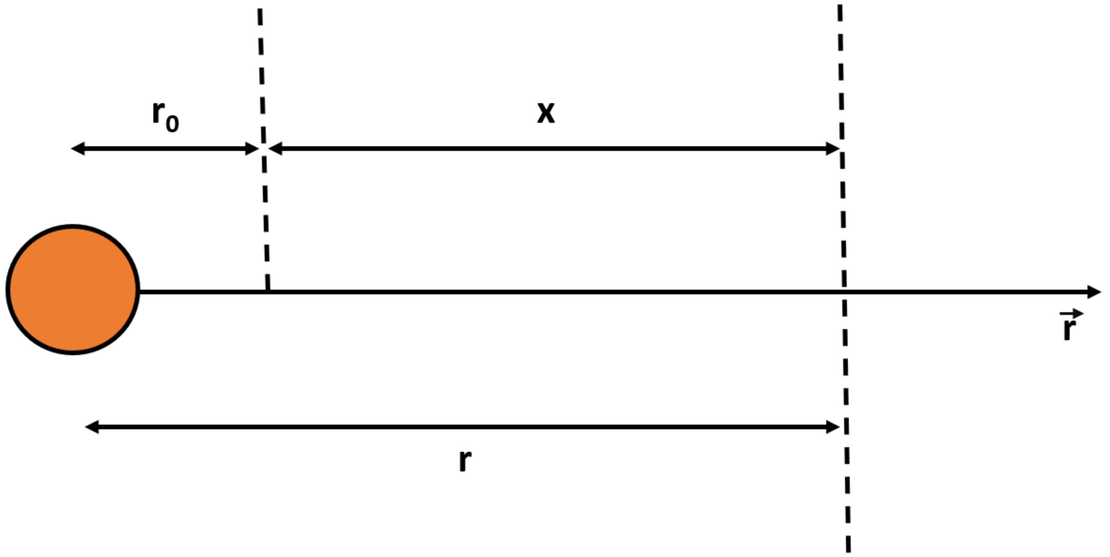
$$S_H = W_H^{\text{EM}} \frac{\mathrm{d}k}{\mathrm{d}\omega} A v_{\mathrm{g}} \frac{1}{4\pi R_{1\ \mathrm{AU}}^2}$$

$dk/d\omega = 1 / v_g$

v_g = group velocity of the EM waves

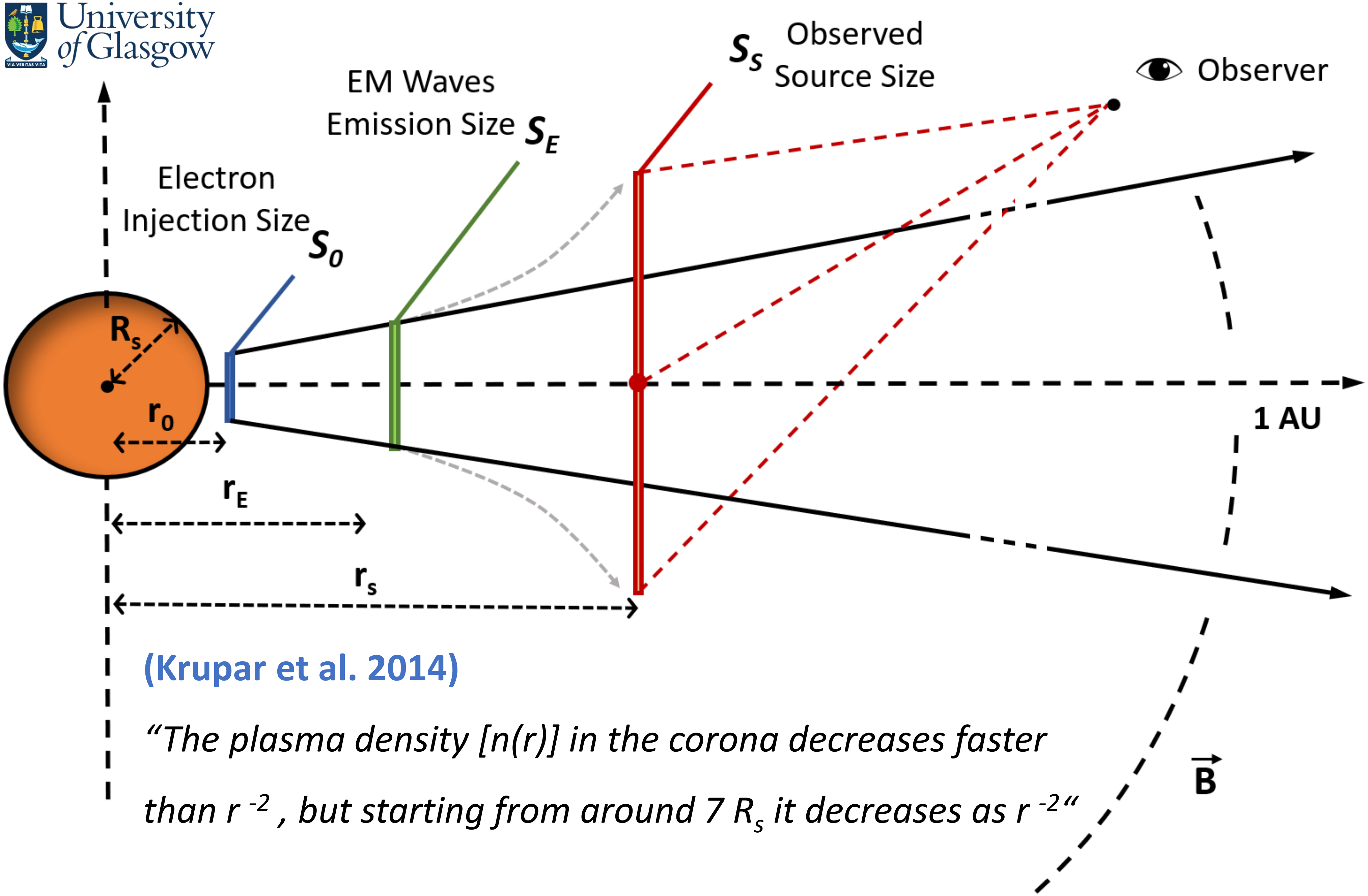
A = area of the source

R_{1AU} = 1 AU distance



Rewrite beam position as $x = r - r_0$, r_0 is the point of electron injection, taken here to be 1 R_s

$$S_H \propto \frac{n_b u_0^3 A}{\omega_{pe}} \frac{1}{\sqrt{1+\frac{2(r-r_0)u_0n_0}{\pi\omega_{pe}n_bd^2}}}$$



(Krupar et al. 2014)

"The plasma density [n(r)] in the corona decreases faster than r^{-2}, but starting from around 7 R_s it decreases as r^{-2}"

Fitting from observations:

$u_0 \propto r^{-2/3}$

Magnetic flux conservation:

$A \propto r^2$

Maximum at 1 MHz

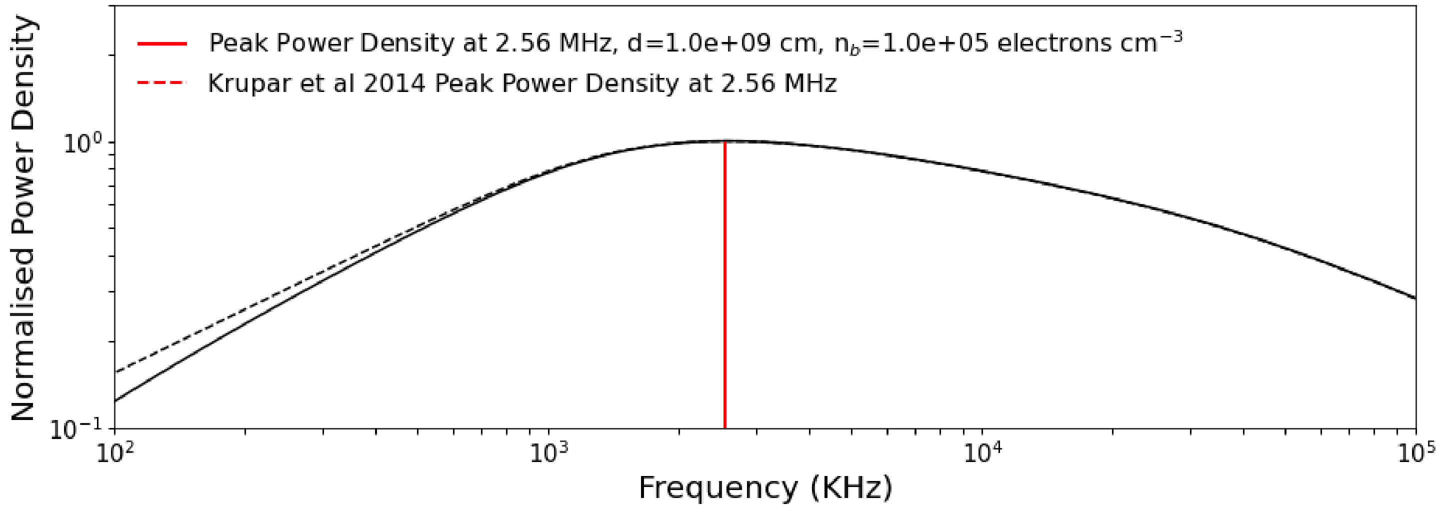
Observations show maximum in flux density around 1 MHz (Krupar et al. 2014 , Raja et al 2022)

(Krupar et al. 2014) $Au_0^3 n_b \propto 1/r^2$ ⟶

$$S_H \propto \frac{1}{r^2 f_{pe}} \frac{1}{\sqrt{1+\frac{2(r-r_0)u_0 n_0}{\pi \omega_{pe} n_b d^2}}}$$

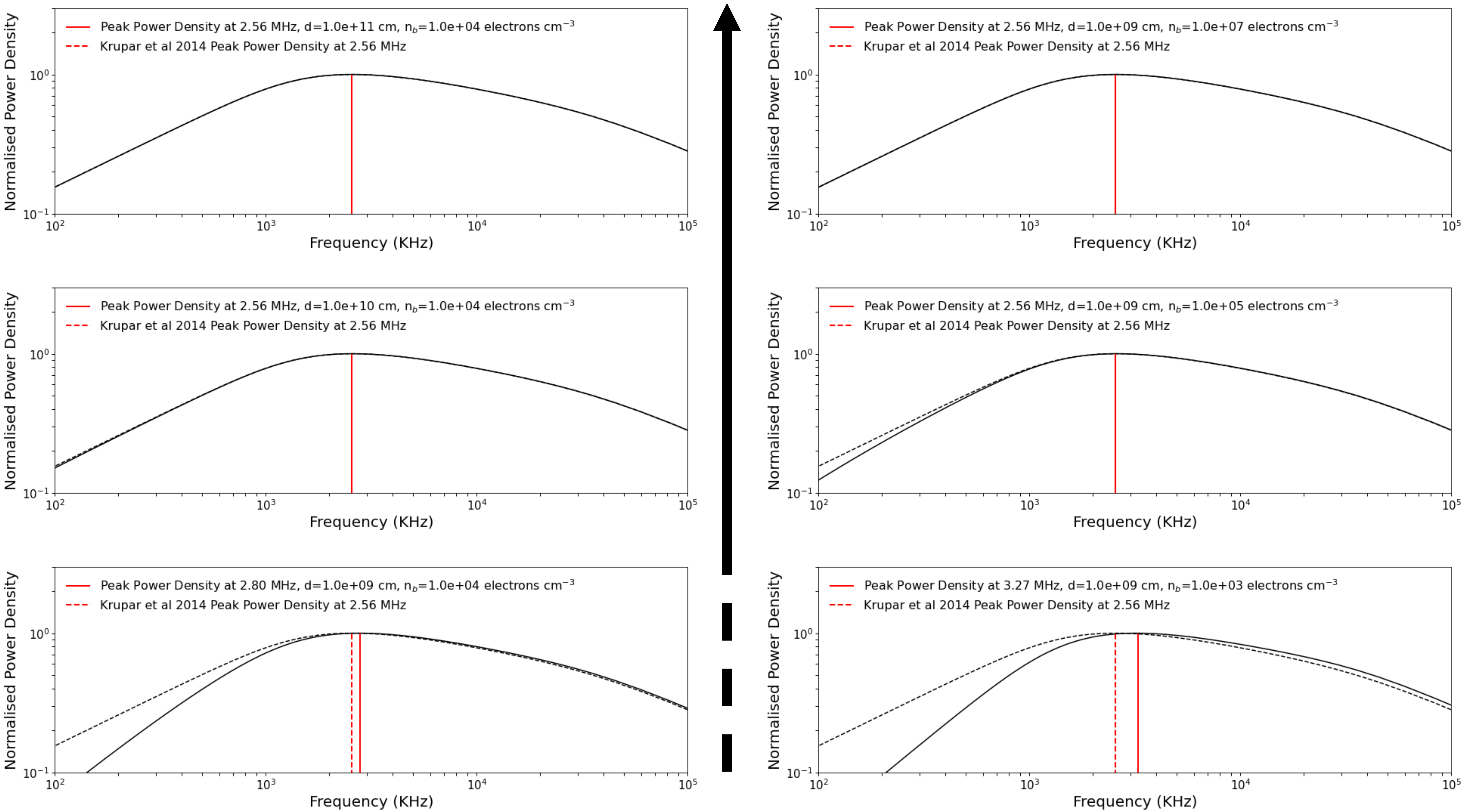
Compare this to result from **Krupar et al. (2014)**:

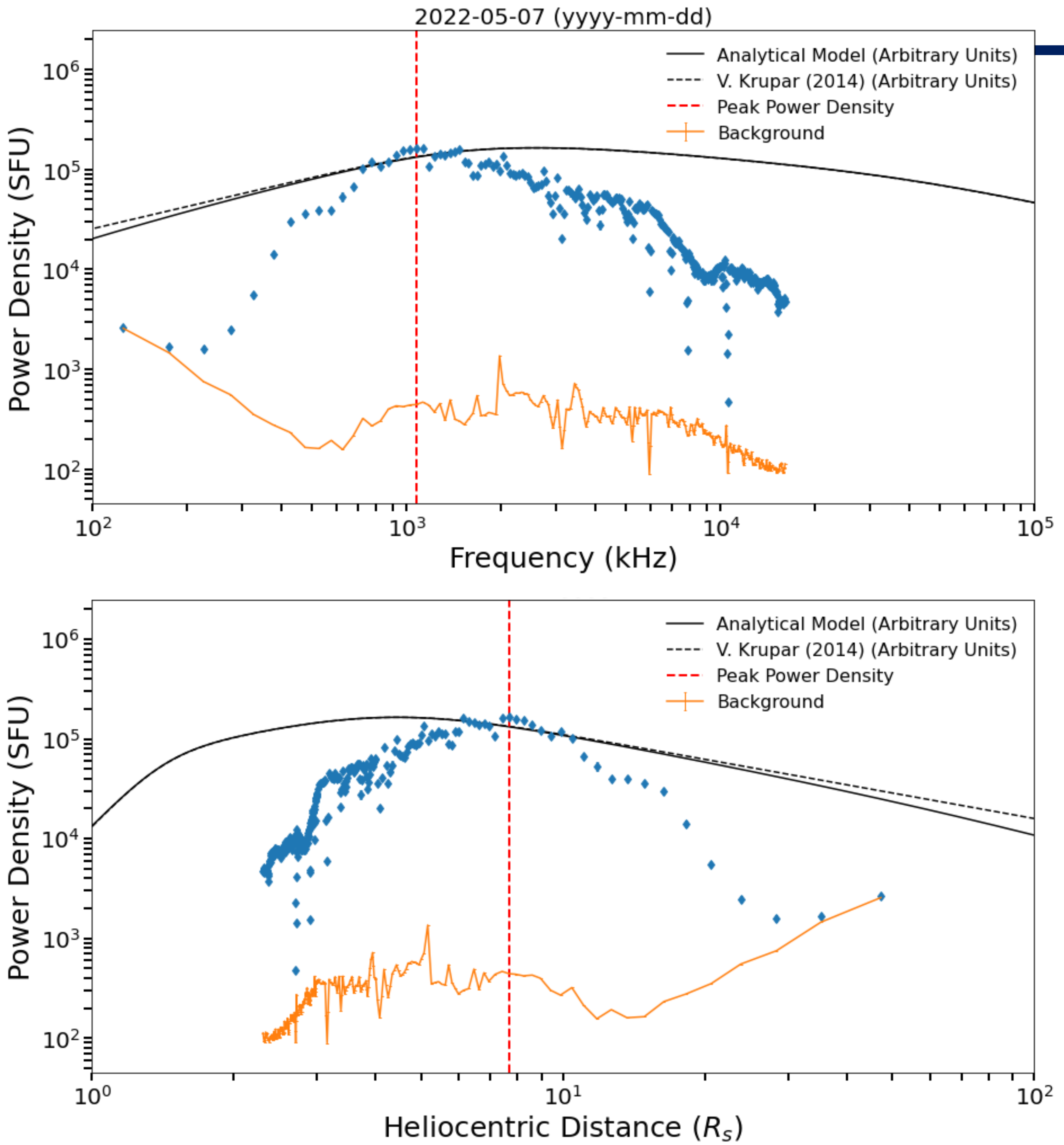
$$S_H \propto \frac{1}{r^2 f_{pe}}$$



Normalised power density as a function of frequency.
It's apparent that the **frequency of peak power density** resulting from our model **approaches the one calculated in Krupar 2014.**

(Preliminary)


Peak Power Density at 2.56 MHz, d=1.0e+11 cm, n_b=1.0e+04 electrons cm^-3
Krupar et al 2014 Peak Power Density at 2.56 MHz
Peak Power Density at 2.56 MHz, d=1.0e+10 cm, n_b=1.0e+04 electrons cm^-3
Krupar et al 2014 Peak Power Density at 2.56 MHz
Peak Power Density at 2.80 MHz, d=1.0e+09 cm, n_b=1.0e+04 electrons cm^-3
Krupar et al 2014 Peak Power Density at 2.56 MHz
Peak Power Density at 2.56 MHz, d=1.0e+09 cm, n_b=1.0e+07 electrons cm^-3
Krupar et al 2014 Peak Power Density at 2.56 MHz
Peak Power Density at 2.56 MHz, d=1.0e+09 cm, n_b=1.0e+05 electrons cm^-3
Krupar et al 2014 Peak Power Density at 2.56 MHz
Peak Power Density at 3.27 MHz, d=1.0e+09 cm, n_b=1.0e+03 electrons cm^-3
Krupar et al 2014 Peak Power Density at 2.56 MHz
Normalised Power Density
Frequency (KHz)



Power density predicted by analytical model over-plotted to **observed power density** from 07/05/2022 event

Orange curve represents subtracted background

Data-points seen here as blue diamonds

Next Steps…

1. Keep investigating how **changing parameters** affects the analytical solution (e.g. n_b, d, r_0, …)

2. Find peak in flux density for **non-linear diffusion**

3. Try to **predict flux density** and compare with type III observations

Thanks!