RADIO AND GAMMA-RAY CONSTRAINTS ALONG THE MINOR AXIS OF STARBURST M82

CCAPP

THE OHIO STATE UNIVERSITY

Benjamin J. Buckman
Tim Linden
Todd A. Thompson
buckman.12@osu.edu

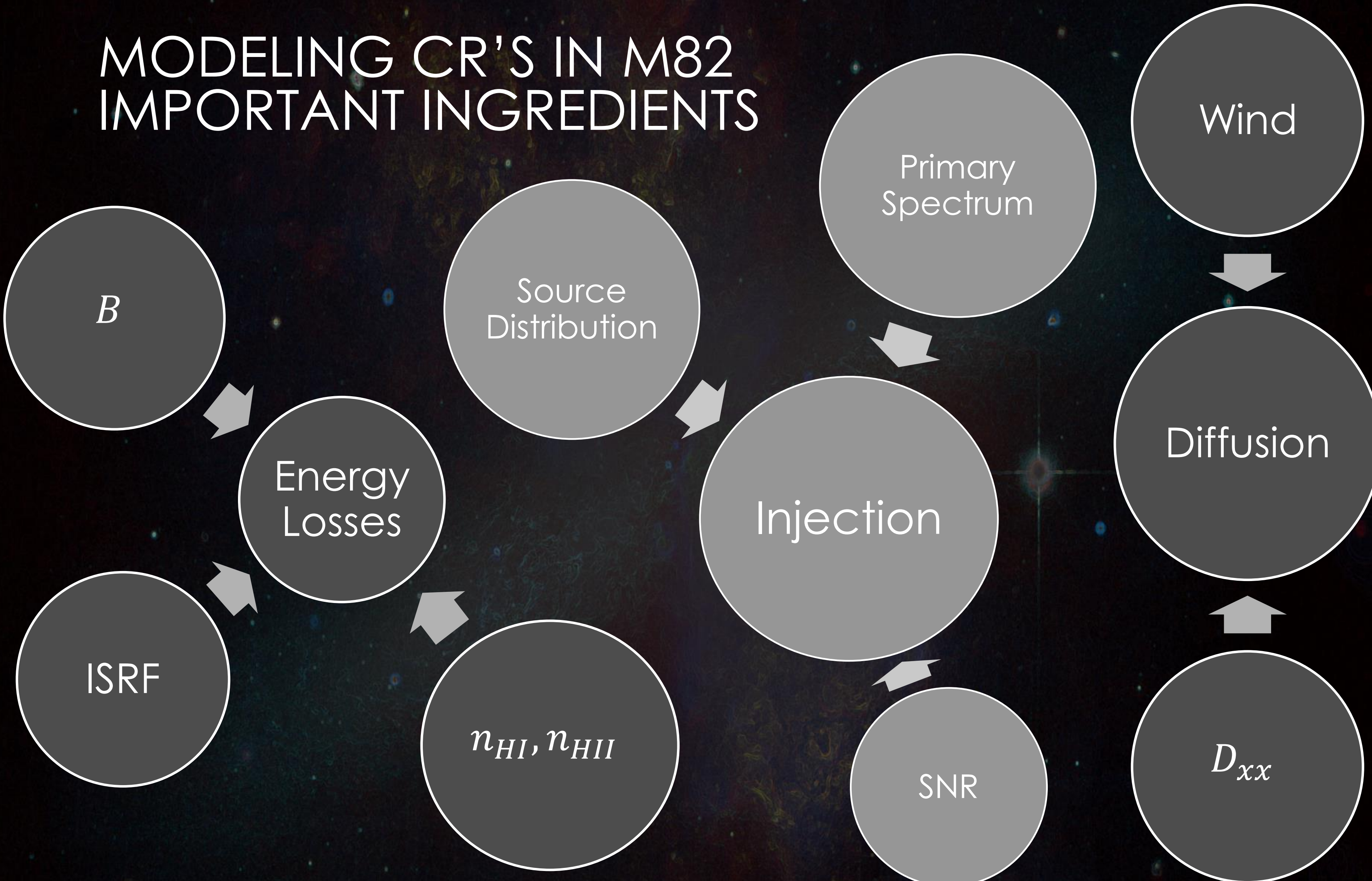
GOOGLE

BING

WHY M82?

- One of the few galaxies with significant detection in gamma-rays
- Well studied
  - Gamma-ray observations – Fermi-LAT & VERITAS
  - Radio halo observations
- Edge-on View
- Exemplar of galactic winds
  - Cosmic-ray driven?

MODELING CR'S IN M82
IMPORTANT INGREDIENTS



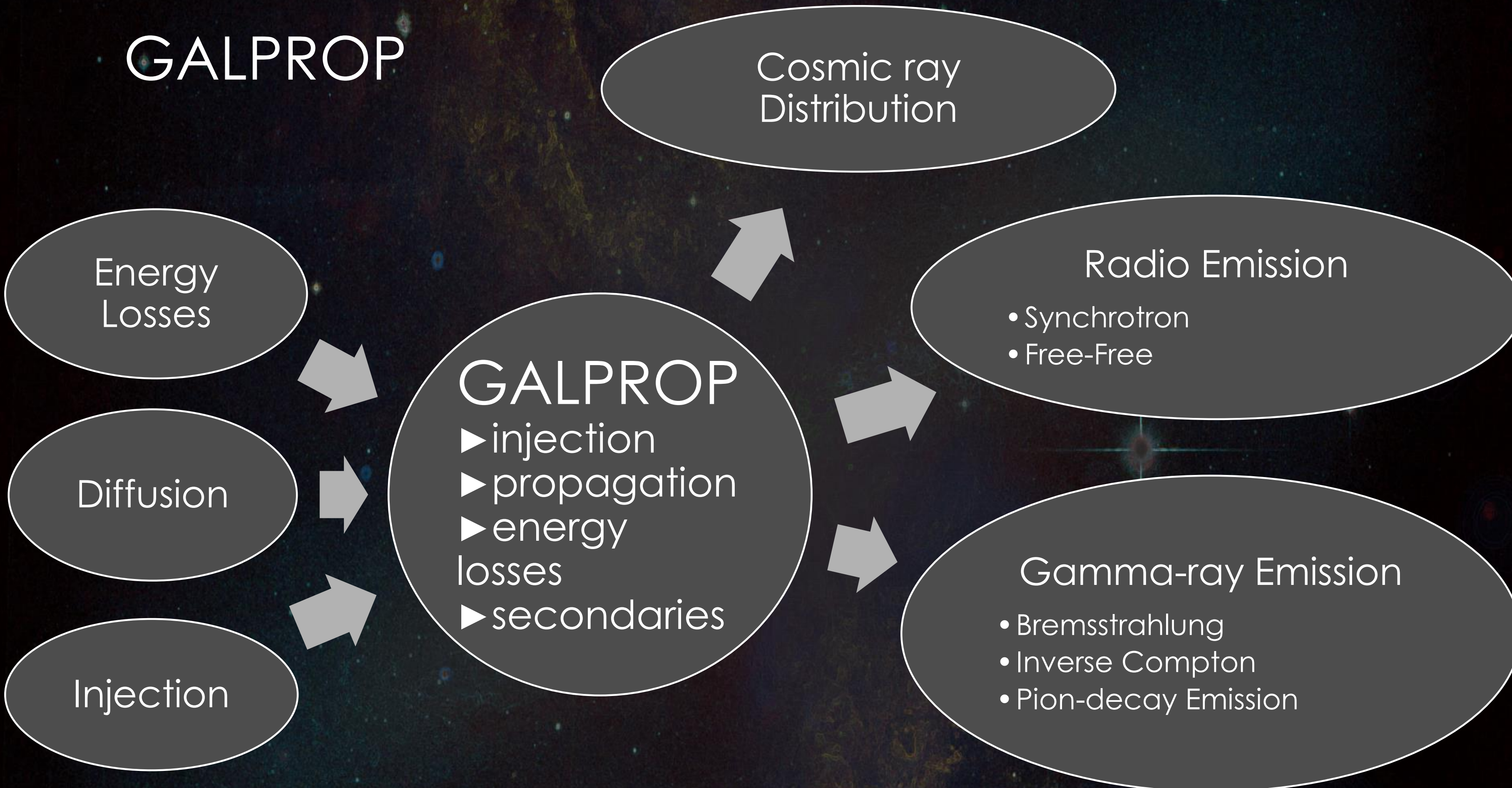
DISTRIBUTIONS

- Magnetic Field – Constant in core + power law
- Gas Density – Constant in core + power law + wind
- ISRF – MW with scaling
- Sources – Constant distribution in core
- Source Spectra $\propto E^{-2.2}$

WHAT WE WANT TO CONSTRAIN

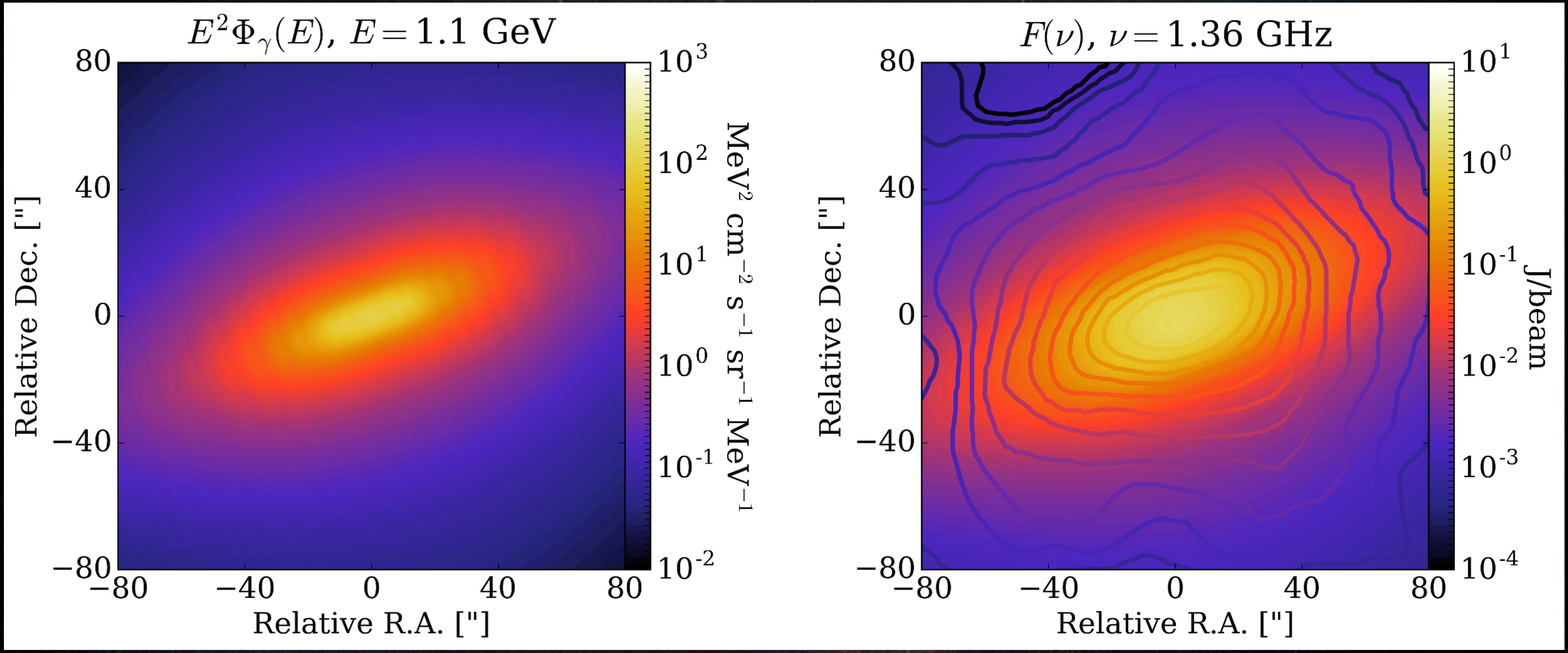
- Magnetic Field and Gas Densities – B_0, n_0 + power laws
- Wind
- Diffusion Coefficient
- Free-free emission + absorption

GALPROP


Cosmic ray Distribution
Energy Losses
Diffusion
Injection
GALPROP
►injection
►propagation
►energy losses
►secondaries
Radio Emission
• Synchrotron
• Free-Free
Gamma-ray Emission
• Bremsstrahlung
• Inverse Compton
• Pion-decay Emission

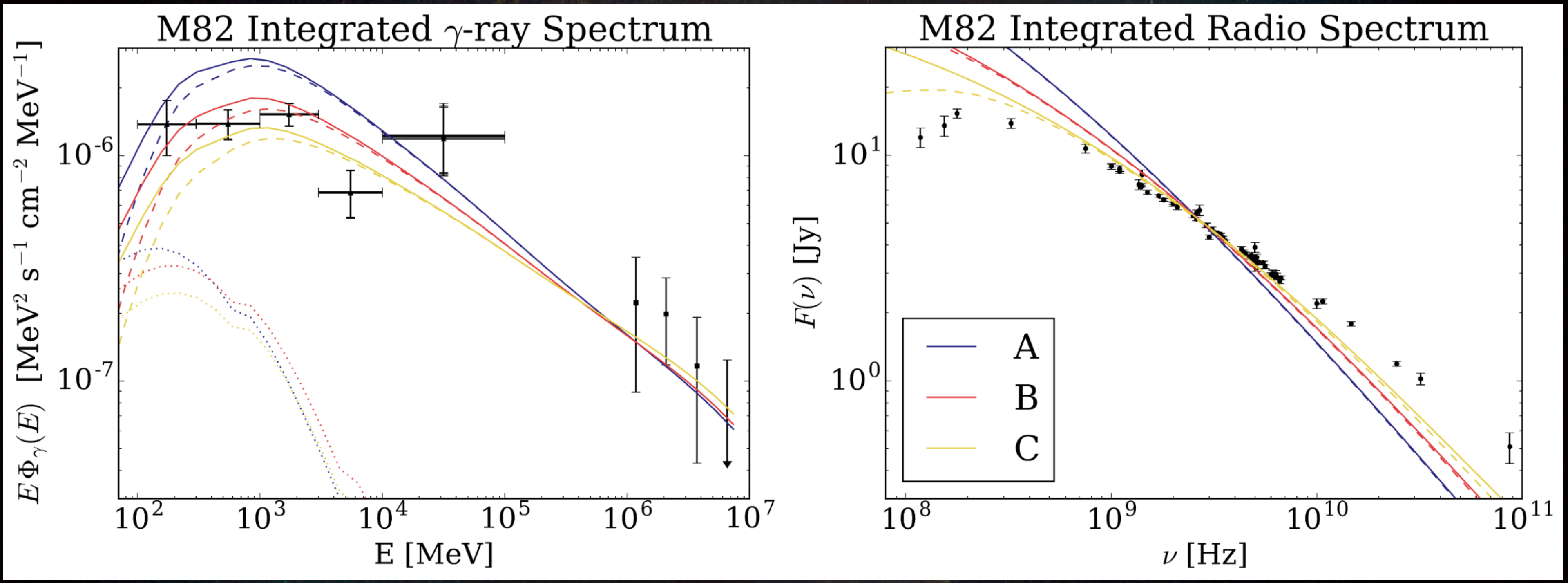
RESULTS I

Create images of M82 in gamma-rays and radio



RESULTS II

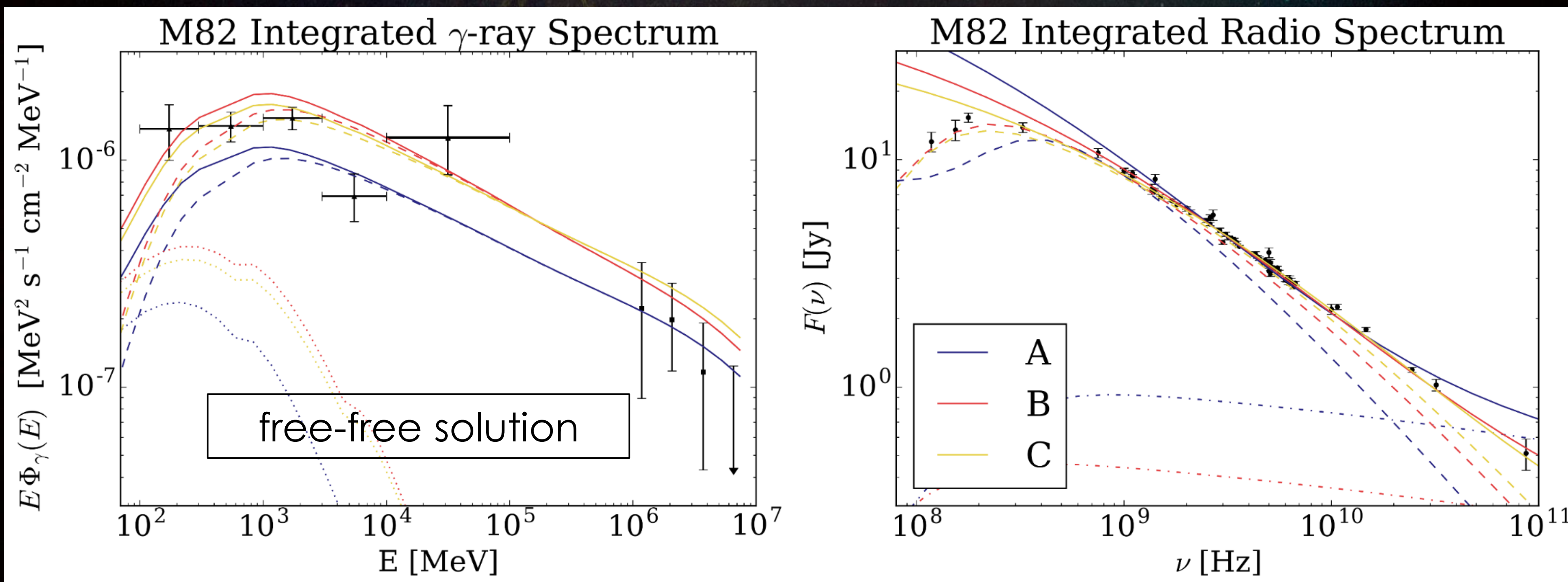
- Finding possible B_0 and n_0
  - From overall normalization of integrated radio and gamma-ray spectra



$[B_0\ (\mu G), n_0\ (cm^{-3})]$ ► A – [200, 200] B – [400,800] C – [800,2000]

RESULTS III

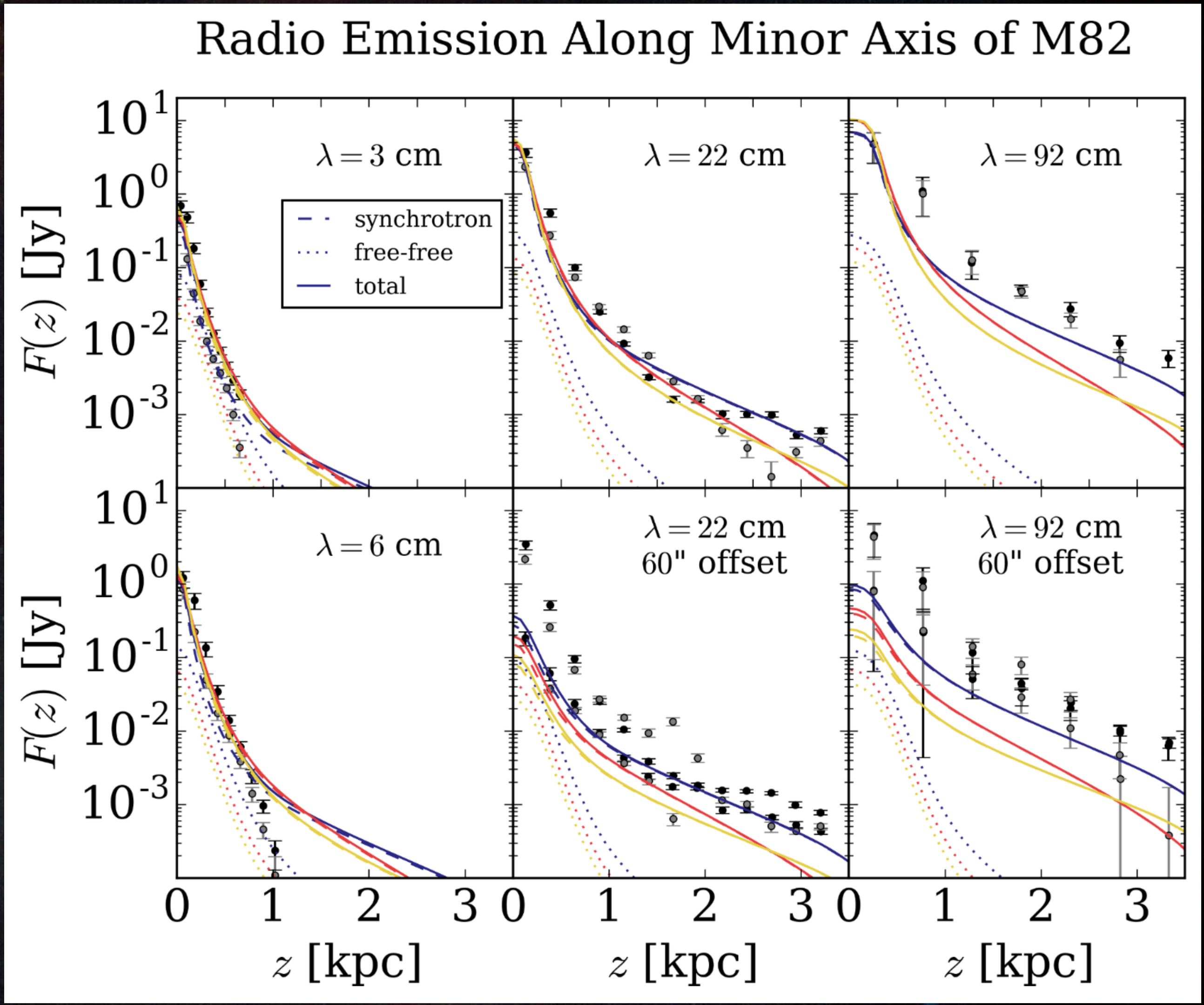
- Possible Solutions
  - Decrease D_{xx}
  - More free-free emission & absorption



$[B_0\ (\mu G), n_0\ (cm^{-3})]$ ► A – [200, 200] B – [400,800] C – [800,2000]

RESULTS IV

- Hardest points to fit are [0.5,1.0] kpc
- Hard to get 92cm and 22cm without overproducing 6cm and 3cm



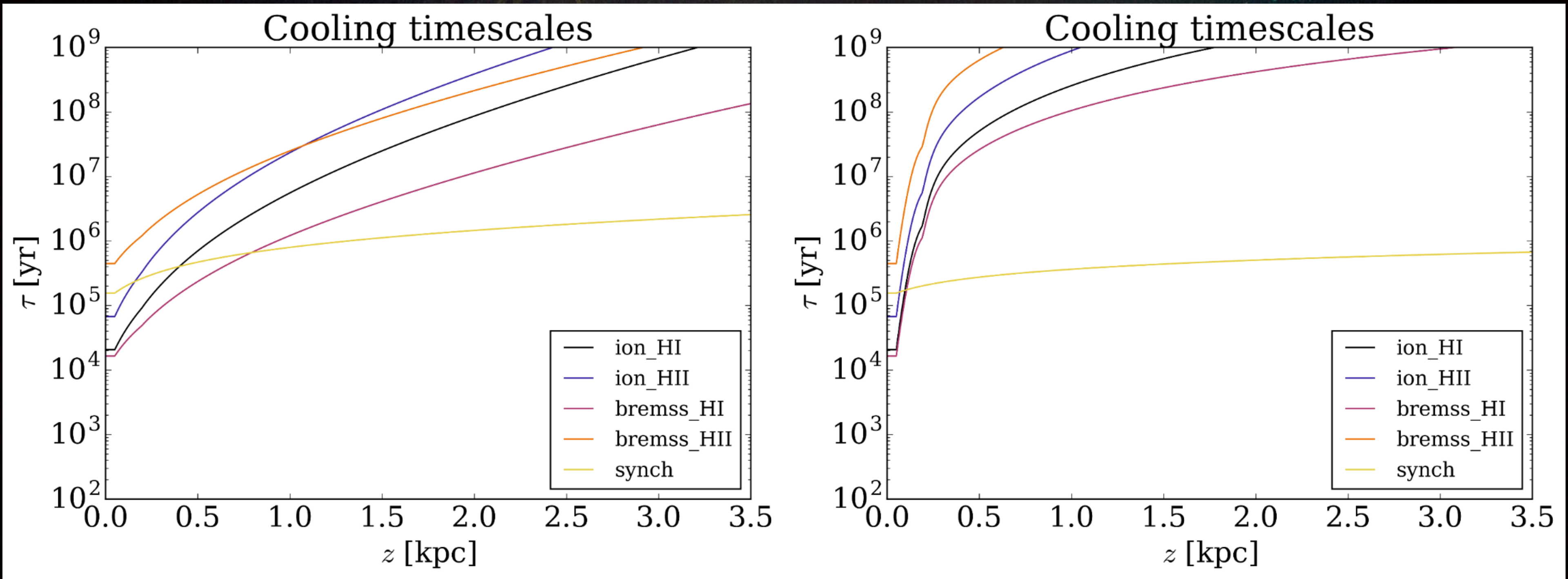
RESULTS V

$$\left(\frac{E}{1\ GeV}\right) = \left(\frac{\nu_{crit}}{1\ GHz}\right)^{\frac{1}{2}} \left(\frac{B}{100\ \mu G}\right)^{-\frac{1}{2}}$$

- Possible solution – synchrotron or IC cooling
  - $\tau_{bremss} \sim 3 \times 10^5 \left(\frac{n}{100\ cm^{-3}}\right)^{-1}$ yr
  - $\tau_{IC} \sim 3 \times 10^5 \left(\frac{\nu_{crit}}{1\ GHz}\right)^{-\frac{1}{2}} \left(\frac{B}{100\ \mu G}\right)^{\frac{1}{2}} \left(\frac{U_{rad}}{1000\ eV\ cm^{-3}}\right)^{-1}$ yr
  - $\tau_{synch} \sim 10^6 \left(\frac{\nu_{crit}}{1\ GHz}\right)^{-\frac{1}{2}} \left(\frac{B}{100\ \mu G}\right)^{-\frac{3}{2}}$ yr

steepen spectrum

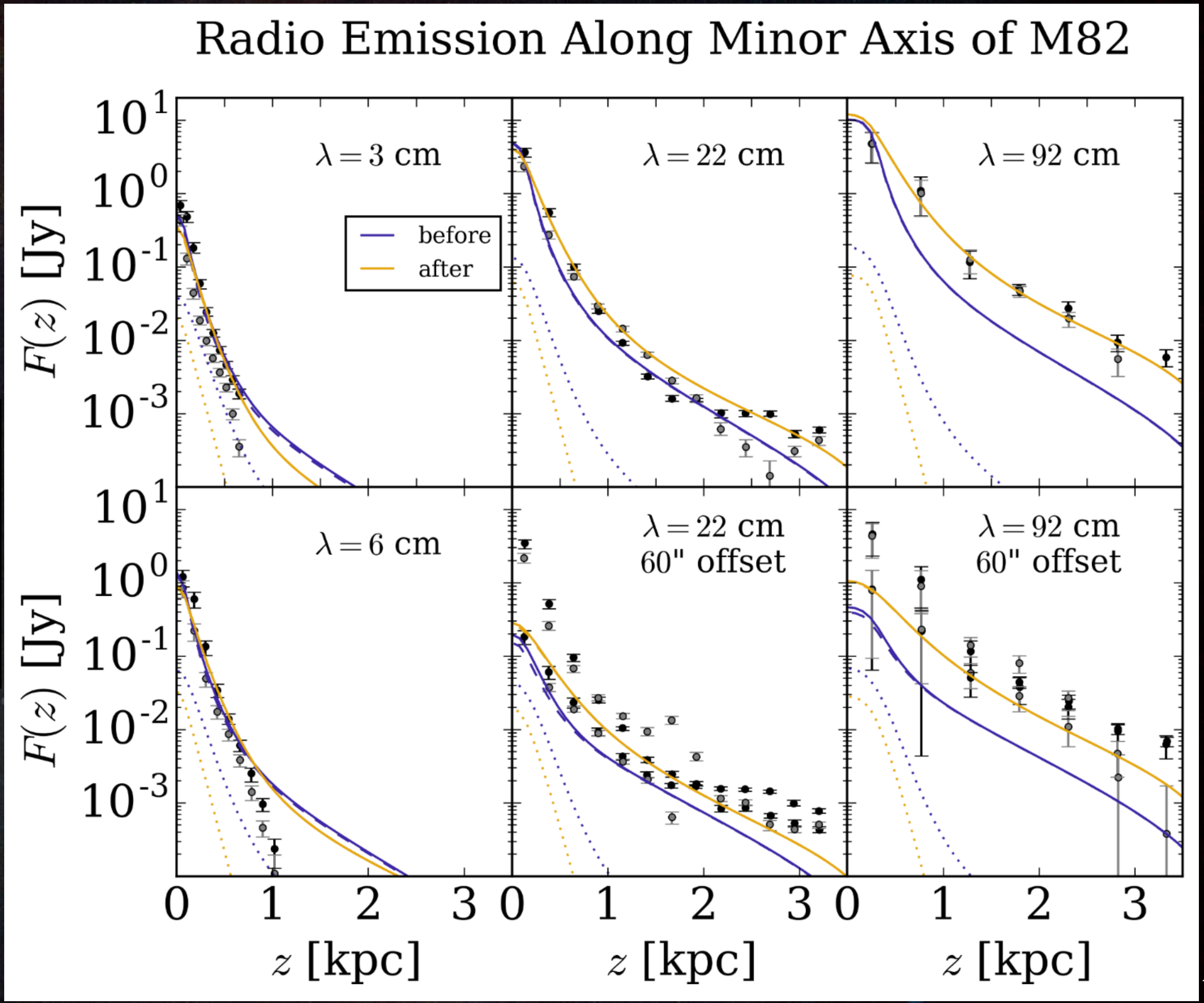
RESULTS VI



Cooling timescales
τ [yr]
z [kpc]
10^2
10^3
10^4
10^5
10^6
10^7
10^8
10^9
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
ion_HI
ion_HII
bremss_HI
bremss_HII
synch
Cooling timescales
τ [yr]
z [kpc]
ion_HI
ion_HII
bremss_HI
bremss_HII
synch

RESULTS VI

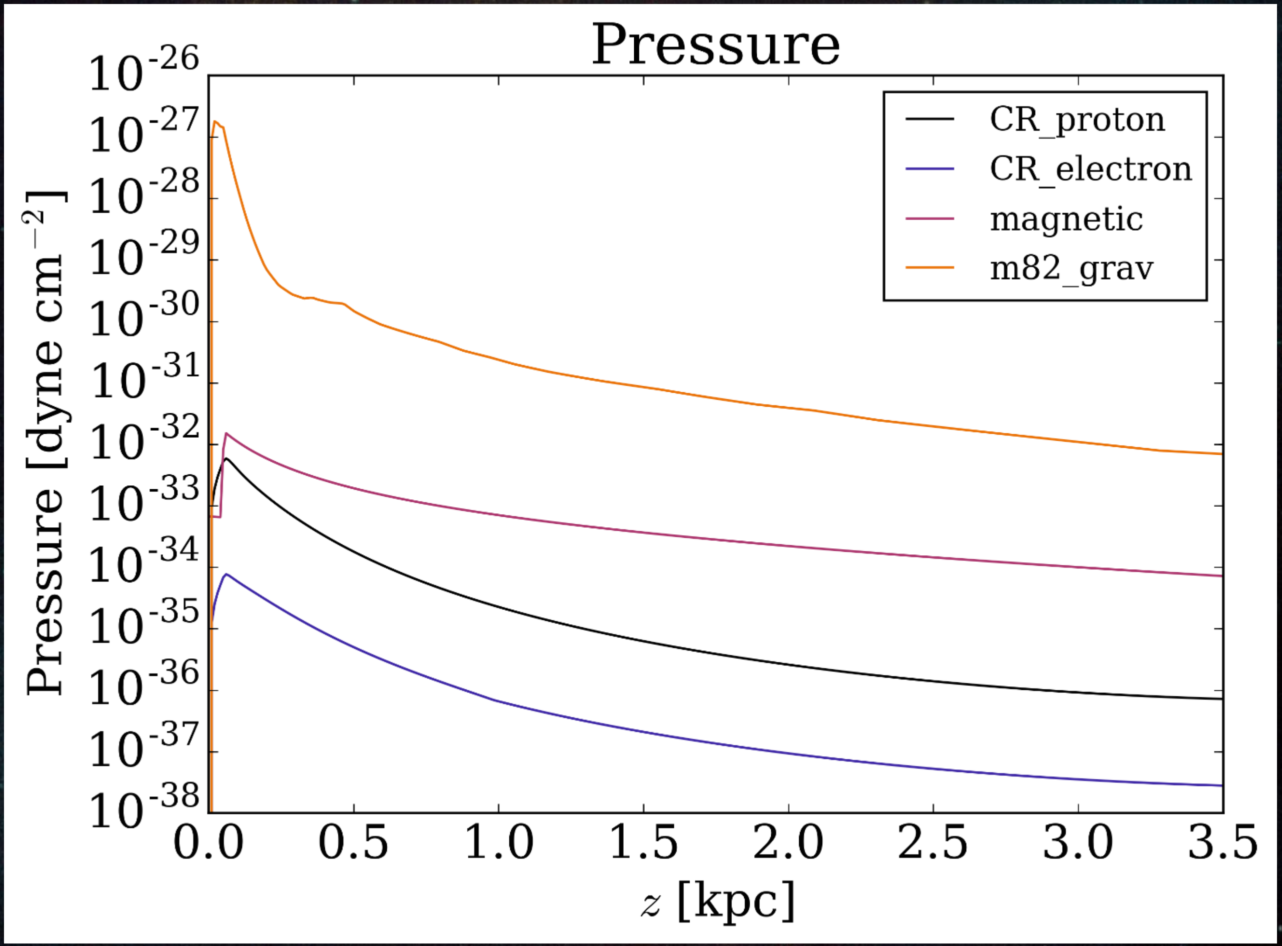
- Allowing the gas density to decrease much faster than magnetic field gives better fits



SUMMARY

- Using GALPROP, able to model starburst galaxy M82 radio and gamma ray emission
- We can put constraints on magnetic fields, gas densities, and cosmic ray propagation properties
- Spectral hardening along minor axis can be due to synchrotron cooling
- Gamma-rays are important for the modeling of cosmic rays

PRESSURE



Pressure
Pressure [dyne cm^{-2}]
10^{-26}
10^{-27}
10^{-28}
10^{-29}
10^{-30}
10^{-31}
10^{-32}
10^{-33}
10^{-34}
10^{-35}
10^{-36}
10^{-37}
10^{-38}
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
z [kpc]
CR_proton
CR_electron
magnetic
m82_grav