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Dusty plasmas with magnetized dust

Bob Merlino
University of Iowa

Full text available at:
http://www.physics.uiowa.edu/~rmerlino/Dusty%20Plasmas.htm

Why?

- New dusty plasma physics to study
- Astrophysical and planetary dusty plasmas have magnetized dust
- Much theoretical work on waves in magnetized dusty plasmas has been done

Criteria for magnetized dust

1. $r_{cd} << \ell_{\perp}$

dust gyroradius << transverse plasma dimension

2. $\omega_{cd} >> \nu_{dn}$

dust gyrofrequency >> dust-neutral collision frequency

Parameter scalings (a = dust radius)

- $r_{cd} = \dfrac{v_{T_d}}{\omega_{cd}} = \dfrac{\left(kT_d / m_d\right)^{\frac{1}{2}}}{eZ_d B / m_d} \sim \dfrac{a^{\frac{1}{2}} T_d^{\frac{1}{2}}}{B}$

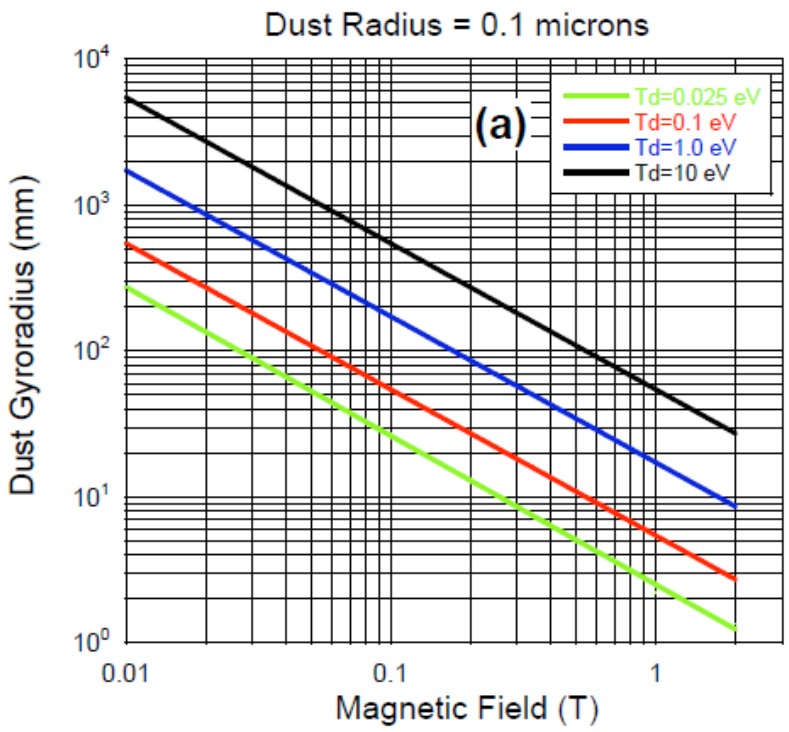
- $\nu_{dn} = \dfrac{4\pi m_n N v_{T_n} a^2}{3m_d} \sim \dfrac{P}{a}$

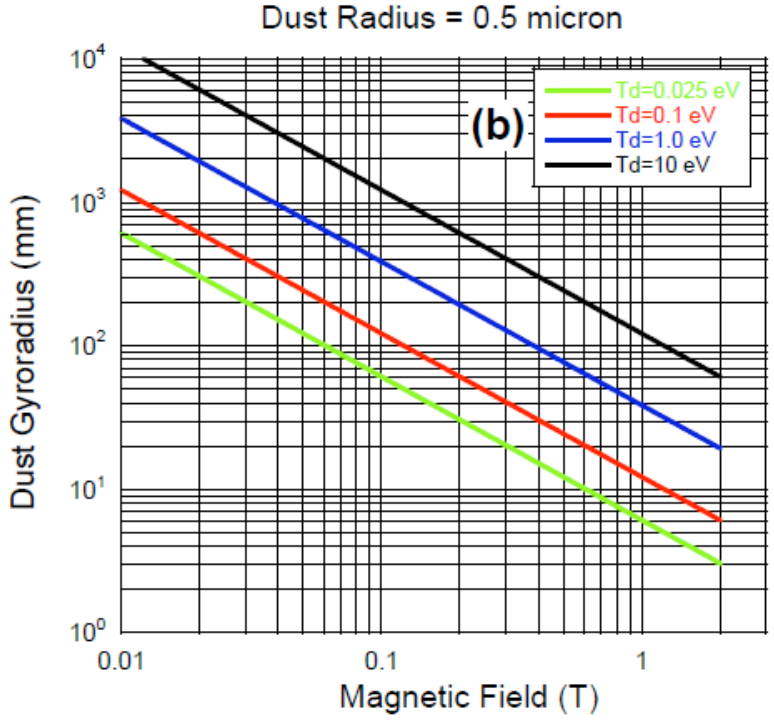
- $\dfrac{\omega_{cd}}{\nu_{dn}} \sim \dfrac{B}{aP}$

- $\dfrac{\text{magnetic force}}{\text{weight}} = \dfrac{F_m}{F_g} = \dfrac{eZ_d v_{T_d} B}{m_d g} \sim \dfrac{T_d^{1/2} B}{a^{7/2}}$

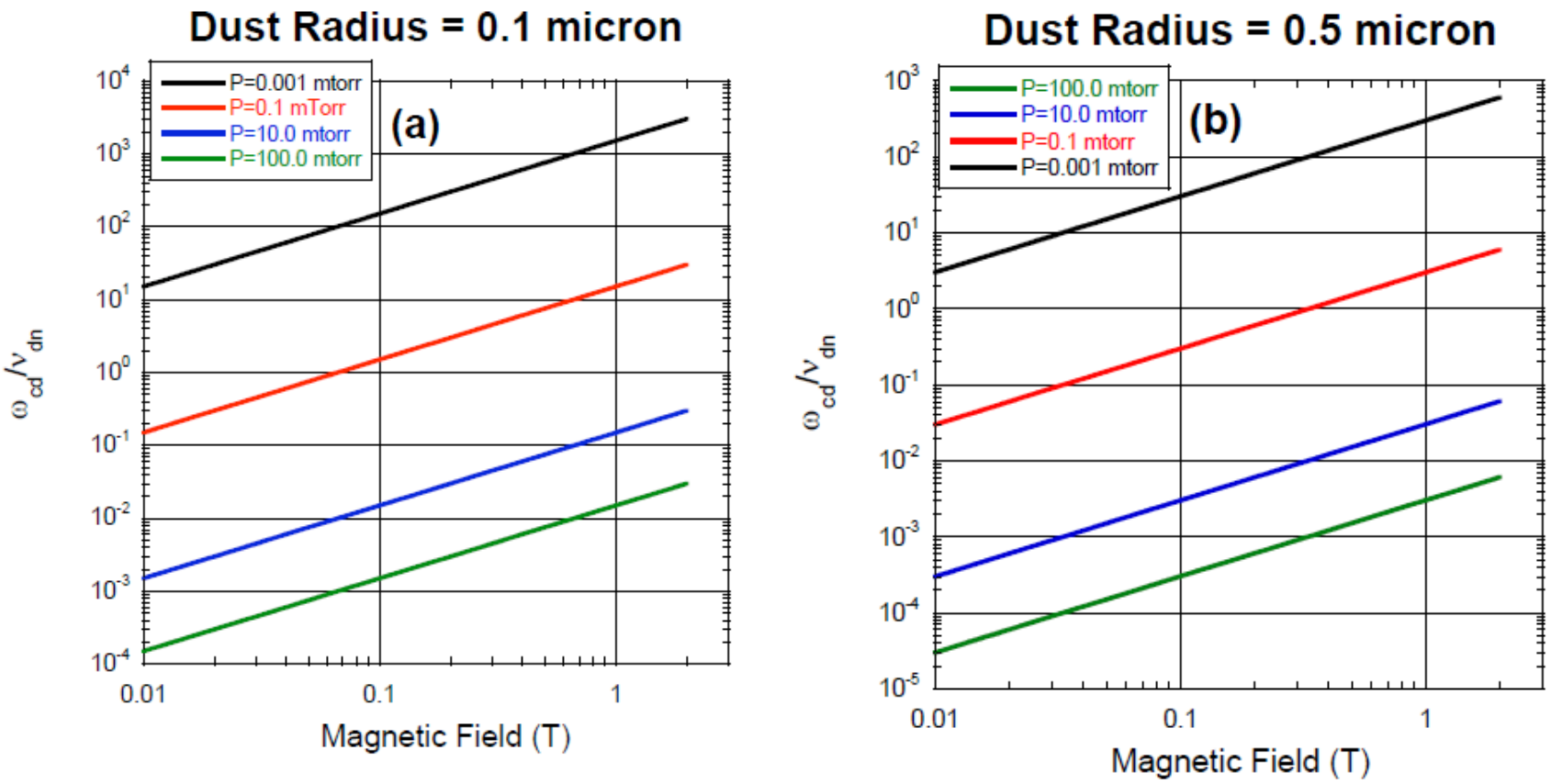
Dust gyroradius vs. B

T_e = 2.5 eV, T_i = 0.025 eV, argon plasma





ω_{cd} / ν_{dn} vs. B



1 mtorr ≈ 0.13 Pa

Magnetic field strength *vs.* device size

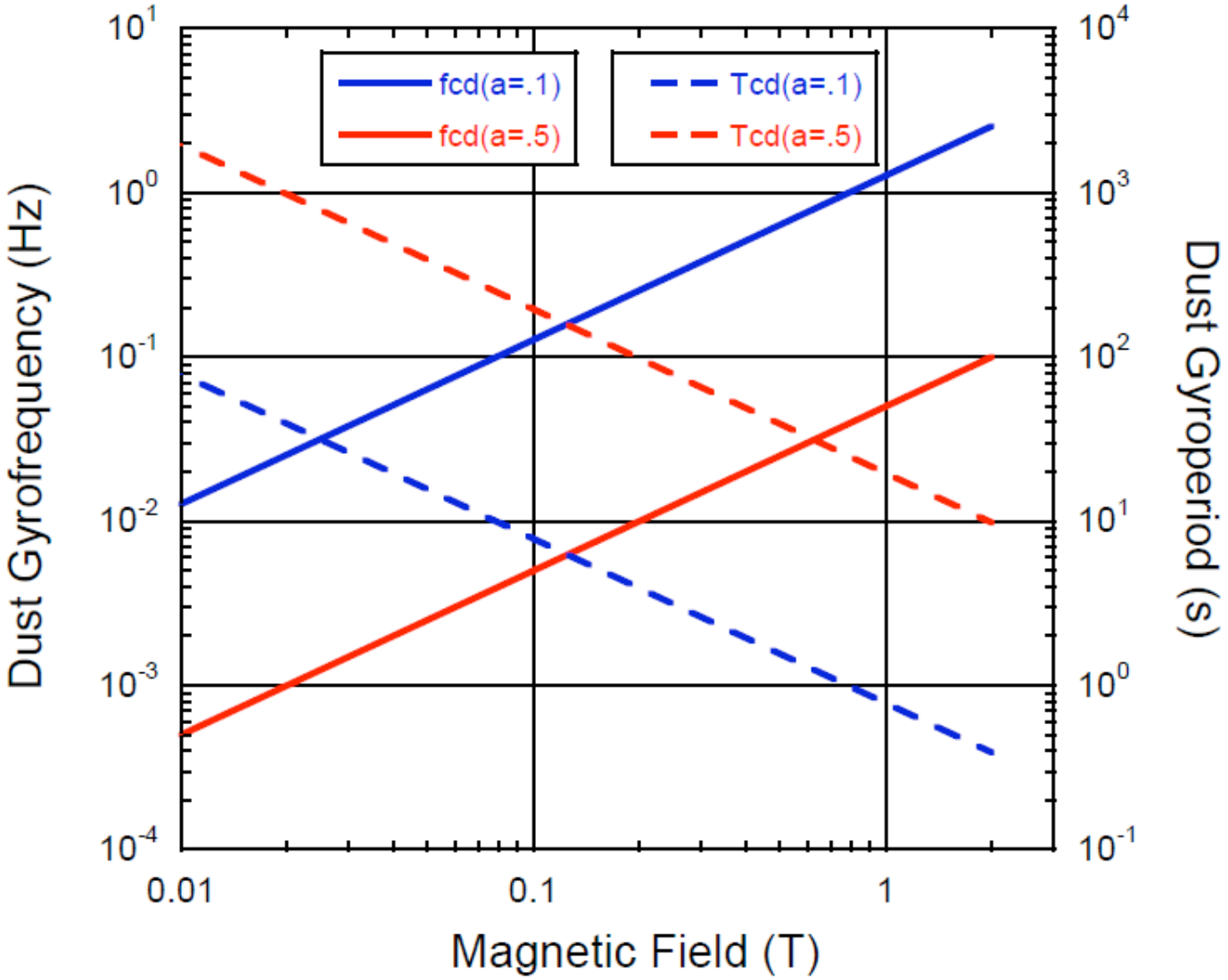
- Criteria can be satisfied with high B and moderate size device, or
- Moderate B and very large device
- Cost trade-off ??

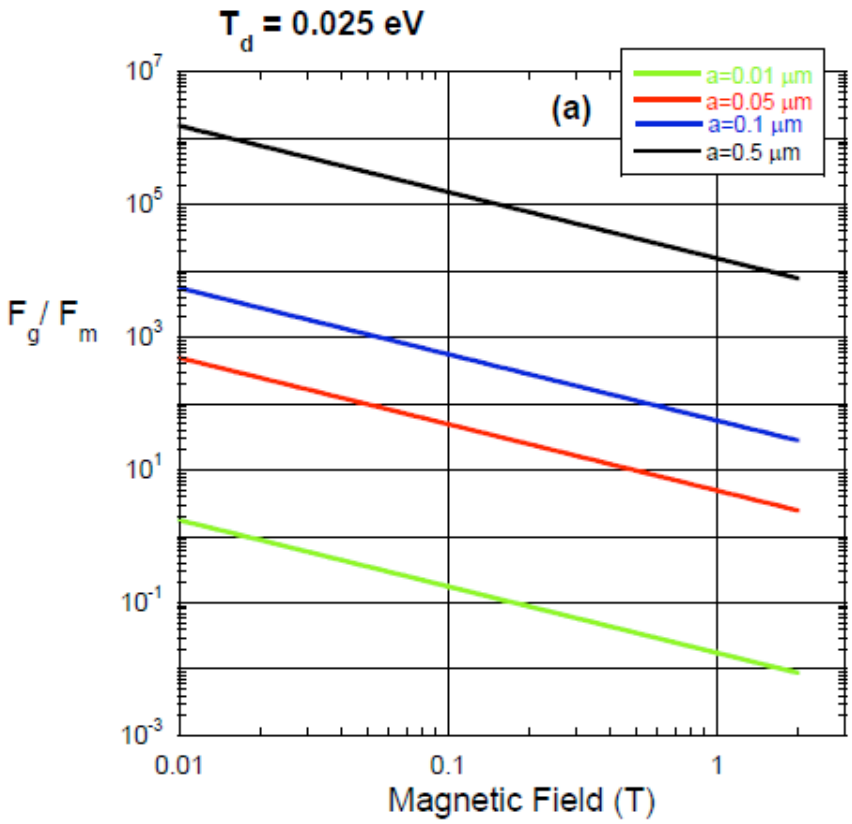
Dust size consideration

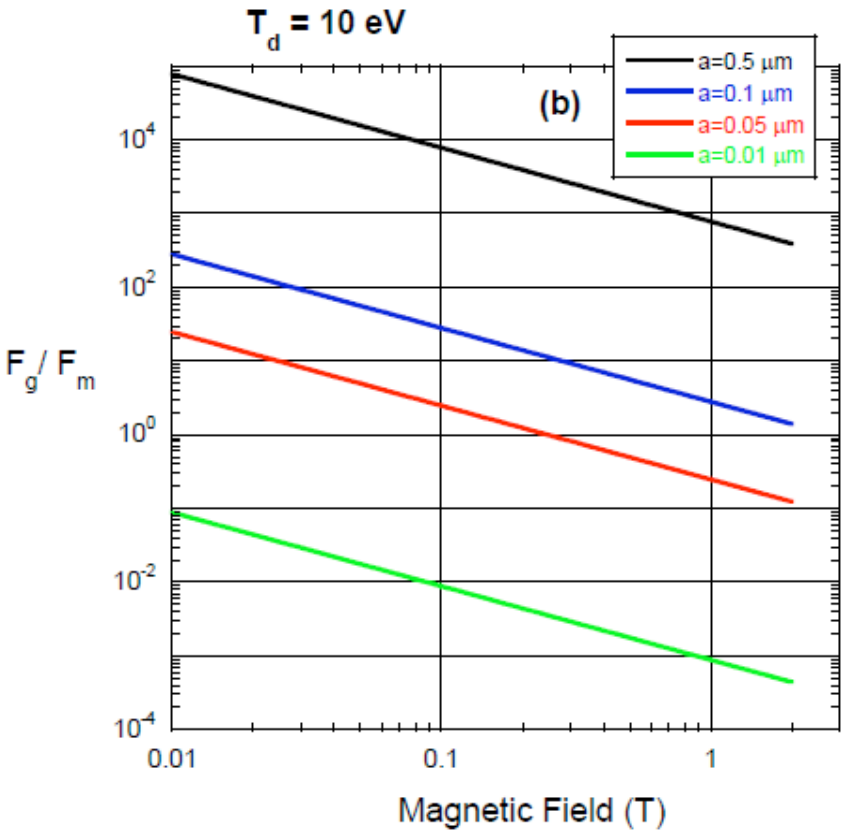
- Both criteria are satisfied more easily with small dust grains
- But, grains that are too small are not easily imaged
- Another issue ➔ diagnostics ??

Plasma source considerations

- Not easy to make uniform and stable plasmas in high B fields
- Discharge sources require neutral gas, and the dust-neutral collision frequency ~ pressure
- Probably need plasma source that operates at lower pressures

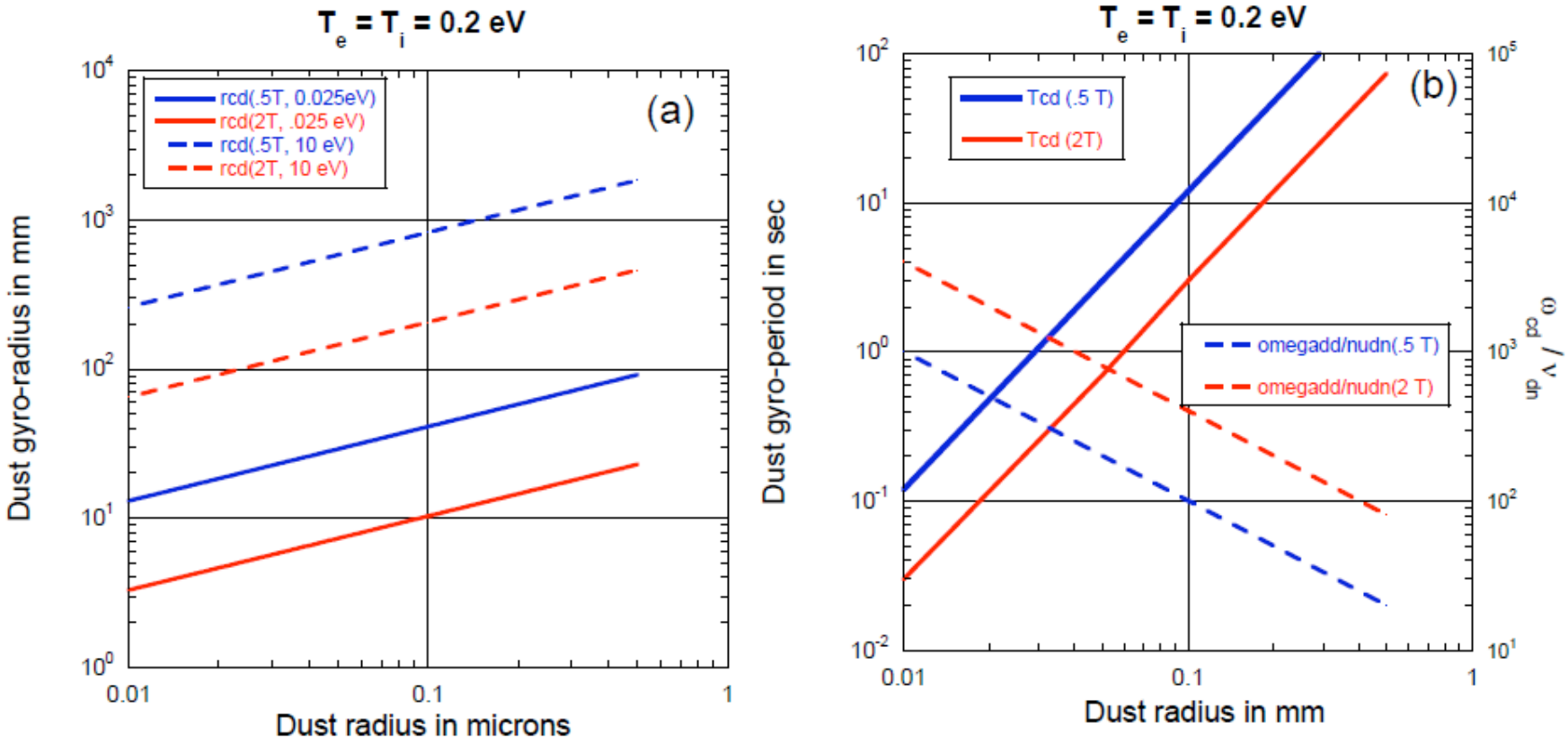

fcd(a=.1)
fcd(a=.5)
Tcd(a=.1)
Tcd(a=.5)
Dust Gyrofrequency (Hz)
Dust Gyroperiod (s)
Magnetic Field (T)
10^1
10^0
10^-1
10^-2
10^-3
10^-4
10^4
10^3
10^2
10^1
10^0
10^-1
0.01
0.1
1


T_d = 0.025 eV
(a)
a=0.01 μm
a=0.05 μm
a=0.1 μm
a=0.5 μm
F_g / F_m
10^7
10^5
10^3
10^1
10^-1
10^-3
0.01
0.1
1
Magnetic Field (T)


T_d = 10 eV
(b)
a=0.5 μm
a=0.1 μm
a=0.05 μm
a=0.01 μm
F_g / F_m
10^4
10^2
10^0
10^-2
10^-4
0.01
0.1
1
Magnetic Field (T)

Q machine parameters

- low temperatures
- low pressure



questions

- Should the particles be large enough to be imaged?
- How will we diagnose this dusty plasma?
- What type of plasma source should be used?
- What dusty plasma physics should be studied?