Using percolation-based effective-medium approximation to determine effective permeability in fractured reservoirs

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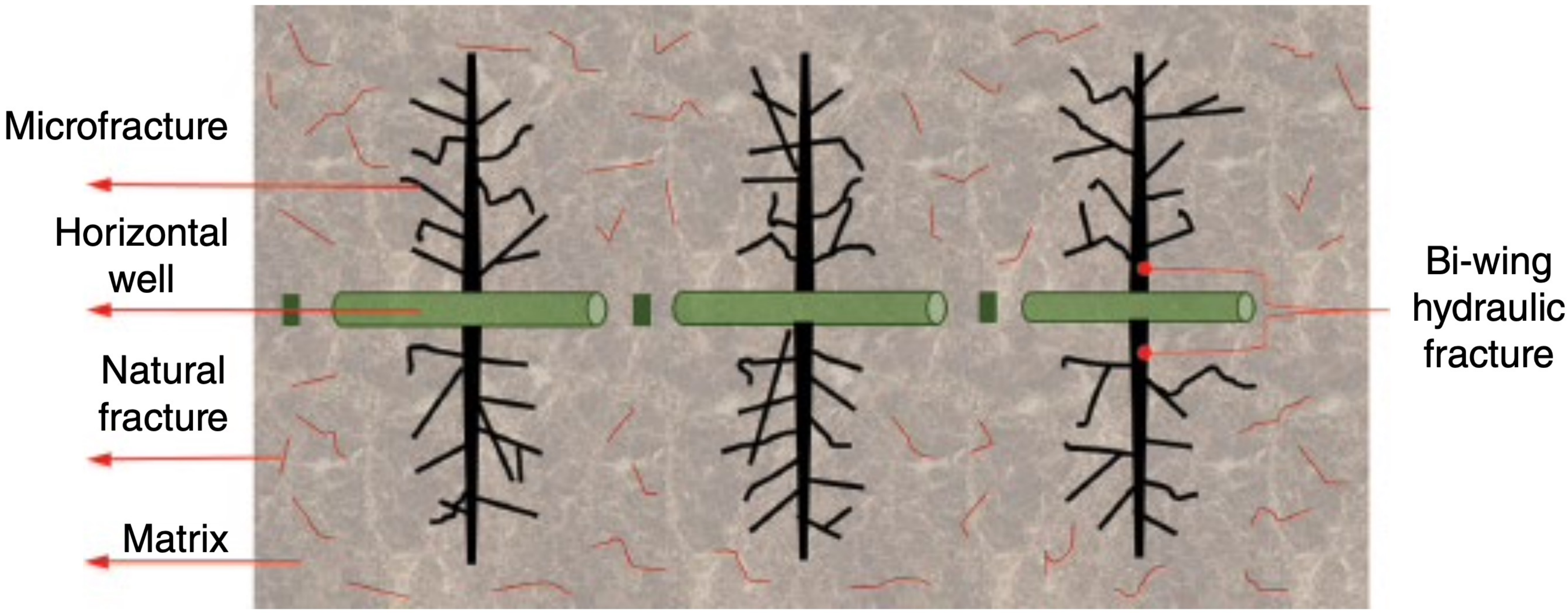
2021 AGU Fall Meeting

Introduction



Schematic of multi-scale fracture system in the shale gas reservoir after hydraulic fracturing operations. Natural fracture, microfracture, and hydraulic fractures coexist (after Chen et al., 2019).

Objectives

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(1) Developing a theoretical model for effective permeability in matrix-fracture systems

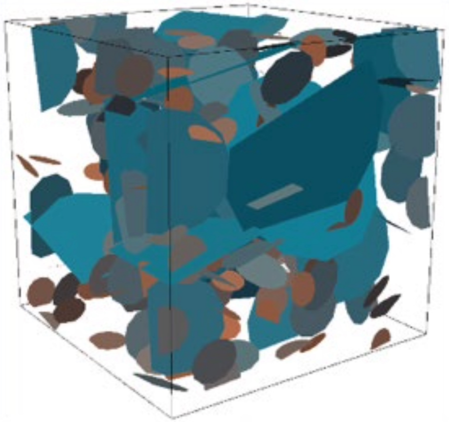
(2) Comparing theoretical estimates with 2- and 3-D numerical simulations

Simulations

Matrix-fracture systems

- Chen et al. (2019)
Discrete fracture-matrix networks were composed of line (2D) and elliptical (3D) fractures.

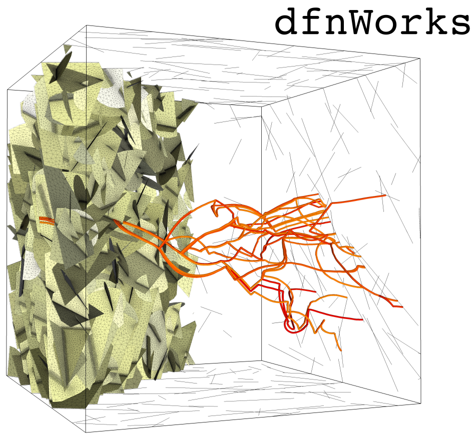
Generalized lattice Boltzmann (LB) method to simulate fluid flow.



Chen et al. (2019)

- New 3-D simulations via dfnWorks
Planar discs with a constant radius.

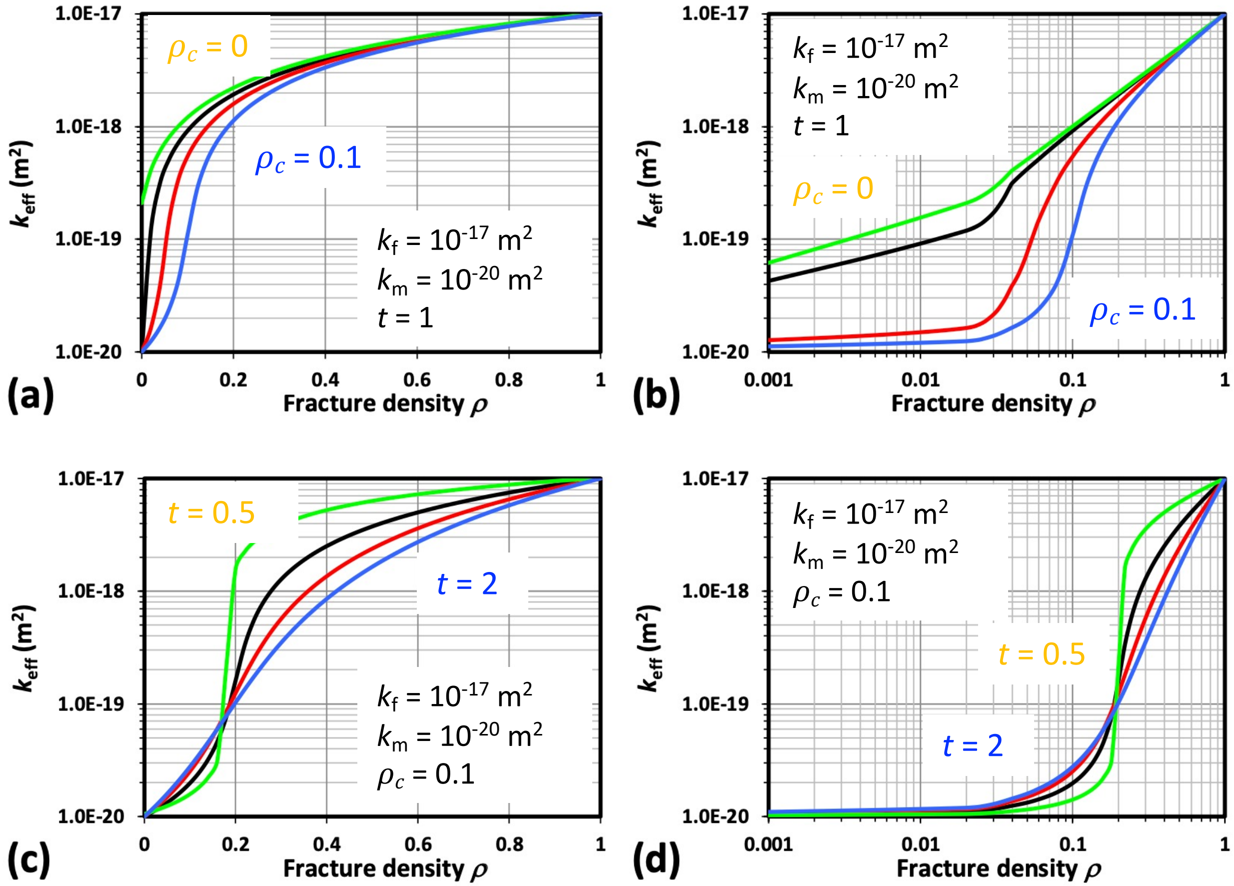
Fluid flow is simulated based on the Reynolds equation.



https://dfnworks.lanl.gov/

Percolation-based EMA

$$(1-\rho)\frac{k_m^{\frac{1}{t}} - k_{eff}^{\frac{1}{t}}}{k_m^{\frac{1}{t}} + \left[\frac{1-\rho_c}{\rho_c}\right] k_{eff}^{\frac{1}{t}}} + \rho\frac{k_f^{\frac{1}{t}} - k_{eff}^{\frac{1}{t}}}{k_f^{\frac{1}{t}} + \left[\frac{1-\rho_c}{\rho_c}\right] k_{eff}^{\frac{1}{t}}} = 0$$



Results

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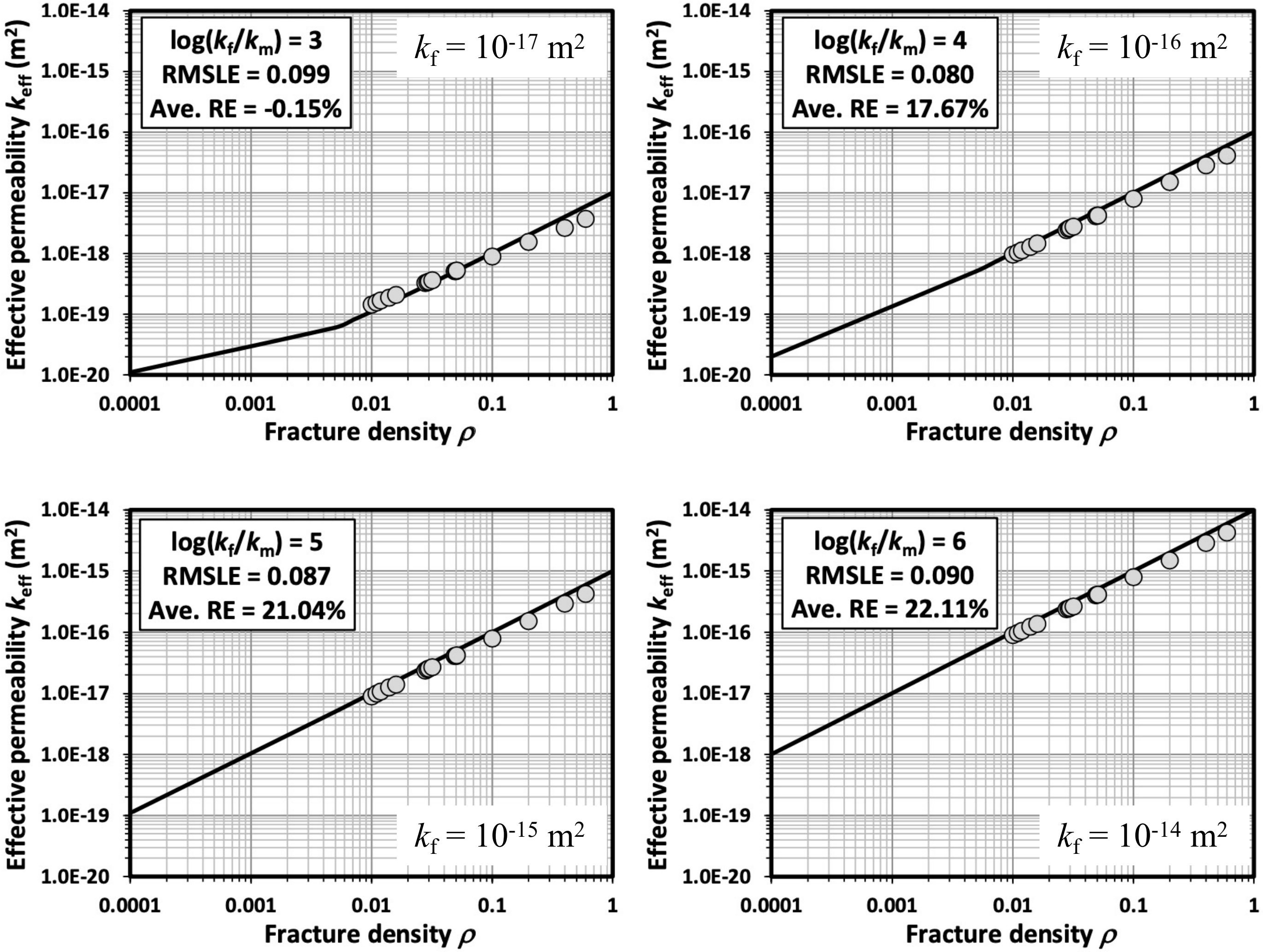
2-D simulations (Chen et al., 2019)

$t = 1$

$\rho_c = 0$

$k_m = 10^{-20}\ m^2$



Results

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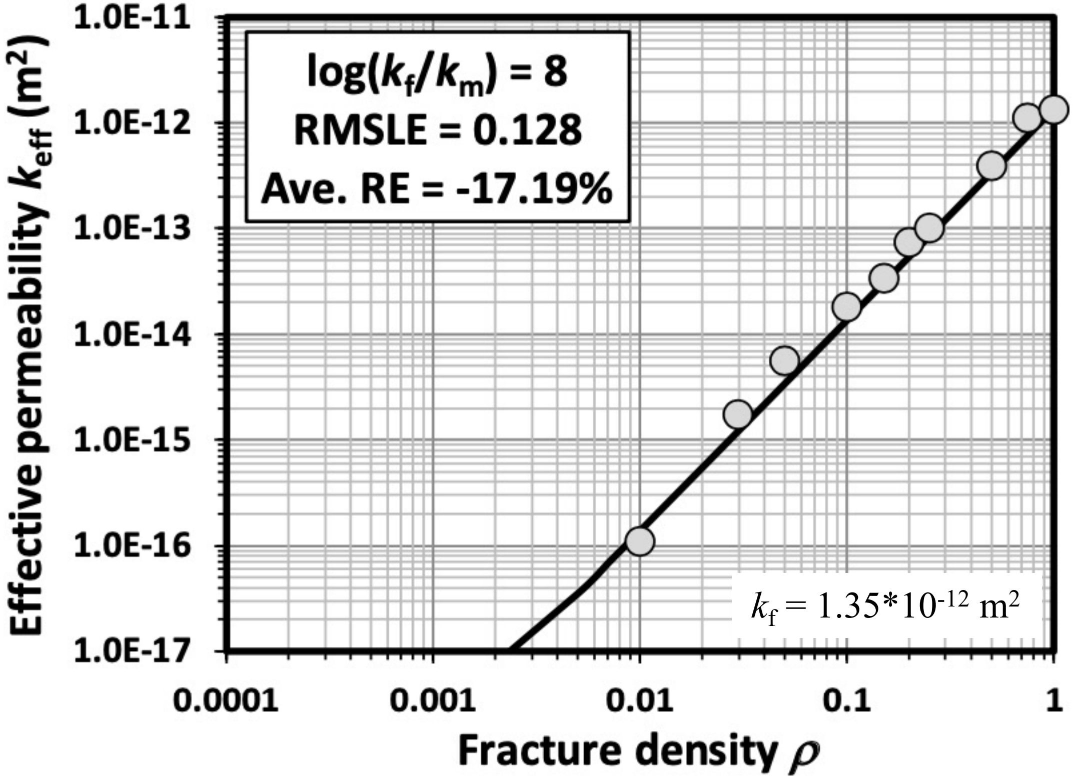
3-D simulations (Chen et al., 2019)

$t = 2$

$\rho_c = 0$

$k_m = 1.35*10^{-20}\ m^2$



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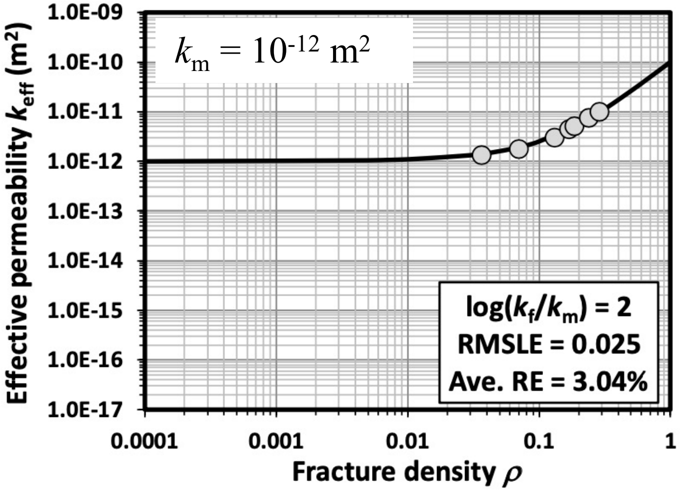
Results

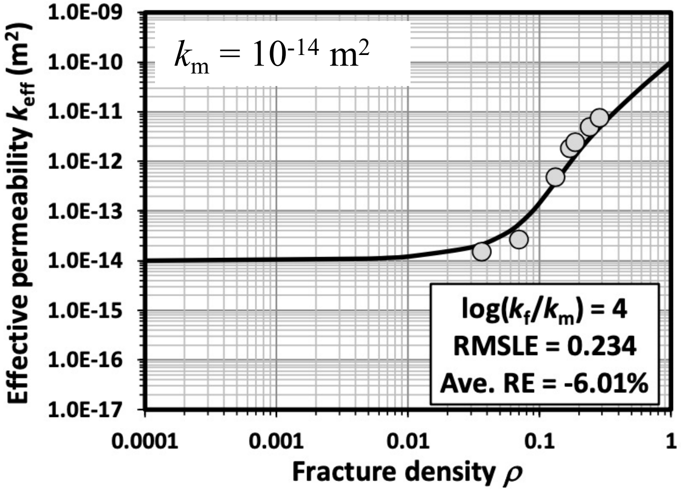
3-D dfnWork simulations

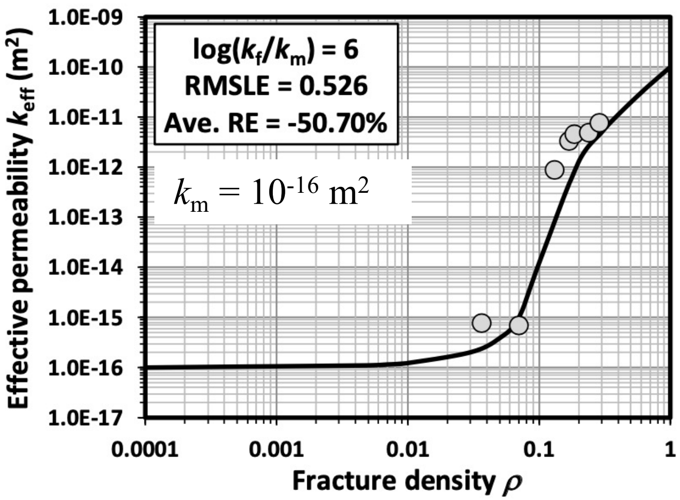
$t = 2$

$\rho_c = 0.1$

$k_f = 10^{-10}\ m^2$







Conclusion

- The proposed P-EMA model estimated the k_{eff} reasonably well.

- We found that the scaling exponent $t = 1$ resulted in accurate estimations of k_{eff} in two dimensions, while $t = 2$ led to good agreement between the theory and simulations in three dimensions.

- In contrast to other empirical and semi-empirical models, our proposed P-EMA k_{eff} model has no ad hoc parameters and is predictive once the parameters t, ρ_c, k_m, and k_f are known for a fractured reservoir.

Acknowledgement

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Questions?

Simulations

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Matrix-fracture systems

- Chen et al. (2019): Two dimensions

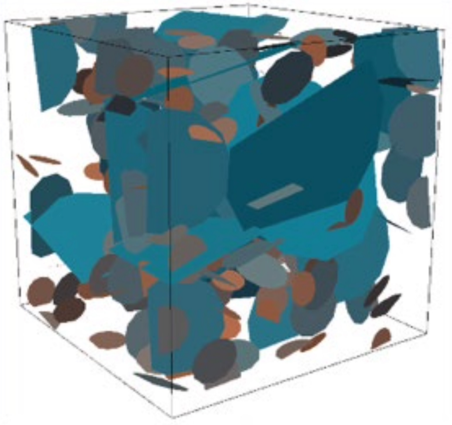
Two random numbers were generated based on a uniform distribution to determine the coordinates of two points in the domain.

A fracture with width of one lattice units and permeability of 3.33×10^{-9} m2 (3.33×10^{3} D; based on the cubic law) was created by connecting the two points via a straight line.

- Chen et al. (2019): Three dimensions

the fracture network was composed of 855 elliptical fractures.

The radius of fractures followed a truncated power-law distribution with lower and upper cutoffs r_{min} = 0.1 µm and r_{max} = 1 µm and exponent 2.28.



Chen et al. (2019)

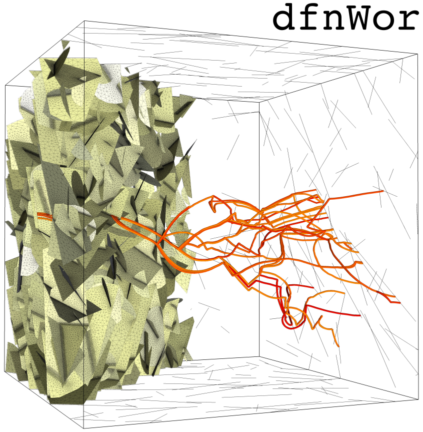
Simulations

Matrix-fracture systems

- New 3-D simulations via dfnWorks
planar discs with a constant radii of 5 meters within a 50 m cubic domain.

The orientation of fractures was sampled from a Fisher distribution with intensity parameter of 0.1 that resulted in a uniform covering of the unit sphere and equiprobable random orientations.

dfnWorks



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