PHYSICS 410

THE 2D ISING MODEL

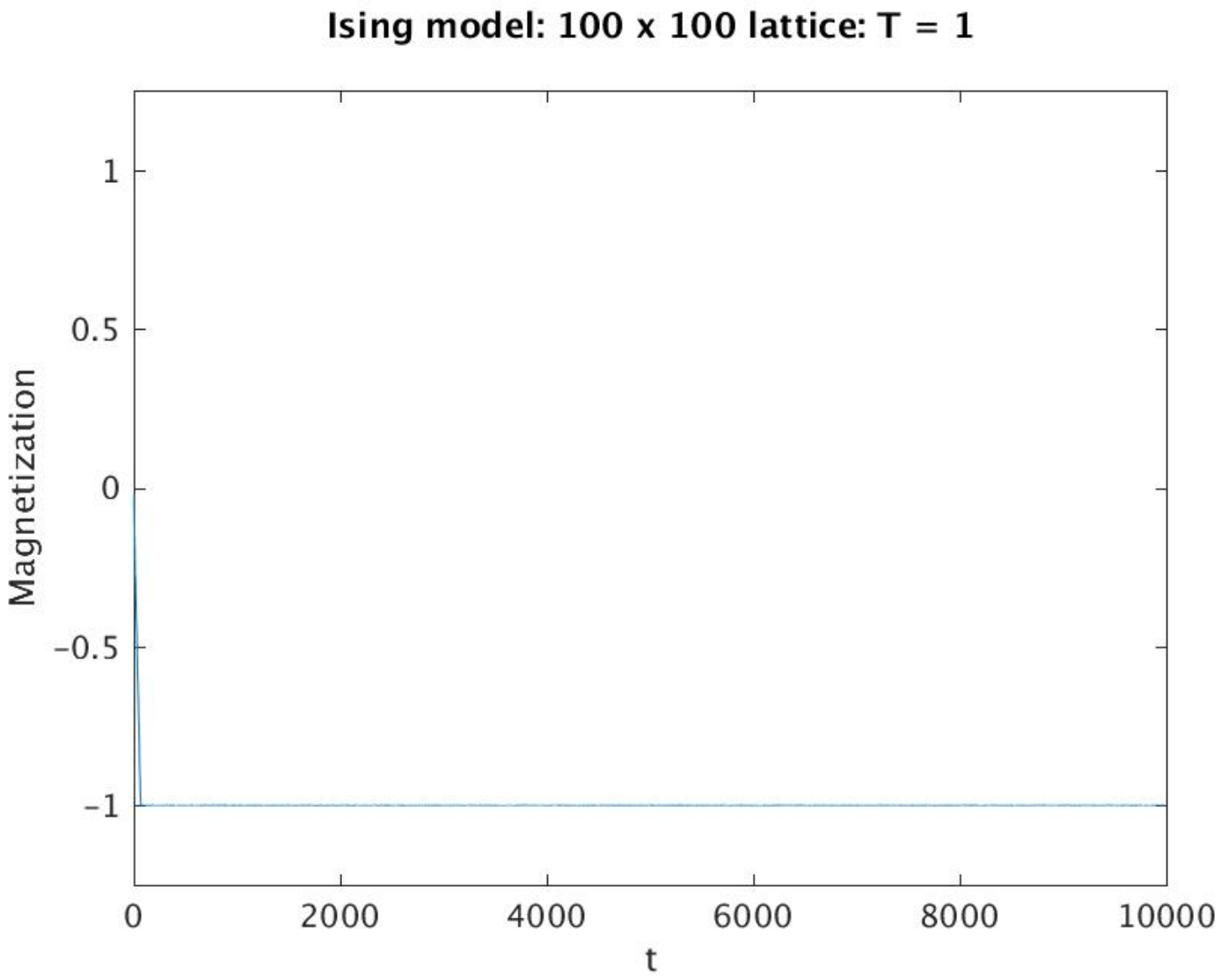
```
function [E M] = ising2d(n, nt, T)
%  ising2d: Simulates 2d Ising model with periodic boundary
%  conditions, J = 1.
%
%  Inputs
%
%     n:        Lattice size
%     nt:       Number of time steps
%     T:        Vector of temperatures [nT]
%
%  Outputs
%
%     E:        Normalized energy [nT x nt]
%     M:        Normalized magnetization [nT x nt]
   nT = length(T);
   M = zeros(nT,nt);
   E = zeros(nT,nt);
   lat = randi([0 1],n,n) * 2 - 1;
   trace = 100;

   for iT = 1 : length(T)
      for it = 1 : nt
```

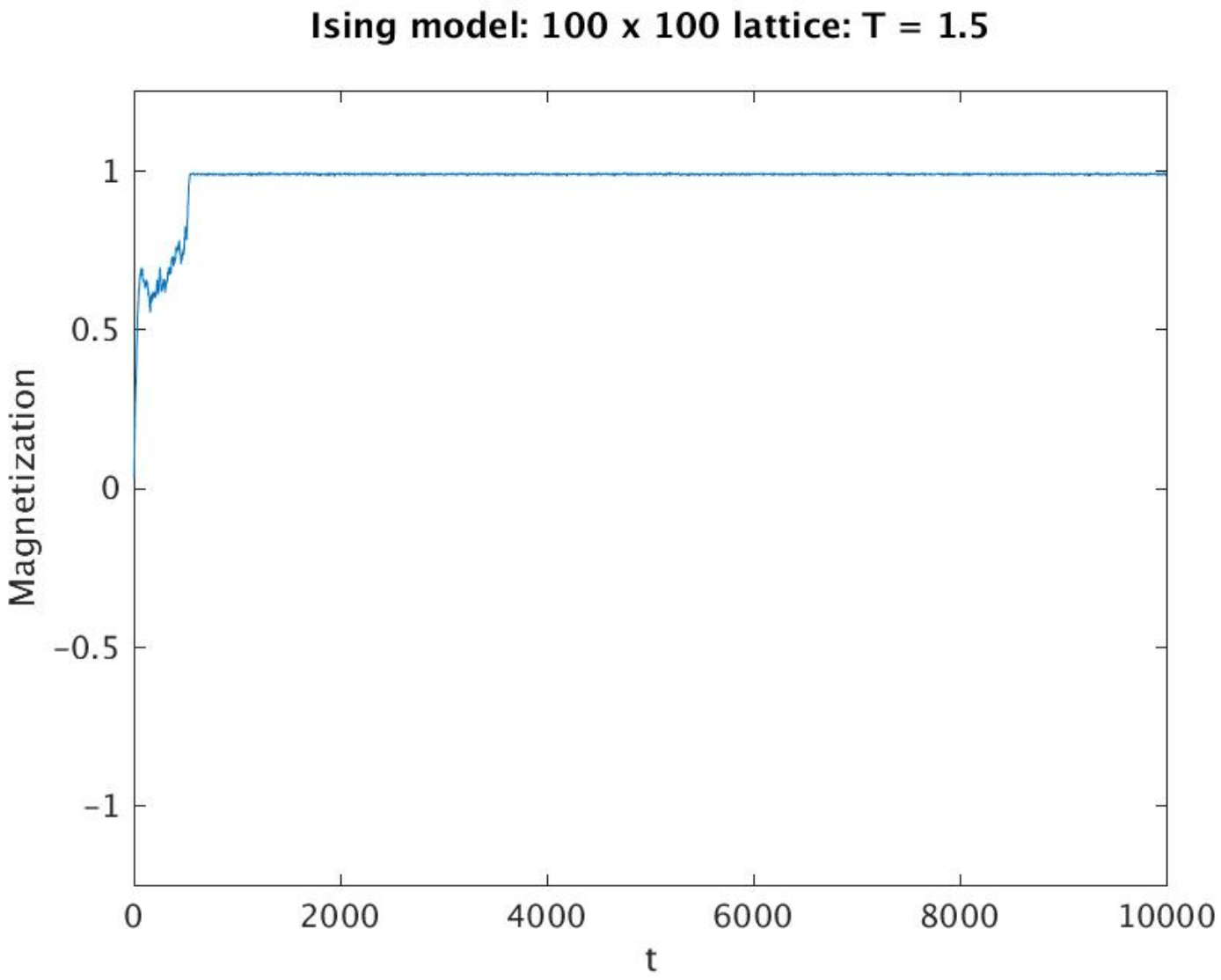
```
if trace & mod(it,trace) == 0
   fprintf('ising2d: Step %d of %d\n', it, nt);
end
for ii = 1 : n
   for jj = 1 : n
      % Handle periodic boundary conditions ...
      if ii == 1
         iiw = n;
      else
         iiw = ii - 1;
      end
      if ii == n
         iie = 1;
      else
         iie = ii + 1;
      end
      if jj == 1
         jjn = n;
      else
         jjn = jj - 1;
      end
      if jj == n
```

```
                jjs = 1;
            else
                jjs = jj + 1;
            end
            % Compute spin-flip energy cost ...
            Eloc = -lat(ii,jj) * (lat(iiw,jj) + lat(iie,jj) + ...
                                  lat(ii,jjs) + lat(ii,jjn));
            E(iT,it) = E(iT,it) + Eloc;
            dE = -2 * Eloc;
            % Monte Carlo step ...
            if dE <= 0
                lat(ii,jj) = -lat(ii,jj);
            elseif rand(1,1) <= exp(-dE/T(iT))
                lat(ii,jj) = -lat(ii,jj);
            end
        end
    end
    % Compute normalized energy and magnetization ...
    E(iT,it) = E(iT,it) / (2 * n^2);
    M(iT,it) = sum(sum(lat)) / n^2;
  end
 end
end
```

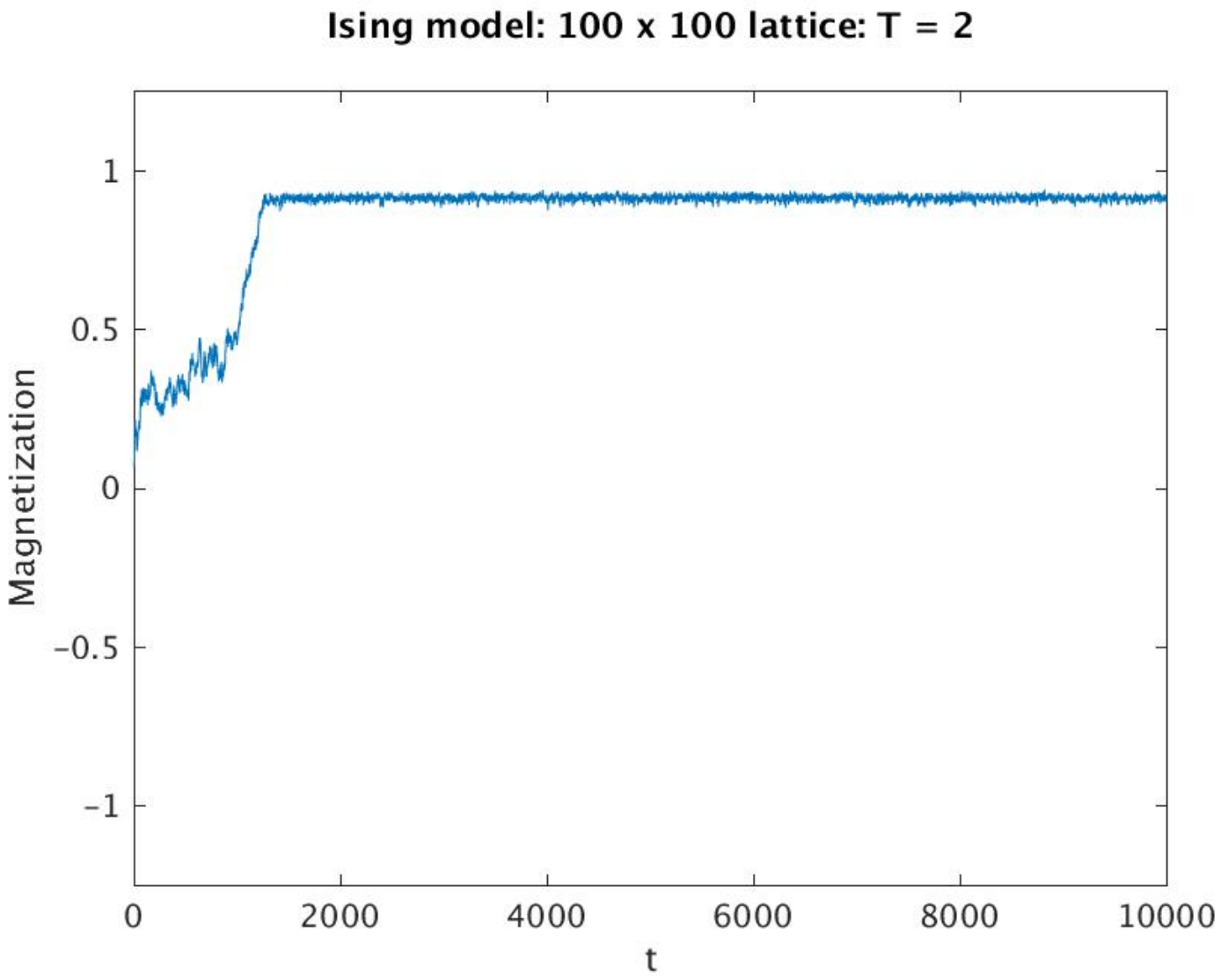
- Magnetization per spin vs discrete time



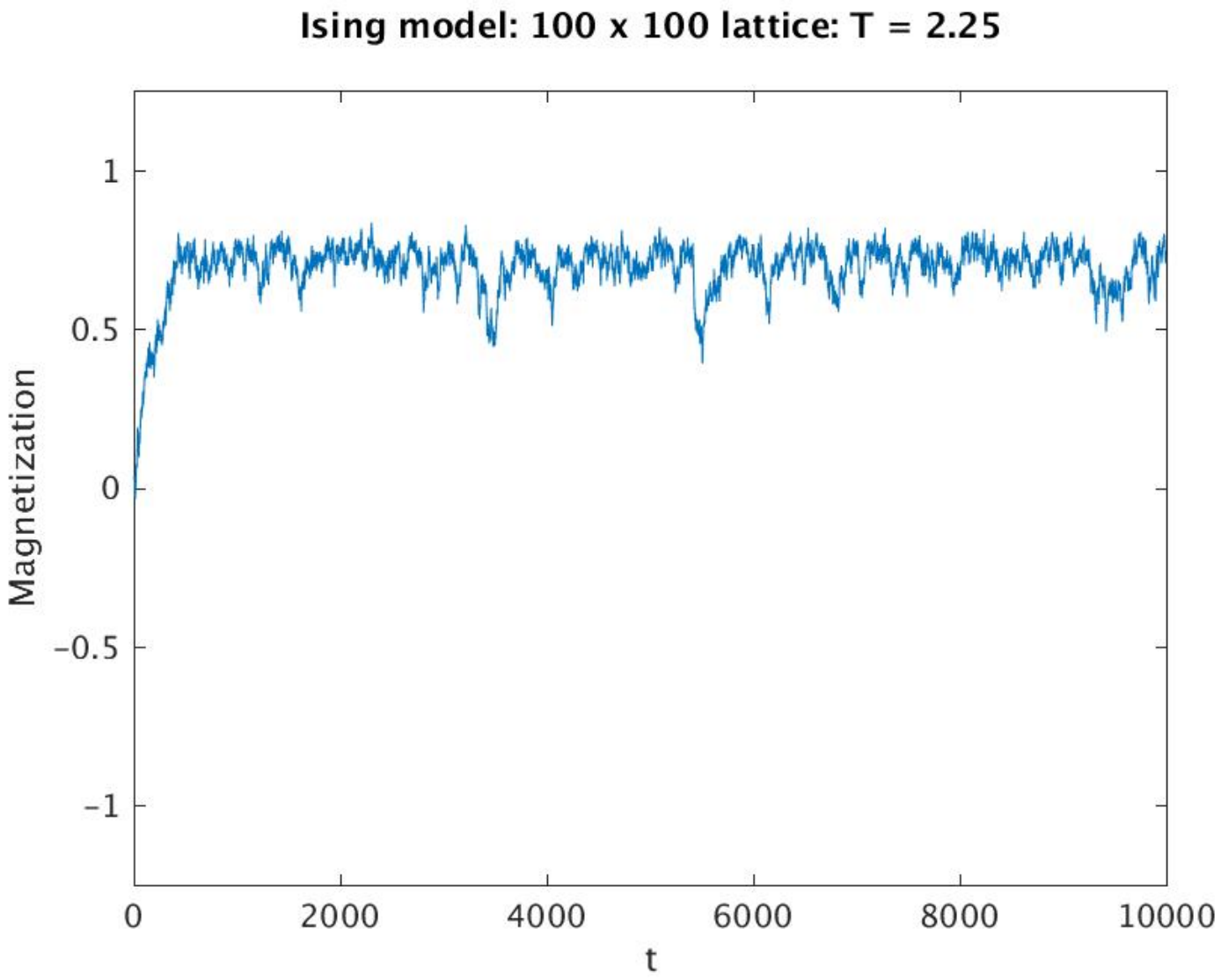
- Magnetization per spin vs discrete time



- Magnetization per spin vs discrete time



- Magnetization per spin vs discrete time



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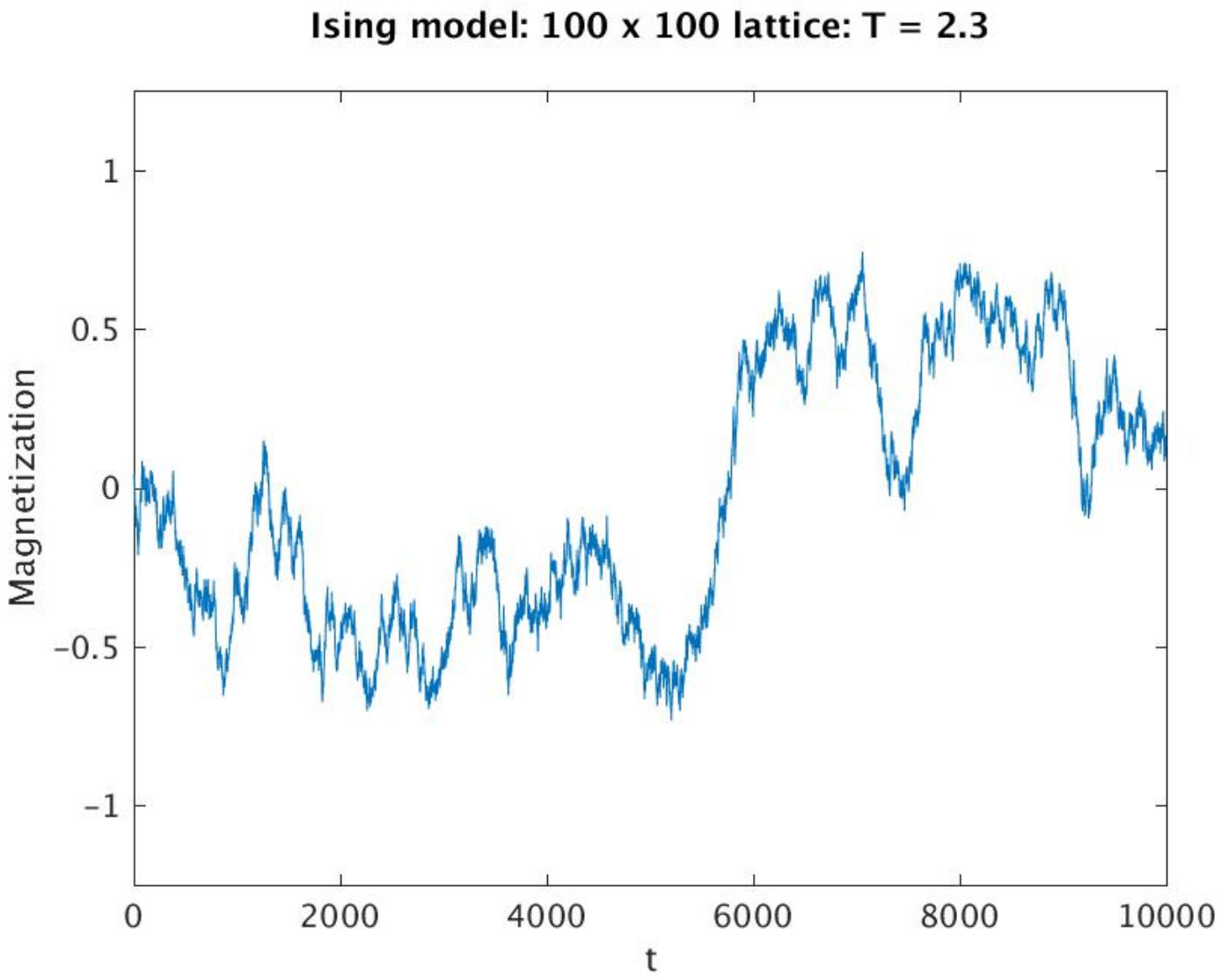
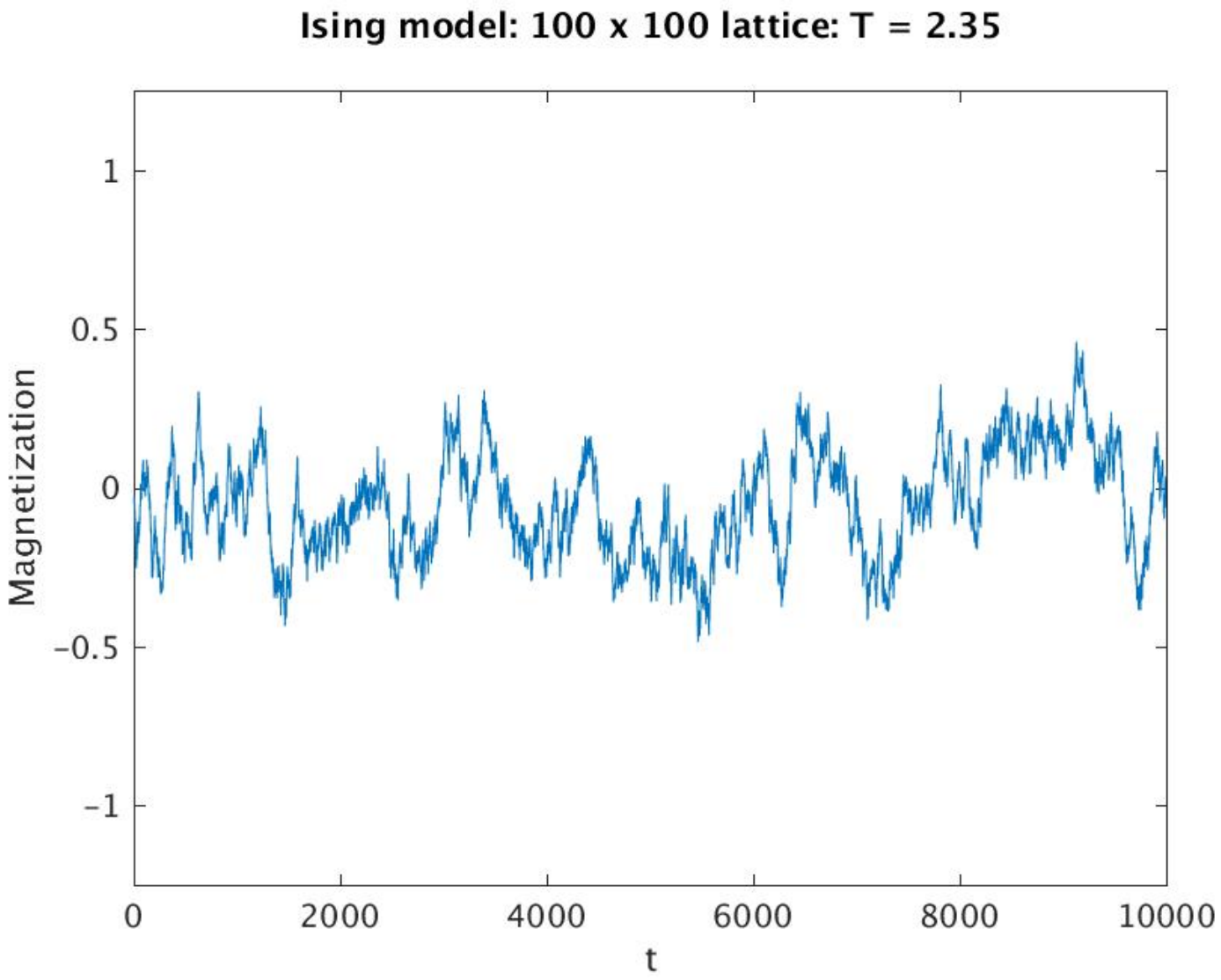
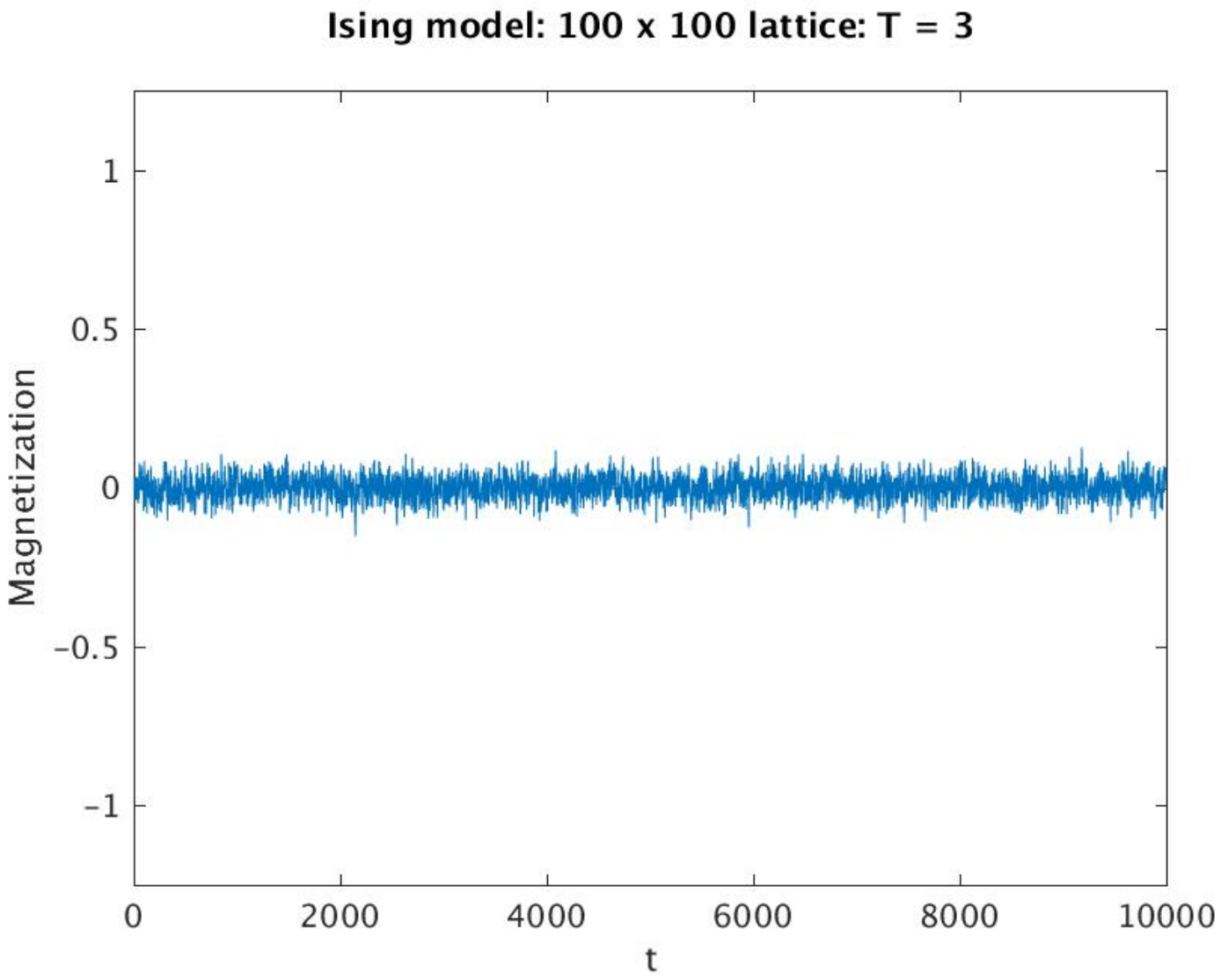


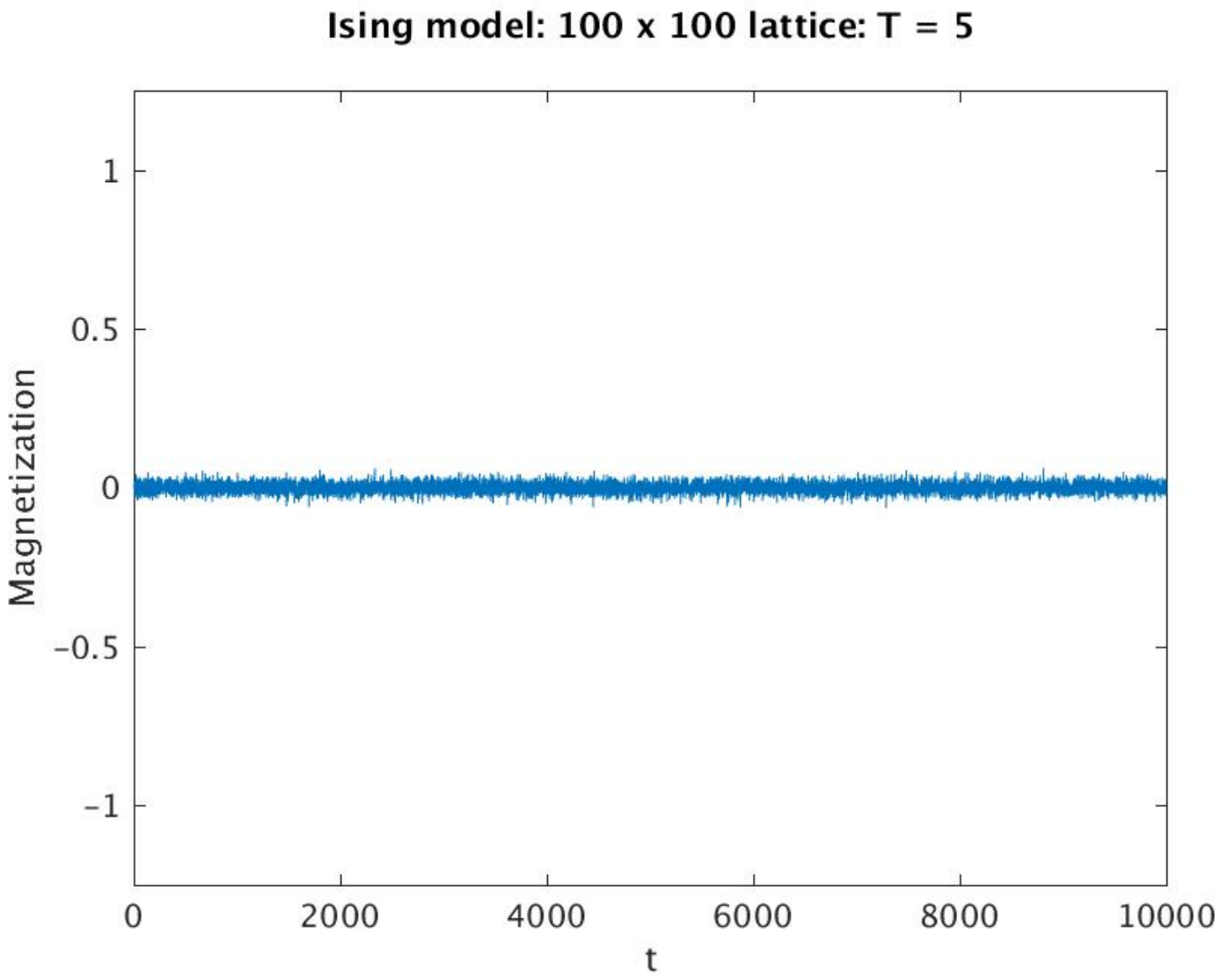
- Magnetization per spin vs discrete time



- Magnetization per spin vs discrete time



- Magnetization per spin vs discrete time



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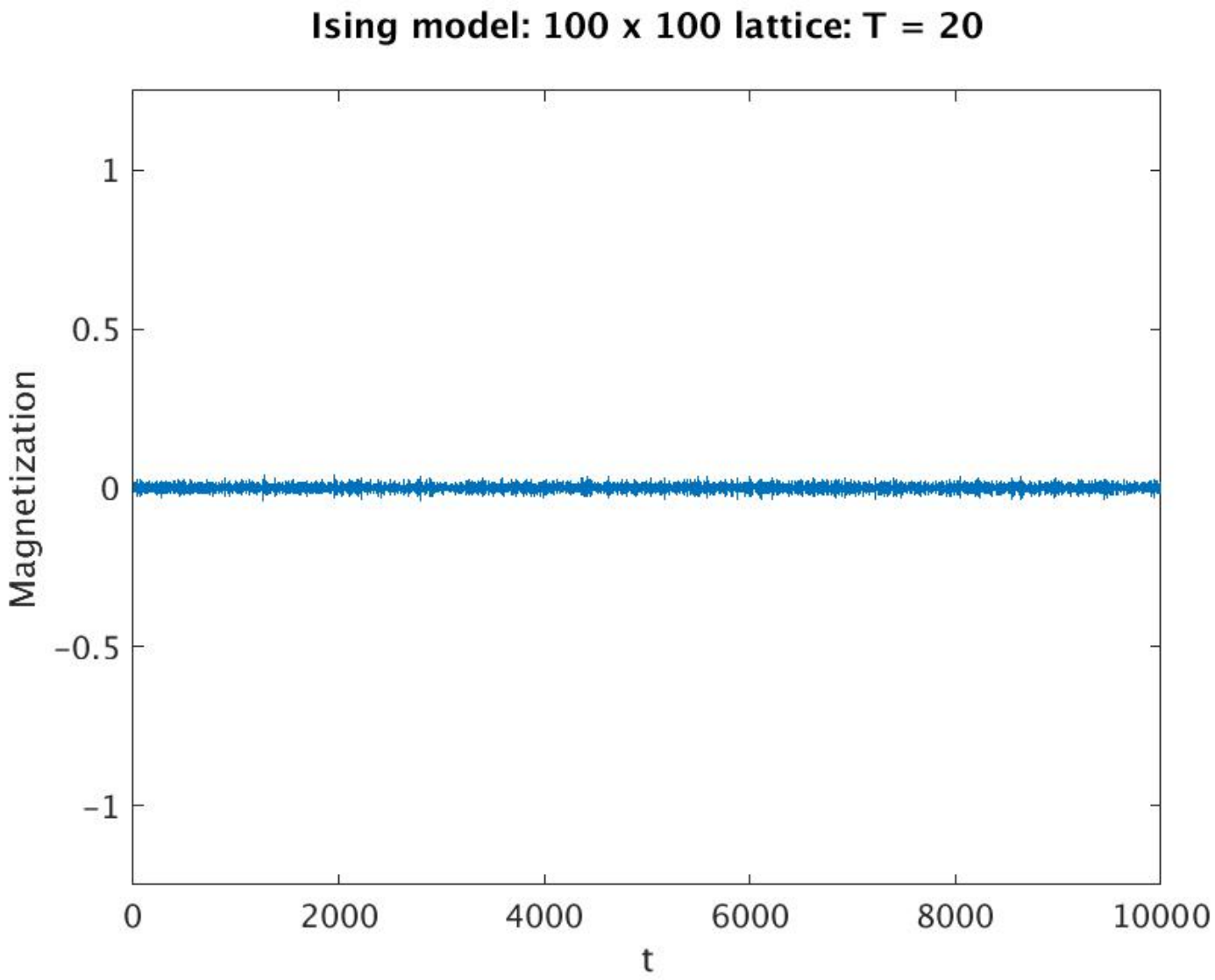
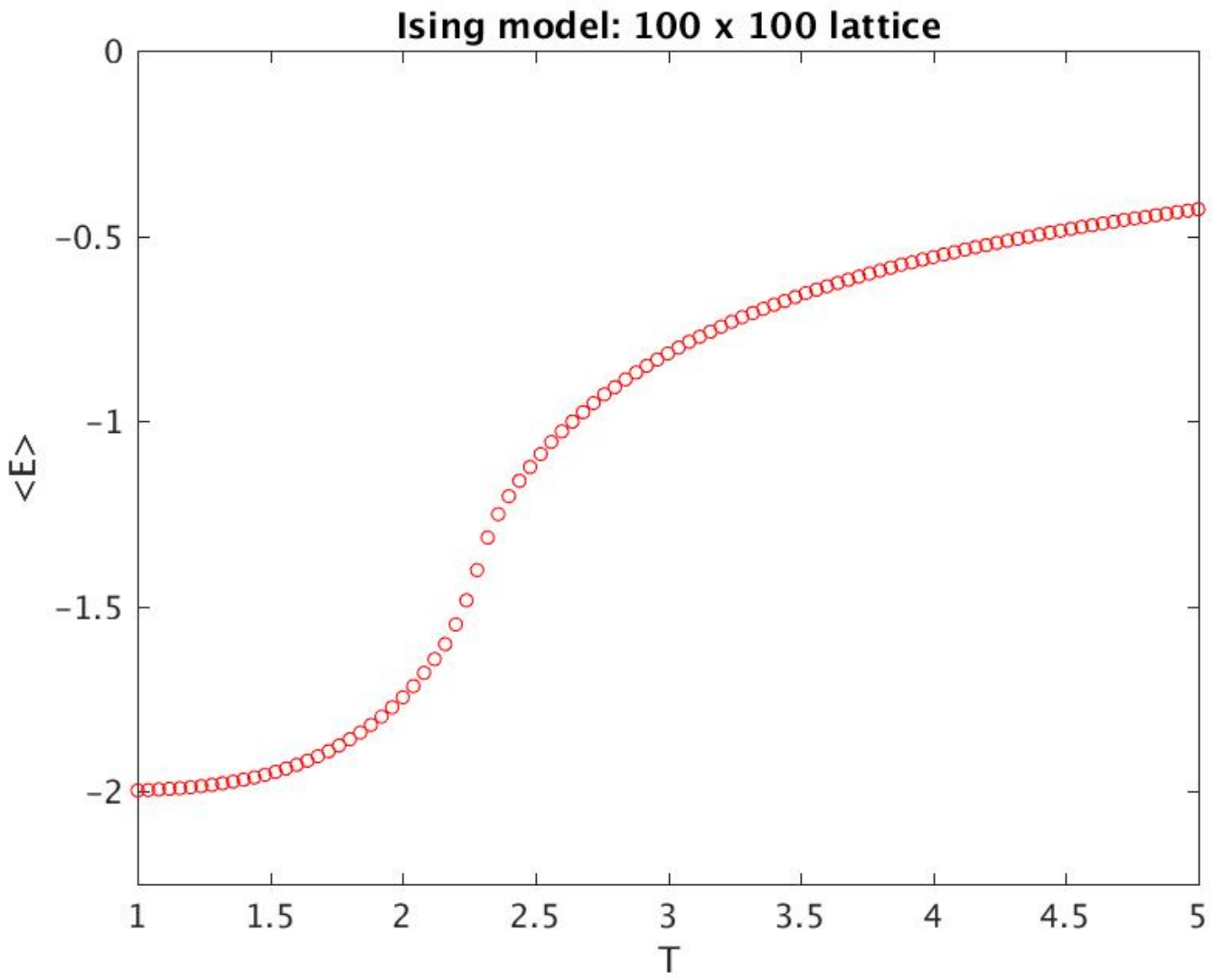
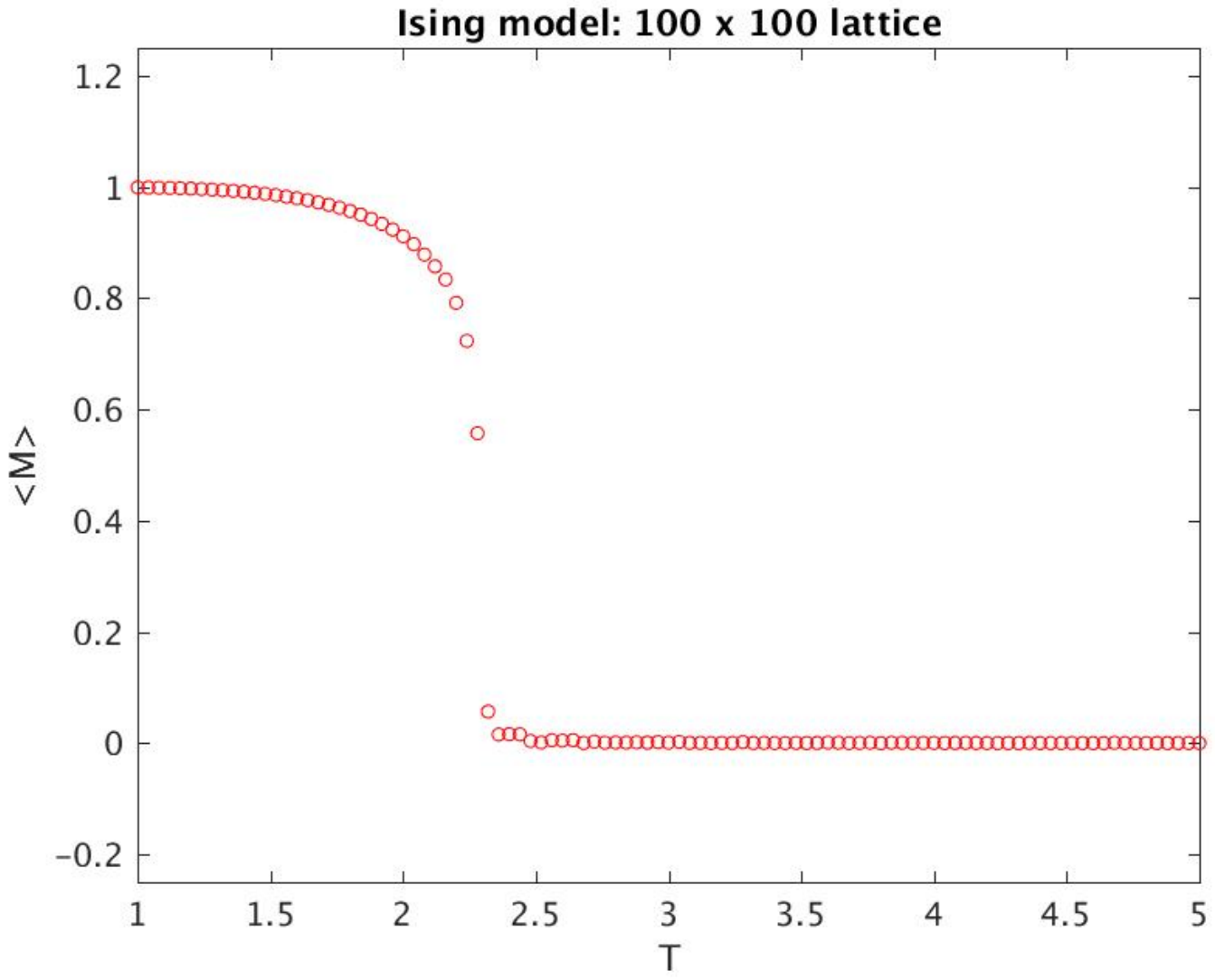


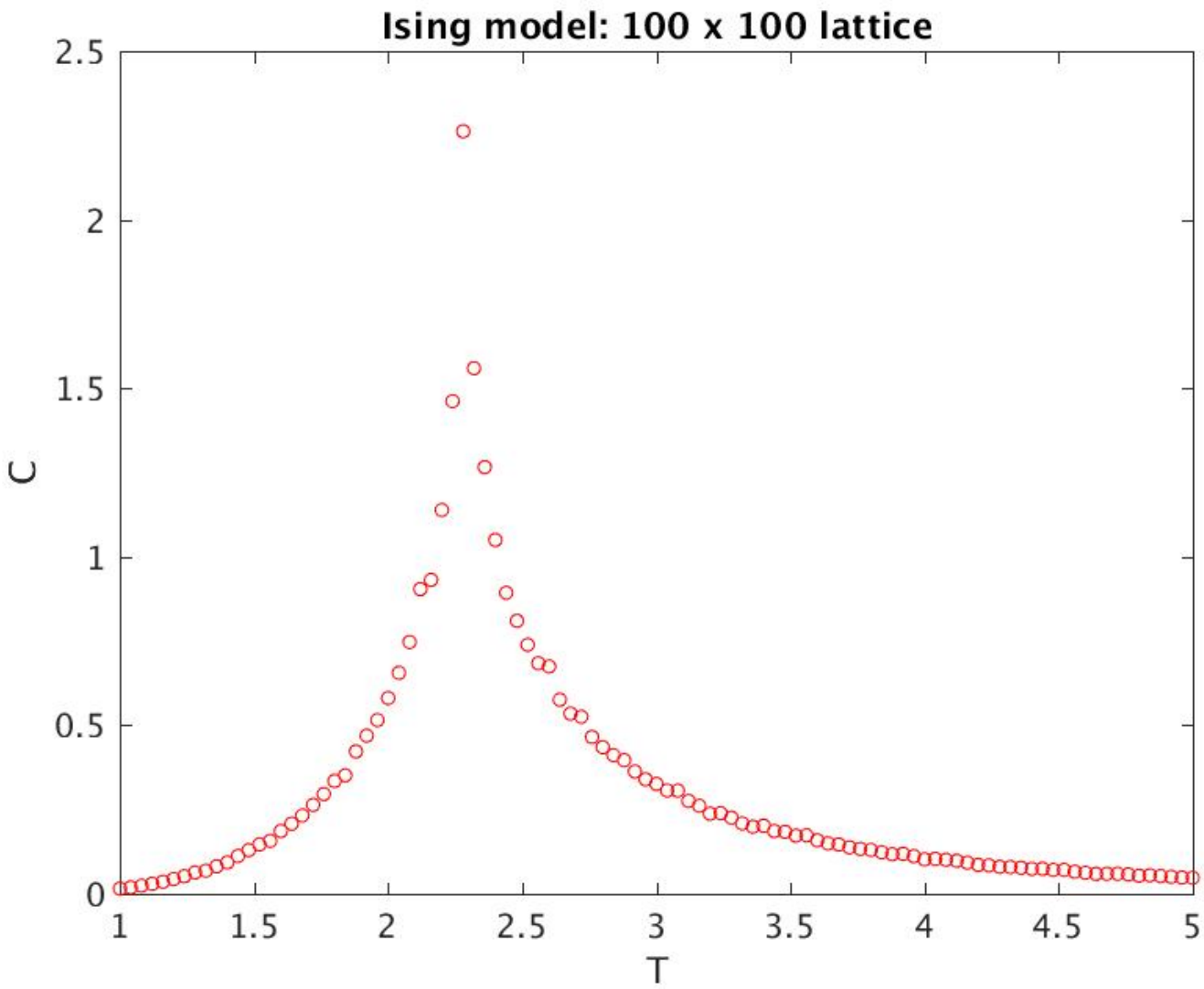
- Energy per spin vs temperature



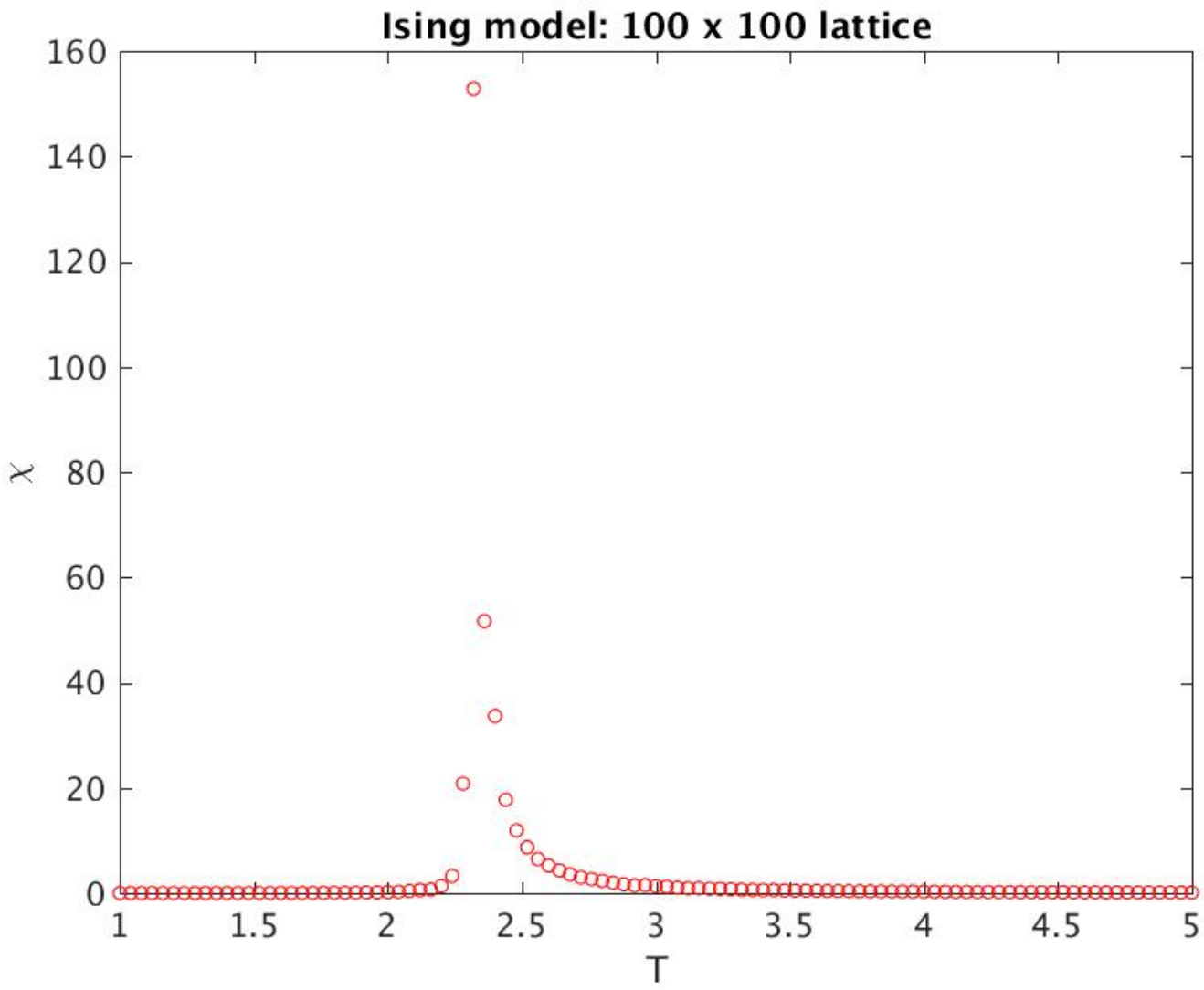
- Magnetization per spin vs temperature (T_C exact ≈ 2.269)



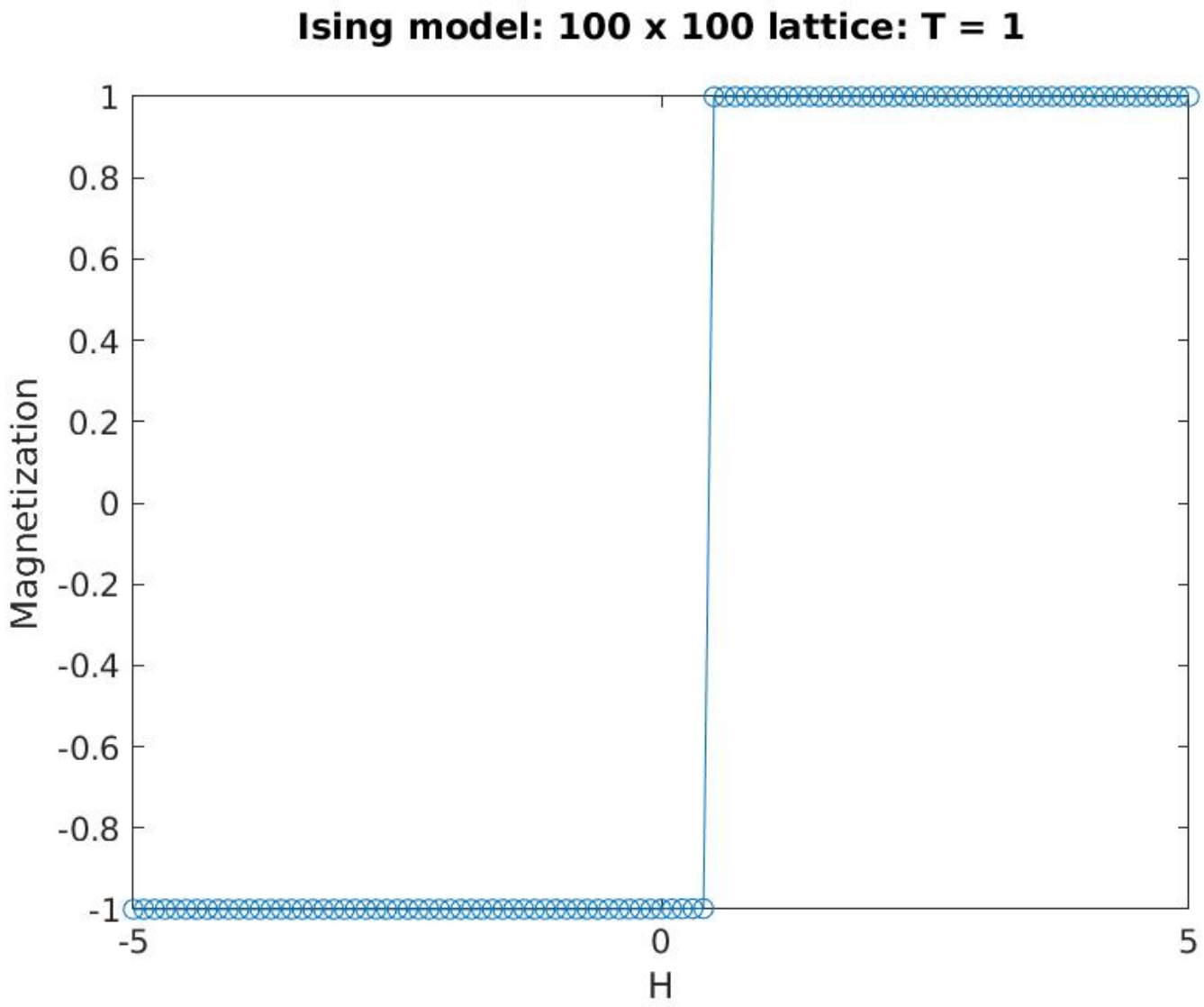
- Heat capacity per spin vs temperature



- Susceptibility per spin vs temperature



- Magnetization per spin vs magnetic field



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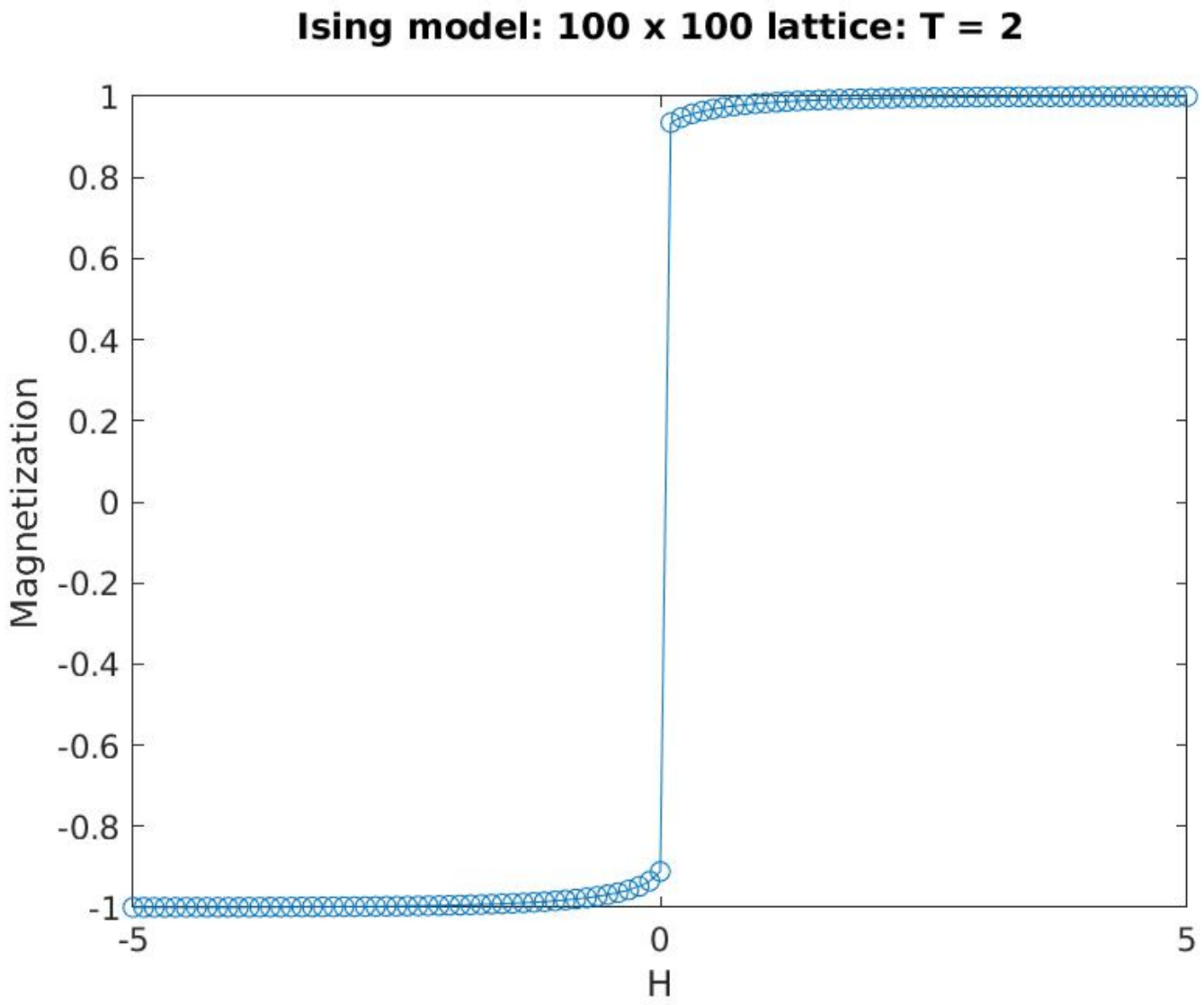

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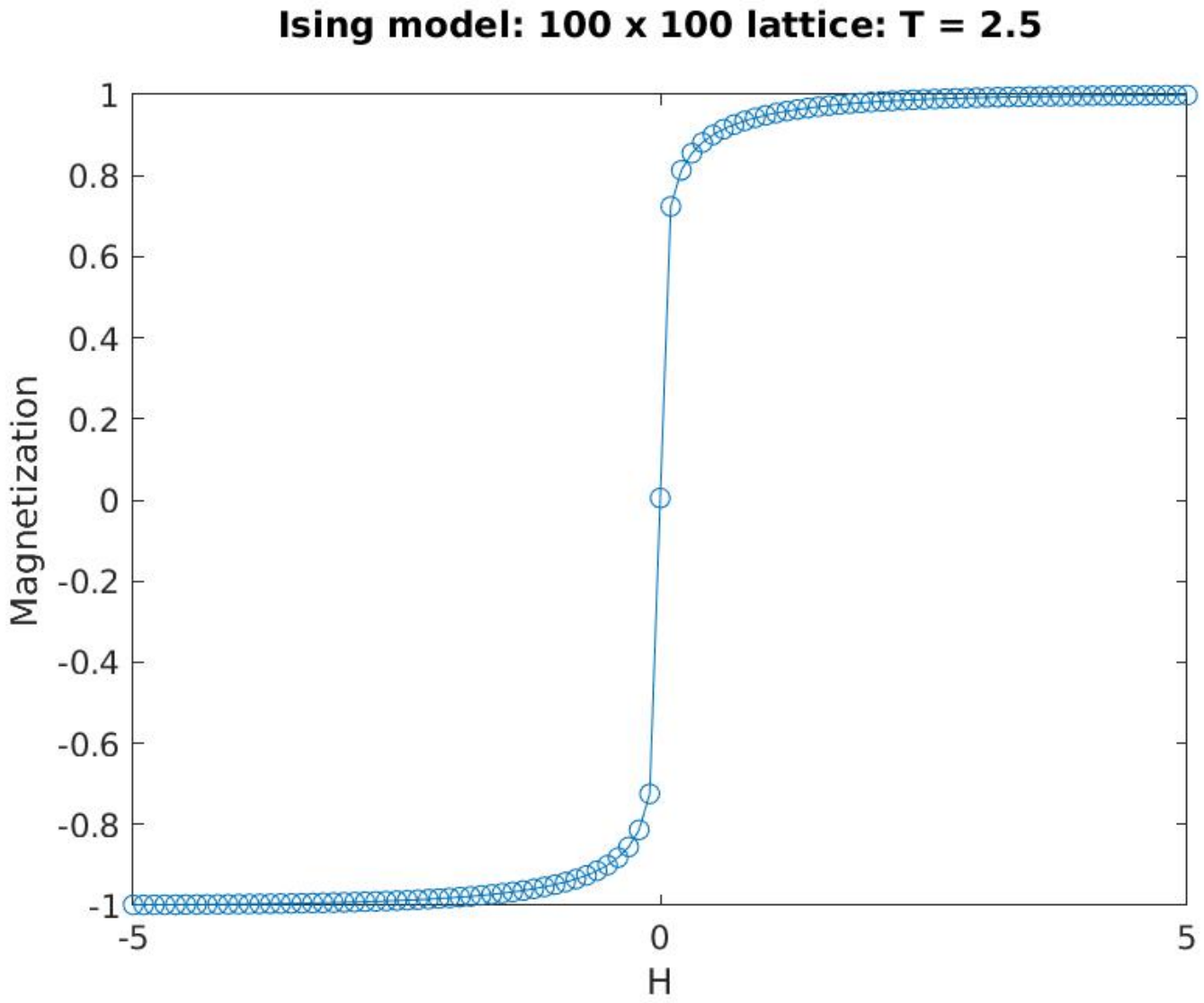

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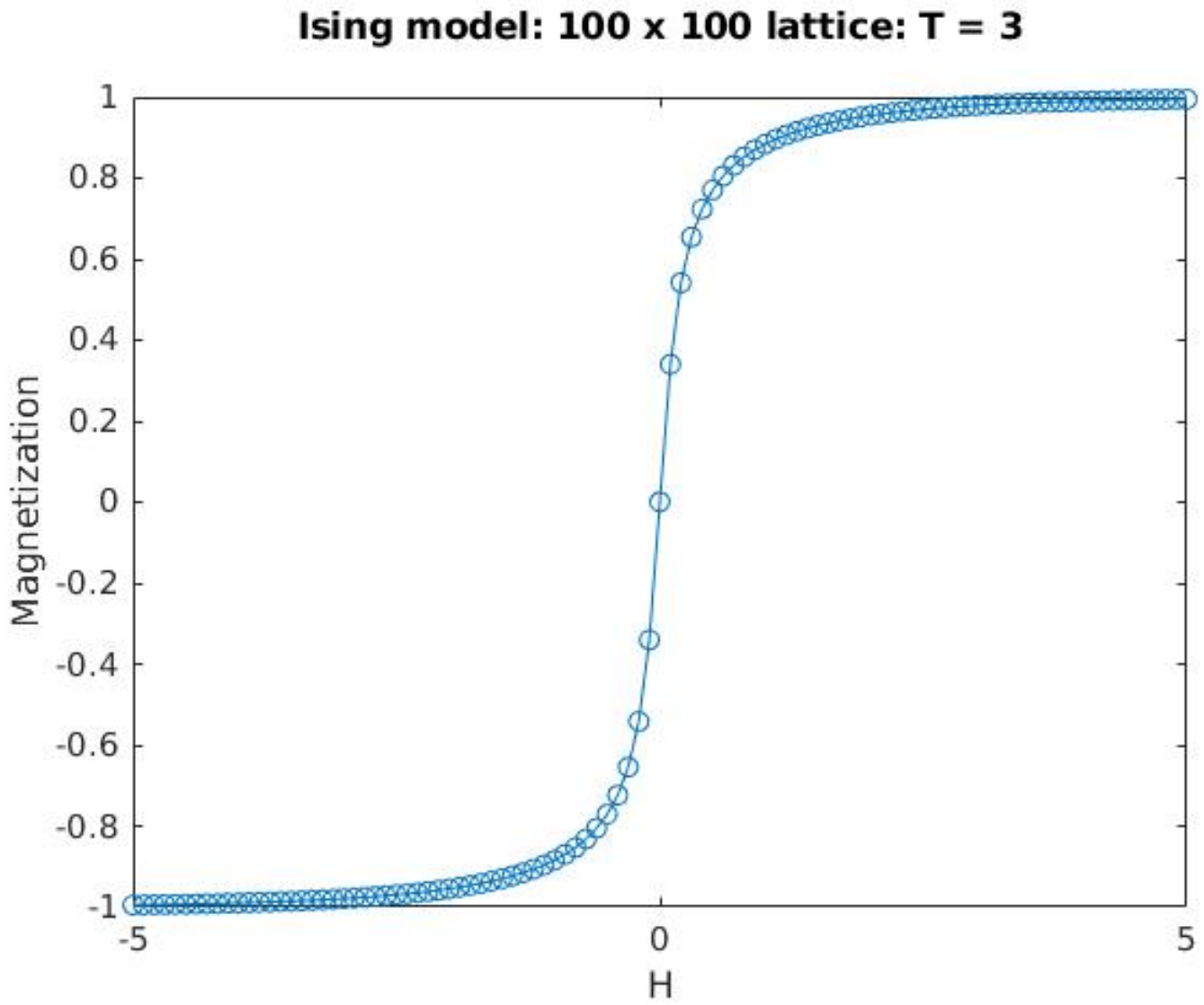

- Magnetization per spin vs magnetic field