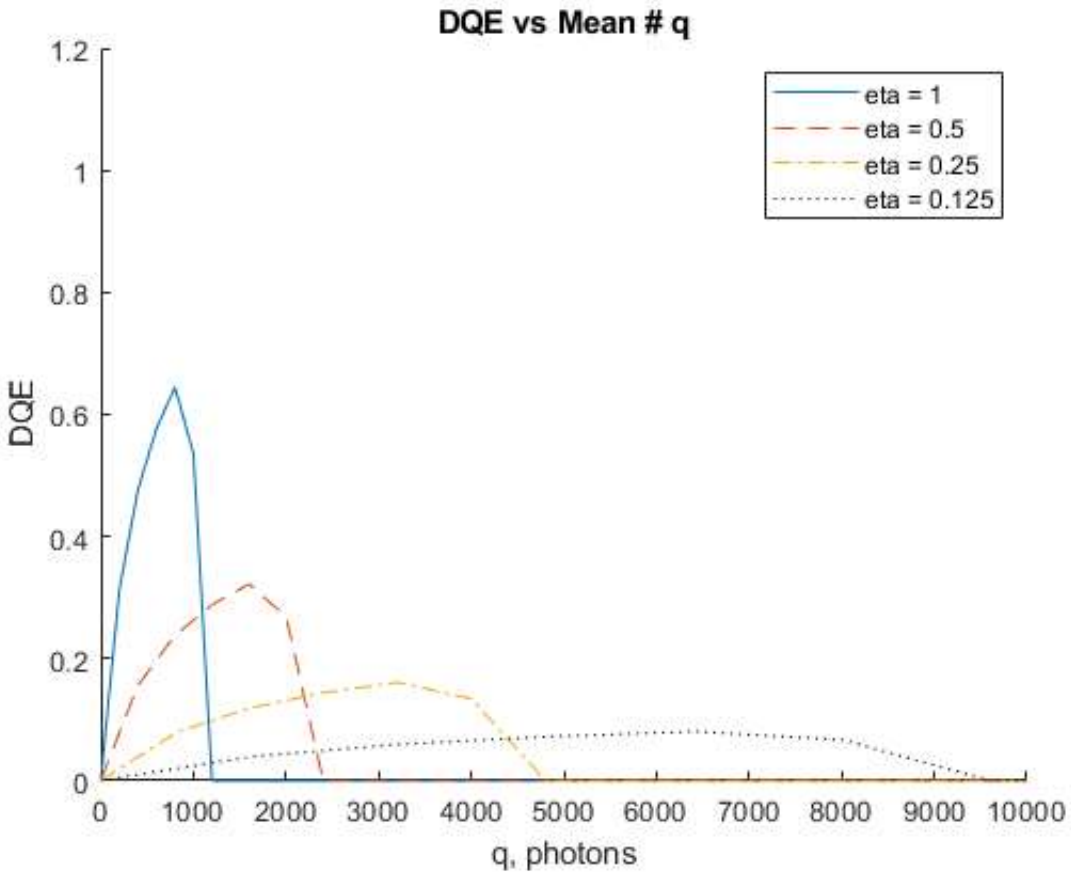
Imaging System Analysis Modeling

Project: Detector Modeling Author: Jared Gregor (jmg2586@rit.edu) Date: Oct 5 2020

Contents

Task 1

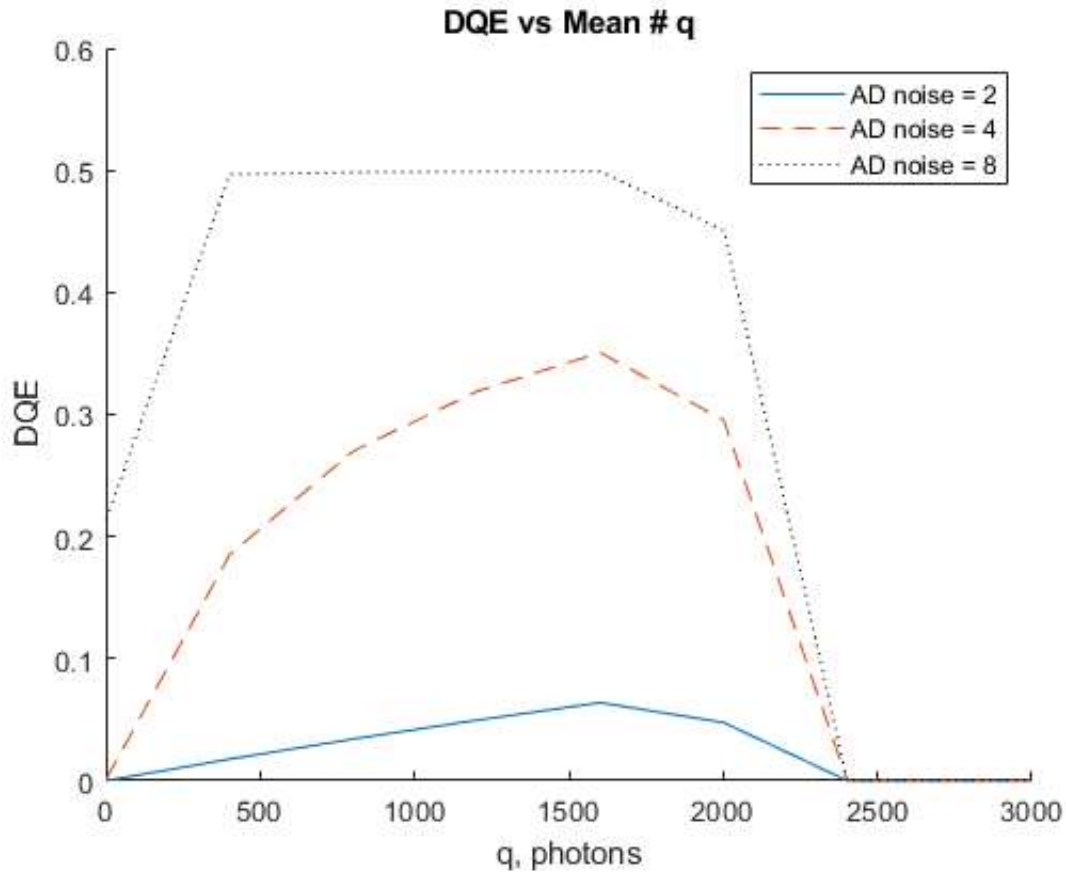
```
clear
close all

% Given Variables
L = 1024; % Saturation level
eta = [1.0, 0.5, 0.25, 0.125];
q = [1:200:8001]; % Lambda/ Mean exposure
q_scaled = [q;q;q;q]; % Scale q for each eta
q_scaled = q_scaled ./ eta';


noise_read = 0; % Electrons
noise_AD = 0;

% Calculate dqe with 0 noise
dqe(1,:) = DQE(L, q, eta(1), noise_AD, noise_read);
dqe(2,:) = DQE(L, q, eta(2), noise_AD, noise_read);
dqe(3,:) = DQE(L, q, eta(3), noise_AD, noise_read);
dqe(4,:) = DQE(L, q, eta(4), noise_AD, noise_read);

% Plot DQE vs q
Plot1(q_scaled, dqe)

% Add noise
noise_read = 10; % Electrons
AD = 4; % bits
noise_AD = NoiseAD(L, AD);

% Calculate dqe with constant read and AD noise
dqe(1,:) = DQE(L, q, eta(1), noise_AD, noise_read);
dqe(2,:) = DQE(L, q, eta(2), noise_AD, noise_read);
dqe(3,:) = DQE(L, q, eta(3), noise_AD, noise_read);
dqe(4,:) = DQE(L, q, eta(4), noise_AD, noise_read);

% Plot DQE vs q with noise
Plot1(q_scaled, dqe)
```



Task 2

```
clear

% Given Variables
L = 1024; % Saturation level
eta = 0.5;
q = [1:200:3001]; % Lambda/ Mean exposure
q_scaled = q ./ eta;

% DQE varying read noise
noise_read = [1,3,10];
noise_AD = 0;

% Calculate DQE varying read noise and 0 AD noise
dqe(1,:) = DQE(L, q, eta, noise_AD, noise_read(1));
dqe(2,:) = DQE(L, q, eta, noise_AD, noise_read(2));
dqe(3,:) = DQE(L, q, eta, noise_AD, noise_read(3));

Plot2(q_scaled, dqe,["read noise = 1", "read noise = 3", "read noise = 10"])

% DQE varying bit level
noise_read = 0;
AD = [2,4,8];
noise_AD = NoiseAD(L, AD);

% Calculate DQE varying AD noise and 0 read noise
```

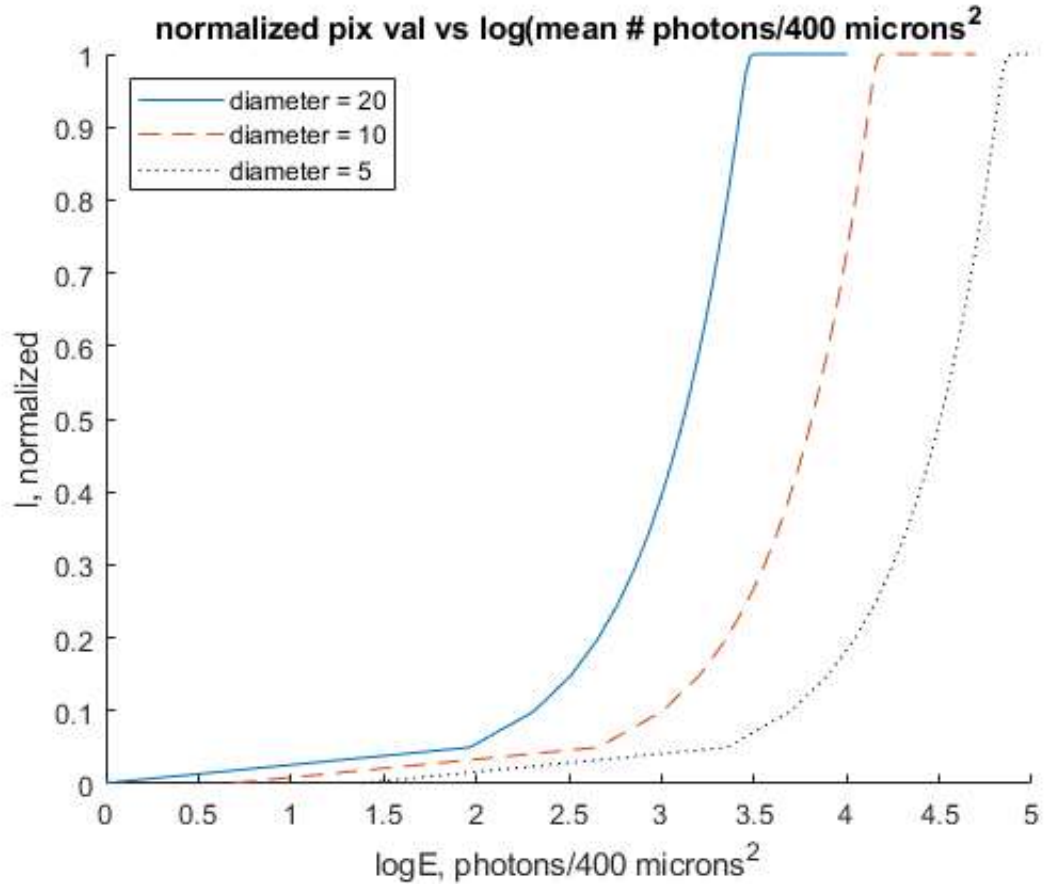
```
dqe(1,:) = DQE(L, q, eta, noise_AD(1), noise_read);
dqe(2,:) = DQE(L, q, eta, noise_AD(2), noise_read);
dqe(3,:) = DQE(L, q, eta, noise_AD(3), noise_read);

Plot2(q_scaled, dqe,["AD noise = 2", "AD noise = 4", "AD noise = 8"])
```



Task 3

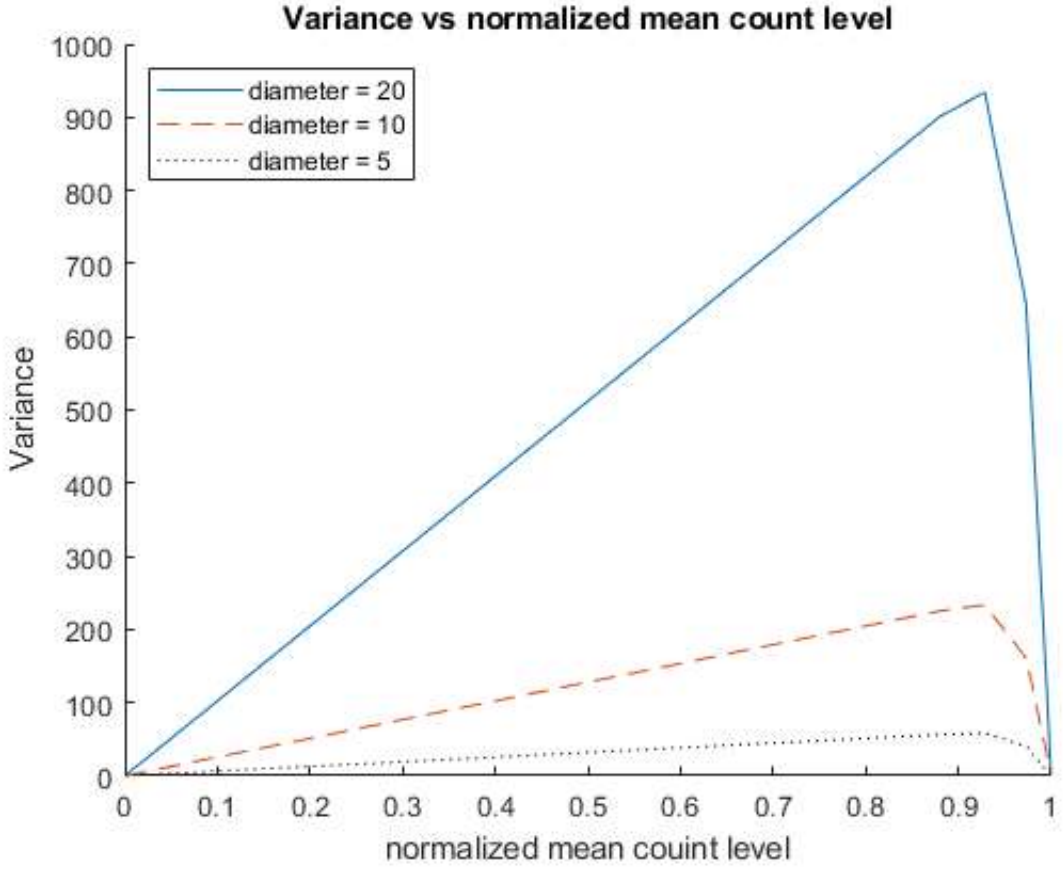
```
clear

% Given Variables
noise_read = 0;
noise_AD = 0;


q = [1:50:3001]; % Lambda/ Mean exposure
L = 1024; % Saturation level
l_norm = (1 - F1(L, q)); % count

diameter = [20,10,5]; %Square Pixel diameter microns
area = diameter.^2; %microns^2
multiplier = area(1) ./ area;

% Calculate E for each area
E(1,:) = q;% ./ area(1);
E(2,:) = multiplier(2) .* E(1,:);
E(3,:) = multiplier(3) .* E(1,:);
```

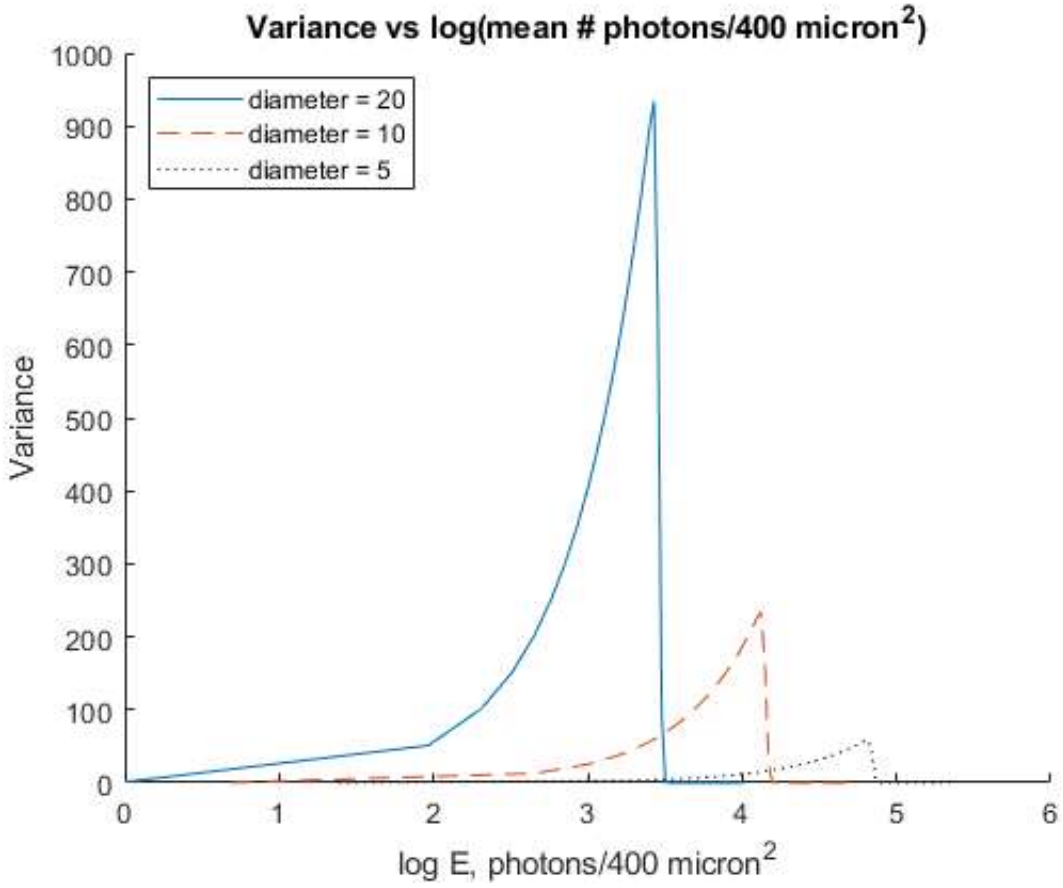
```
logE = log(E)./2;

Plot3(logE, l_norm,["diameter = 20", "diameter = 10", "diameter = 5"])
```



Task 4

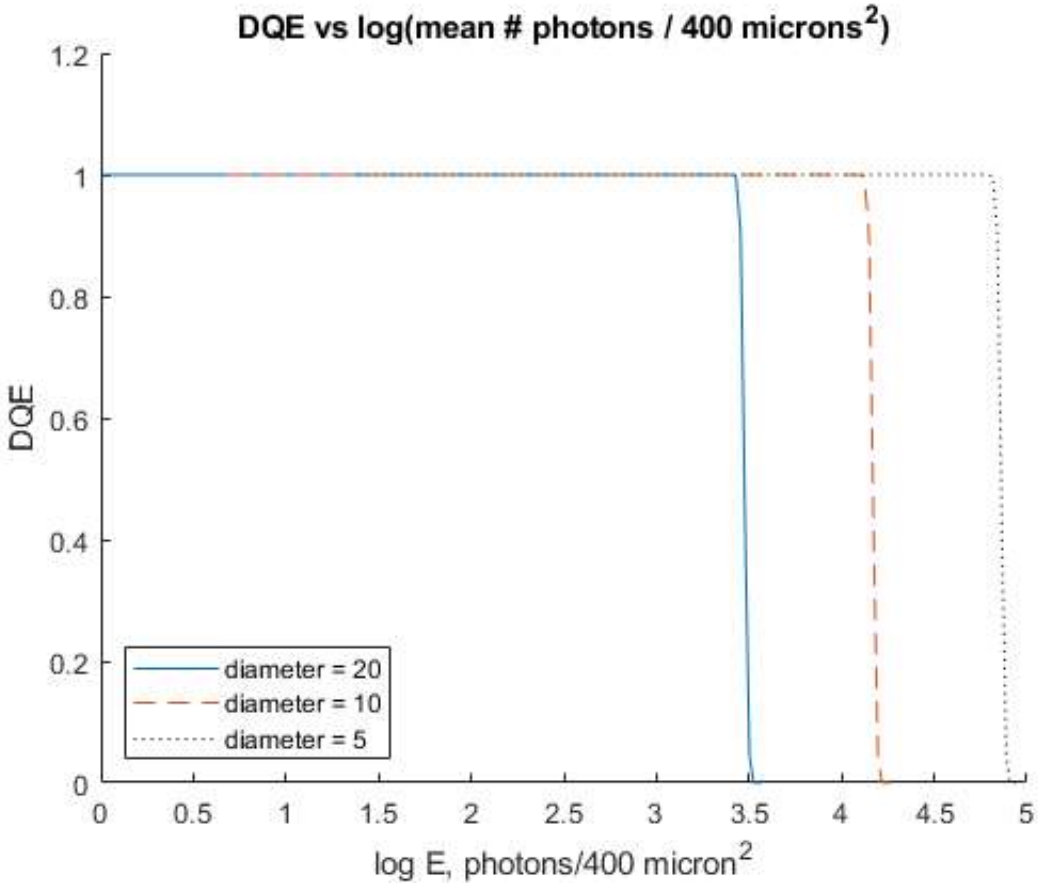
```
% Calculate variance for each area
variance = Variance(L, q);
variance = [variance; variance; variance];
variance = variance ./ multiplier';

Plot4_1(l_norm, variance,["diameter = 20", "diameter = 10", "diameter = 5"])
Plot4_2(logE, variance,["diameter = 20", "diameter = 10", "diameter = 5"])
```

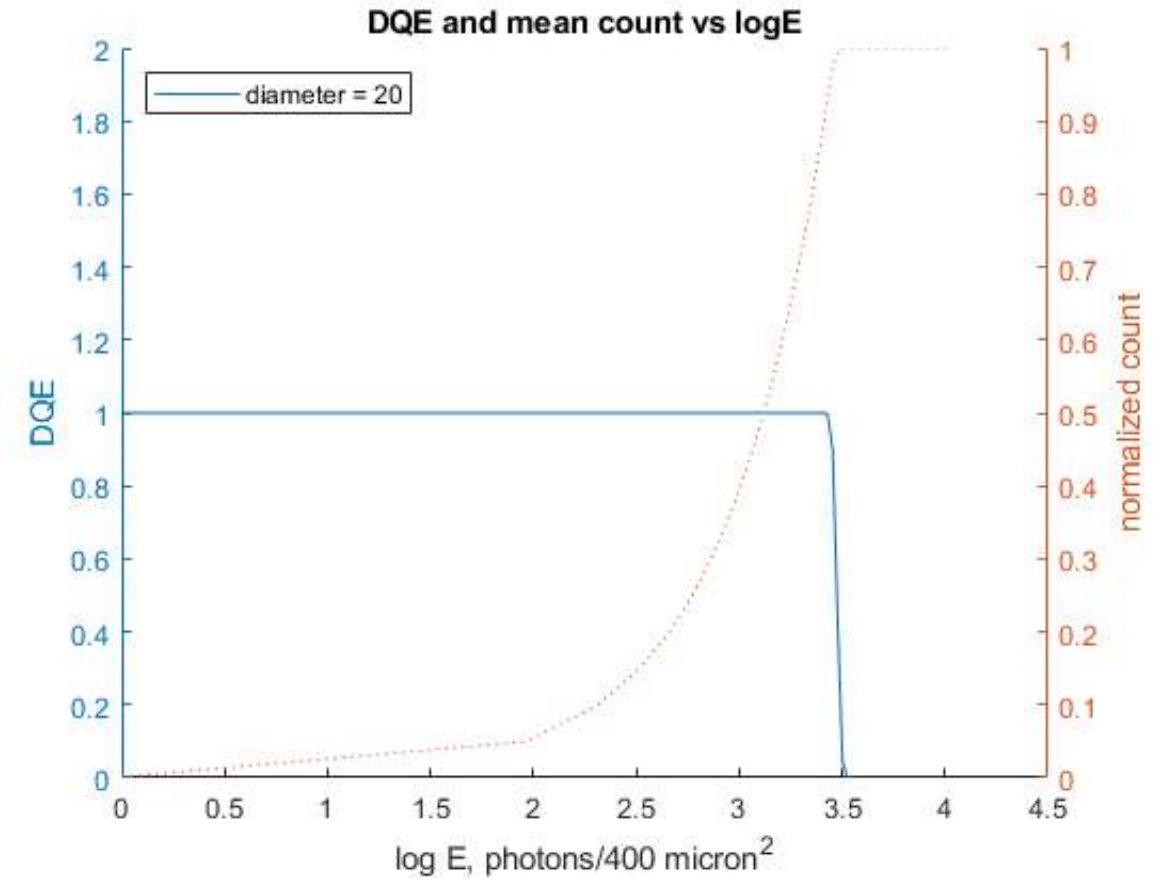

Variance vs normalized mean count level
diameter = 20
diameter = 10
diameter = 5
Variance
normalized mean couint level
0
100
200
300
400
500
600
700
800
900
1000
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1


Variance vs log(mean # photons/400 micron^2)
diameter = 20
diameter = 10
diameter = 5
Variance
log E, photons/400 micron^2
0
100
200
300
400
500
600
700
800
900
1000
1
2
3
4
5
6

Task 5

```
% Calculate DQE for each area
eta = 1;
dqe = DQE(L, q, eta, noise_AD, noise_read);

Plot5_1(logE, dqe, ["diameter = 20", "diameter = 10", "diameter = 5"])
Plot5_2(logE, dqe, 1_norm, ["diameter = 20", "diameter = 10", "diameter = 5"])
```





Functions

```
% AD noise
function noise = NoiseAD(L, AD)
    noise = (L.^2)./(12.*2.^(2.*AD));
end

% Compute f1 (eq 6)
% Compute f2 (eq 9)
% Compute f3 (eq 16)
function f1 = F1(L,q)
    f1 = 0;
    for i = 0:L-1
        f1 = f1 + (1/L) * poisscdf(i,q);
    end
end
function f2 = F2(L,q)
    f2 = (1/L) * poisscdf(L-1,q);
end
function f3 = F3(L,q)
    f3 = 0;
    for i = 0:L-1
        f3 = f3 + ((1/(L*L)) * (2*i+1) * poisscdf(i,q));
    end
end

% DQE
function dqe = DQE(L, q, eta, noise_AD, noise_read)
    f1 = F1(L,q);
```

```
    f2 = F2(L,q);
    f3 = F3(L,q);

    % Calculate DQE(qN) (Eq 21)
    DQE_qN = (q.*f2.*f2.*L.^2)./(noise_AD + noise_read^2 + L.^2 *((1.-f3)-(1.-f1).^2));

    % Calculate DQE(q) (Eq 24)
    dqe = DQE_qN .* eta;
end
% Variance
function sig = Variance(L, q)
    f1 = F1(L,q);
    f3 = F3(L,q);
    sig = L^2 .* ((1-f3)-(1-f1).^2);
end
```

Plots

```
function Plot1(q_scaled, dqe)
    figure
    hold on
    plot(q_scaled(1,:), dqe(1,:), '-')
    plot(q_scaled(2,:), dqe(2,:), '--')
    plot(q_scaled(3,:), dqe(3,:), '-.')
    plot(q_scaled(4,:), dqe(4,:), ':k')
    xlim([0 10000])
    ylim([0 1.2])
    legend('eta = 1', 'eta = 0.5','eta = 0.25','eta = 0.125')
    title('DQE vs Mean # q')
    ylabel('DQE')
    xlabel('q, photons')
    hold off
end
function Plot2(q_scaled, dqe, leg)
    figure
    hold on
    plot(q_scaled, dqe(1,:), '-')
    plot(q_scaled, dqe(2,:), '--')
    plot(q_scaled, dqe(3,:), ':k')
    xlim([0 3000])
    ylim([0 0.6])
    legend(leg(1), leg(2), leg(3))
    title('DQE vs Mean # q')
    ylabel('DQE')
    xlabel('q, photons')
    hold off
end
function Plot3(q_scaled, LogE, leg)
    figure
    hold on
    plot(q_scaled(1,:), LogE, '-')
    plot(q_scaled(2,:), LogE, '--')
    plot(q_scaled(3,:), LogE, ':k')
    xlim([0 5])
    ylim([0 1])
    legend({leg(1), leg(2), leg(3)},'Location','northwest')
```

```
    title('normalized pix val vs log(mean # photons/400 microns^2')
    ylabel('l, normalized')
    xlabel('logE, photons/400 microns^2')
    hold off
end
function Plot4_1(a, b, leg)
    figure
    hold on
    plot(a, b(1,:), '-')
    plot(a, b(2,:), '--')
    plot(a, b(3,:), ':k')
    legend({leg(1), leg(2), leg(3)},'Location','northwest')
    title('Variance vs normalized mean count level')
    ylabel('Variance')
    xlabel('normalized mean couint level')
    hold off
end
function Plot4_2(a, b, leg)
    figure
    hold on
    plot(a(1,:), b(1,:), '-')
    plot(a(2,:), b(2,:), '--')
    plot(a(3,:), b(3,:), ':k')
    legend({leg(1), leg(2), leg(3)},'Location','northwest')
    title('Variance vs log(mean # photons/400 micron^2)')
    ylabel('Variance')
    xlabel('log E, photons/400 micron^2')
    hold off
end
function Plot5_1(a, b, leg)
    figure
    hold on
    plot(a(1,:), b, '-')
    plot(a(2,:), b, '--')
    plot(a(3,:), b, ':k')
    legend({leg(1), leg(2), leg(3)},'Location','southwest')
    title('DQE vs log(mean # photons / 400 microns^2)')
    ylabel('DQE')
    xlabel('log E, photons/400 micron^2')
    hold off
end
function Plot5_2(a, b, c, leg)
    figure
    hold on
    yyaxis left
    plot(a(1,:), b, '-')
    ylim([0 2])
    ylabel('DQE')
    yyaxis right
    ylabel('normalized count')
    plot(a(1,:), c, ':')
    ylim([0 1])
    legend({leg(1)},'Location','northwest')
    title('DQE and mean count vs logE')
    xlabel('log E, photons/400 micron^2')
    hold off
end
```

```
function Plot_extra()
    figure
    hold on
    title('Mean pix val vs mean # photons')
    ylabel('l')
    xlabel('q, photons')
    ylim([0 L])
    xlim([0 1.5*L])
    plot(q, L*(1-F1(L,q)))
    hold off
    xline(L, ':', {'L'});

    figure
    hold on
    title('gain vs mean # photons')
    ylabel('gain')
    xlabel('q, photons')
    plot(q, L*F2(L,q))
    xlim([0 1.5*L])
    hold off
    xline(L, ':', {'L'});
    yline(1);


    figure
    hold on
    title('Variance vs mean # photons')
    ylabel('variance')
    xlabel('q, photons')
    plot(q, Variance(L, F1(L,q), F3(L,q)))
    ylim([0 L])
    xlim([0 1.5*L])
    hold off
    xline(L, ':', {'L'});


    figure
    hold on
    title('DQE vs mean # photons')
    ylabel('DQE')
    xlabel('q, photons')
    plot(q, DQE(L, q, 1, noise_AD, noise_read))
    xlim([0 1.5*L])
    hold off
    xline(L, ':', {'L'});
    yline(1, ':', {'max dqe'});
end
```

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