

(* Photon Flux Estimate at the Top of the Atmosphere and Limiting V Magnitudes using CCD Detector for Main Sequence Stars *)

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In[1]:= m = 1;
        μm = 10-6 m;
        nm = 10-9 m;
        pJ = 10-12;
        arcsec = N[1 / 206 265];
        << PhysicalConstants`
        h = PlanckConstant[[1]]
        k = BoltzmannConstant[[1]]
        c = SpeedOfLight[[1]]

```

Out[7]= 6.62607 × 10⁻³⁴

Out[8]= 1.38065 × 10⁻²³

Out[9]= 299 792 458

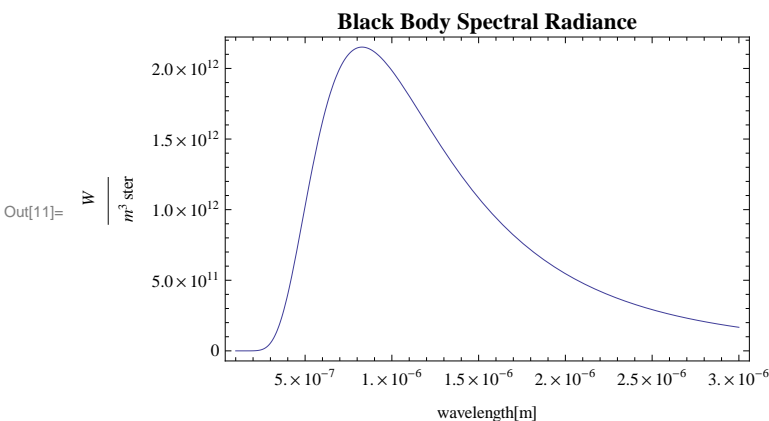
(* Spectral Radiance of a Black Body (emissivity ε=1): *)

$$L[\lambda, T] := \frac{2 h c^2}{\lambda^5 \left(\text{Exp}\left[\frac{h c}{\lambda k T}\right] - 1 \right)}$$

```

In[11]:= Plot[L[λ, 3500], {λ, 100 nm, 3000 nm},
            PlotLabel → Style["Black Body Spectral Radiance", FontSize → 12, FontWeight → "Bold"],
            FrameLabel → {"wavelength[m]",
                          "\!\(\*\FractionBox[\(W\), \(\*\SuperscriptBox[\(m\), \(\{3\}\}\)] ster\)\)\)"},
            PlotRange → All, Frame → True, Axes → None]

```

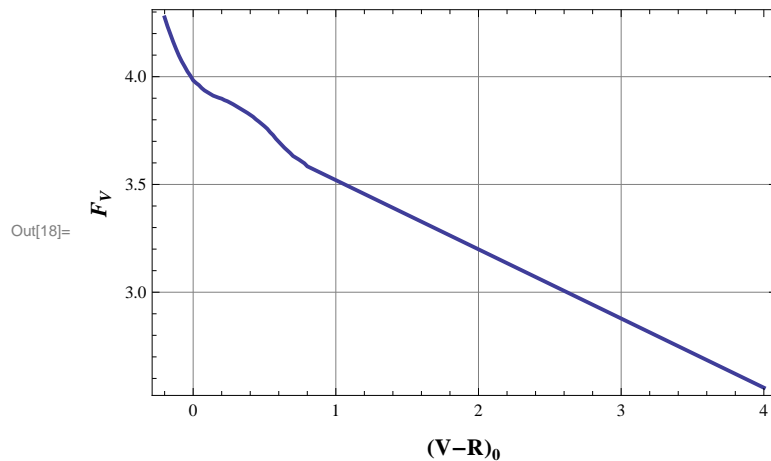


Angular Diameter(Barnes & Evans)

■ $F_V - (V - R)_0$ Calibration

```
In[12]:= VmR1 = Table[-0.2 + (i - 1) 0.02, {i, 1, 50}];
Fv = {4.275, 4.234, 4.198, 4.162, 4.129, 4.098, 4.071, 4.048, 4.024, 4.005, 3.983, 3.971, 3.961};
FVR1 = Table[{VmR1[[i]], Fv[[i]]}, {i, 1, 50}];
VmR2 = Table[0.8 + (i - 1) 0.02, {i, 1, 161}];
FVR2 = Table[{VmR2[[i]], 3.841 - 0.321 VmR2[[i]]}, {i, 1, 161}];
FVR = Join[FVR1, FVR2];
```

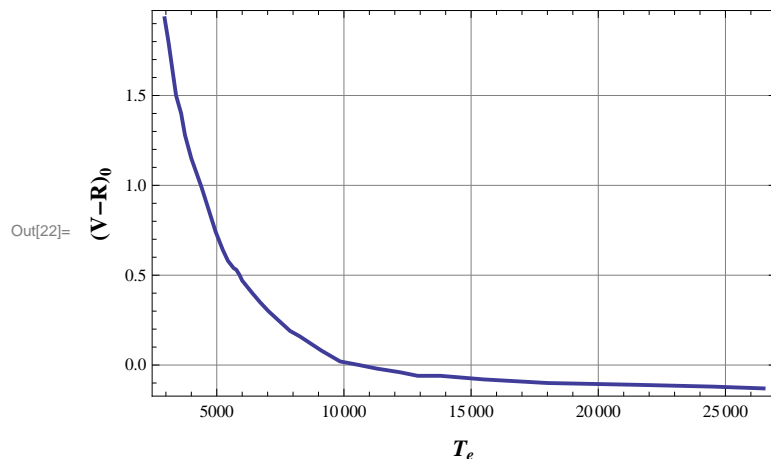
```
In[18]:= LFvVR = ListPlot[FVR, Frame -> True, Axes -> None, GridLines -> Automatic, FrameLabel -> {Style["(V-R)_0",
```



■ $(V - R)_0 - T_{\text{eff}}$ Calibration

```
In[19]:= Te = {26 500, 24 500, 21 500, 18 000, 15 500, 13 800, 12 900, 12 200, 11 300,
10 600, 9850, 9120, 8260, 7880, 7030, 6700, 6400, 6000, 5900, 5770, 5660,
5440, 5240, 4960, 4400, 4000, 3750, 3600, 3400, 3300, 3200, 3100, 2950};
VmR = {-0.13, -0.12, -0.11, -0.1, -0.08, -0.06, -0.06, -0.04, -0.02, 0.0,
0.02, 0.08, 0.16, 0.19, 0.30, 0.35, 0.40, 0.47, 0.50, 0.53, 0.54, 0.58,
0.64, 0.74, 0.99, 1.15, 1.28, 1.40, 1.50, 1.60, 1.70, 1.80, 1.93};
VRT = Table[{Te[[i]], VmR[[i]]}, {i, 1, Length[Te]}];
```

```
In[22]:= LVRT = ListPlot[VRT, Frame -> True, Axes -> None, GridLines -> Automatic, FrameLabel -> {Style["(V-R)_0",
```



```

In[23]:= fvr = Interpolation[FVR];
          vrt = Interpolation[VRT];

In[25]:= PowerAtTheTopOfTheAtmosphere[T_, V_, λ_] :=
          
$$\frac{\pi}{4} \left( 4.85 \cdot 10^{-9} \cdot 10^{(8.441 - 2 \text{fvr}[\text{vrt}[T]] - 0.2 V)} \right)^2 L[\lambda, T] \cdot 10^{-9} \text{ (*W/m}^2\text{/nm*)}$$

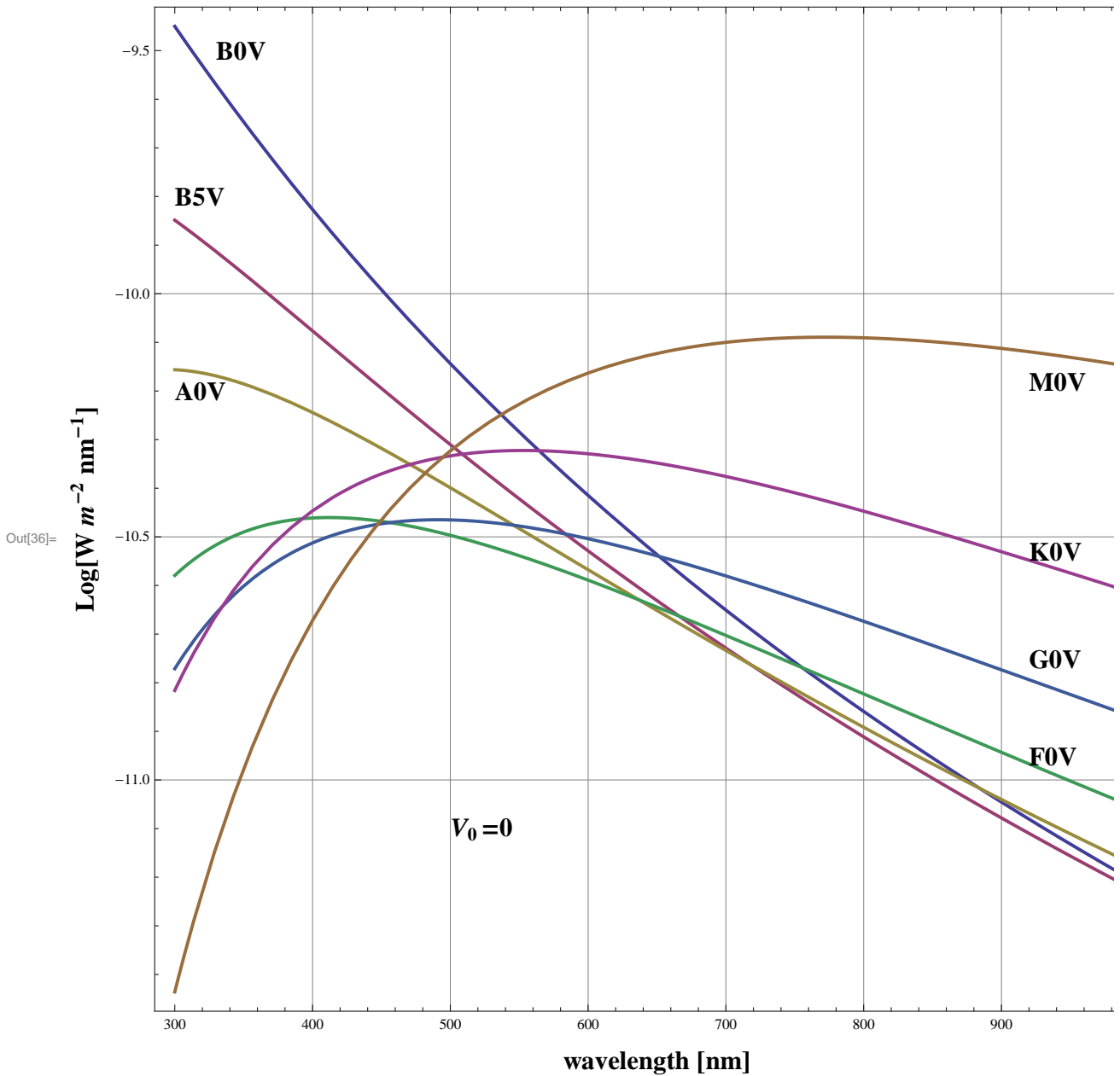

In[26]:= Teff = {26500, 13800, 9850, 7030, 5900, 5240, 3750}; (*B0,B5,A0,F0,G0,K0,M0*)

In[27]:= PLIRR = Plot[Evaluate[
          Table[Log[10, PowerAtTheTopOfTheAtmosphere[Teff[[i]], 0, λ nm]], {i, 1, Length[Teff]}]],
          {λ, 300, 1000}, PlotRange → All, Frame → True, Axes → None,
          GridLines → Automatic, PlotStyle → AbsoluteThickness[2],
          FrameLabel → {Style["wavelength [nm]", FontSize → 16, FontWeight → "Bold"],
          Style["Log[W \!\(\*\SuperscriptBox[\(m\), \(-2\)\]\) \!\(\*\SuperscriptBox[\(nm\),
          \(-1\)\]\)"]], FontSize → 16, FontWeight → "Bold"}], AspectRatio → 1];

In[28]:= TEXT1 = Graphics[
          Text[Style["A0V", FontSize → 16, FontWeight → "Bold"], {300, -10.2}, {-1, 0}]];
TEXT2 = Graphics[Text[Style["F0V", FontSize → 16, FontWeight → "Bold"],
          {920, -10.95}, {-1, 0}]];
TEXT3 = Graphics[Text[Style["G0V", FontSize → 16, FontWeight → "Bold"],
          {920, -10.75}, {-1, 0}]];
TEXT4 = Graphics[Text[Style["K0V", FontSize → 16, FontWeight → "Bold"],
          {920, -10.53}, {-1, 0}]];
TEXT5 = Graphics[Text[Style["M0V", FontSize → 16, FontWeight → "Bold"],
          {920, -10.18}, {-1, 0}]];
TEXT6 = Graphics[Text[Style["V0 = 0", FontSize → 16, FontWeight → "Bold"],
          {500, -11.1}, {-1, 0}]];
TEXT7 = Graphics[Text[Style["B5V", FontSize → 16, FontWeight → "Bold"],
          {300, -9.8}, {-1, 0}]];
TEXT8 = Graphics[Text[Style["B0V", FontSize → 16, FontWeight → "Bold"],
          {330, -9.5}, {-1, 0}]];

```

In[36]:= Show[{PLIRR, TEXT1, TEXT2, TEXT3, TEXT4, TEXT5, TEXT6, TEXT7, TEXT8}]



```
In[37]:= PhotonAtTheTopOfTheAtmosphere[T_, V_, λ_] :=
  PowerAtTheTopOfTheAtmosphere[T, V, λ] λ / h / c; (* Photon flux => photons/m²/s/nm*)

(* EXAMPLE:
  # of photons which will reach the primary[area 0.77m²]
  from a given Teff star of given V magn in the band specified: *)
```

```
In[38]:= NIntegrate[PhotonAtTheTopOfTheAtmosphere[9850, 0, λ nm], {λ, 300, 1000}] * 0.77
```

Out[38]= 4.06166×10^{10}

EEV CCD39

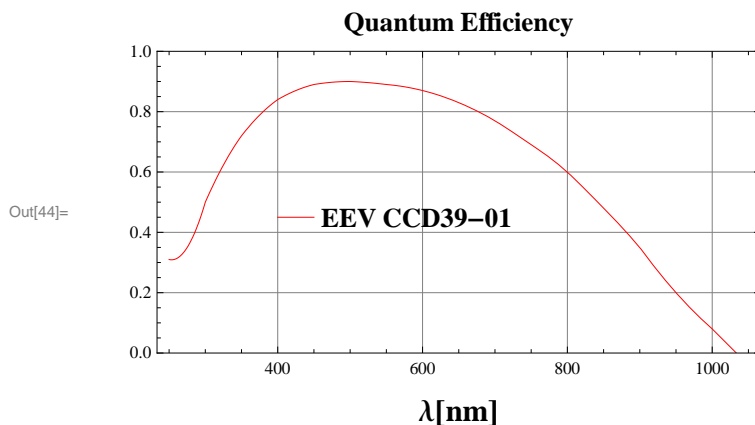
```

In[39]:= DETECTORQE = {{250 nm, 0.31}, {275 nm, 0.35}, {300 nm, 0.5},
  {350 nm, 0.72}, {400 nm, 0.84}, {450 nm, 0.89}, {500 nm, 0.90}, {550 nm, 0.89},
  {600 nm, 0.87}, {650 nm, 0.83}, {700 nm, 0.77}, {750 nm, 0.69}, {800 nm, 0.6},
  {850 nm, 0.48}, {900 nm, 0.35}, {950 nm, 0.2}, {1000 nm, 0.08}, {1050, 0}};
CCDdetectorQE = Interpolation[DETECTORQE, InterpolationOrder -> 2];
qeccd = Plot[CCDdetectorQE[λ nm], {λ, 250, 1050},
  Frame -> True, GridLines -> Automatic, PlotStyle -> RGBColor[1, 0, 0],
  FrameLabel -> {Style["λ[nm]", FontSize -> 16, FontWeight -> "Bold"], ""},
  AspectRatio -> 0.5, PlotRegion -> {{0.02, 0.98}, {0.02, 0.98}},
  Prolog -> AbsoluteThickness[2], PlotRange -> {0, 1}, DisplayFunction -> Identity];

In[42]:= L2 = Graphics[{RGBColor[1, 0, 0], Line[{{400, 0.45}, {450, 0.45}}]}];
T2 = Graphics[
  Text[Style["EEV CCD39-01", FontSize -> 14, FontWeight -> "Bold"], {460, 0.45}, {-1, 0}]];

In[44]:= QEgra = Show[qeccd, L2, T2,
  PlotLabel -> Style["Quantum Efficiency", FontSize -> 14, FontWeight -> "Bold"],
  DisplayFunction -> $DisplayFunction]

```



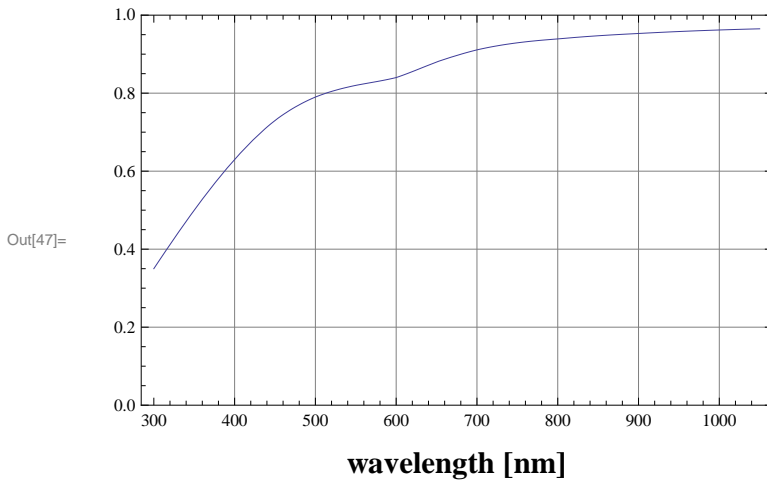
Atmosphere plus M1-> M4 and two more mirrors

```

In[45]:= ATMOSPHERE = {{300 nm, 0.35}, {400 nm, 0.63}, {450 nm, 0.73},
  {500 nm, 0.79}, {550 nm, 0.82}, {600 nm, 0.84}, {650 nm, 0.88}, {700 nm, 0.911},
  {800 nm, 0.939}, {900 nm, 0.953}, {1000 nm, 0.962}, {1050 nm, 0.965}};
atmosphere = Interpolation[ATMOSPHERE];

```

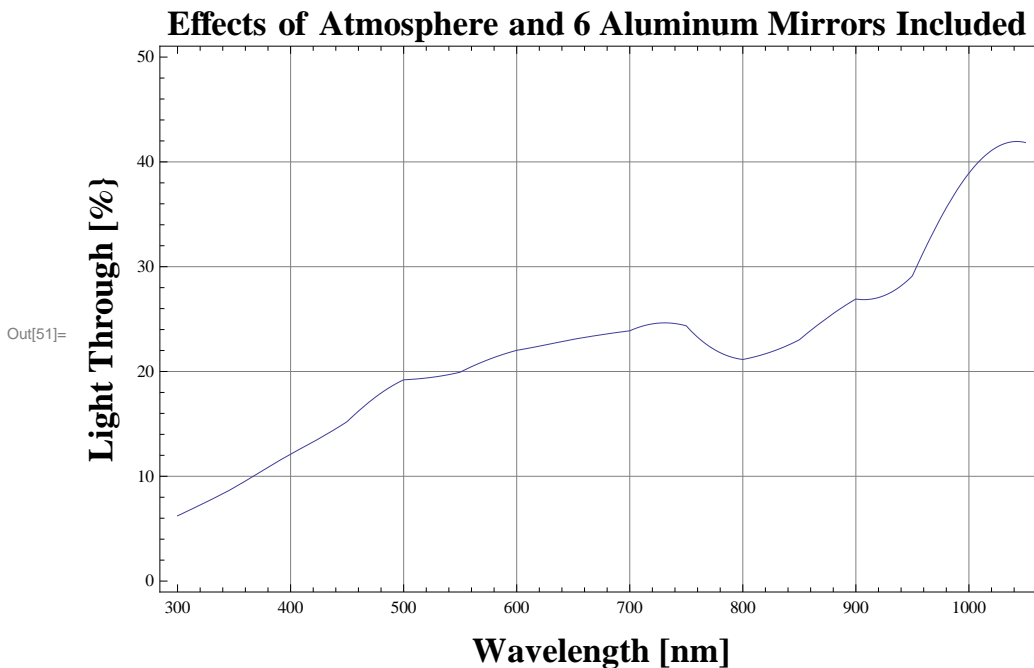
```
In[47]:= Plot[atmosphere[λ nm], {λ, 300, 1050}, Frame → True, GridLines → Automatic, FrameLabel →
{Style["wavelength [nm]", FontSize → 16, FontWeight → "Bold"], ""}, PlotRange → {0, 1}]
```



```
In[48]:= OldAluD = {{300 nm, 0.75}, {350 nm, 0.75}, {400 nm, 0.76},
{450 nm, 0.77}, {500 nm, 0.79}, {550 nm, 0.79}, {600 nm, 0.80},
{650 nm, 0.80}, {700 nm, 0.80}, {750 nm, 0.80}, {800 nm, 0.78}, {850 nm, 0.79},
{900 nm, 0.81}, {950 nm, 0.82}, {1000 nm, 0.86}, {1050 nm, 0.87}};
```

```
In[49]:= OldAlu = Interpolation[OldAluD, InterpolationOrder → 2];
```

```
In[50]:= Ltr = Plot[atmosphere[λ nm] * OldAlu[λ nm]^6 * 100, {λ, 300, 1050}];
Show[Ltr, Frame -> True, Axes -> None, PlotRange -> {0, 50},
PlotLabel -> Style["Effects of Atmosphere and 6 Aluminum Mirrors Included ",
FontSize -> 18, FontWeight -> "Bold"],
FrameLabel -> {Style["Wavelength [nm]", FontSize -> 18, FontWeight -> "Bold"], Style[
"Light Through [%]", FontSize -> 18, FontWeight -> "Bold"]}, GridLines -> Automatic]
```



```
In[52]:= M1a = 0.77; (* Primary area 0.77 m2 *)
```

```

In[57]:= IncidentPhotons[T_, m_, a_, λ_] :=
  PhotonAtTheTopOfTheAtmosphere[T, m, λ nm] * atmosphere[λ nm] * M1a * OldAlu[λ nm]^6;
  (*ph/nm/sec on the detector*)

In[58]:= TotalNumberOfPhotons[T_, m_, a_] :=
  NIntegrate[IncidentPhotons[T, m, a, λ], {λ, 300, 1050}] a (*photons/sec*)

In[59]:= TotalNumberOfDetectedP[T_, m_, a_] :=
  NIntegrate[IncidentPhotons[T, m, a, λ] * CCDdetectorQE[λ nm], {λ, 300, 1000}]
  a (*counts/sec*)

In[60]:= Teff = {26 500, 13 800, 9850, 7030, 5900, 5240, 3750}; (*B0,B5,A0,F0,G0,K0,M0*)

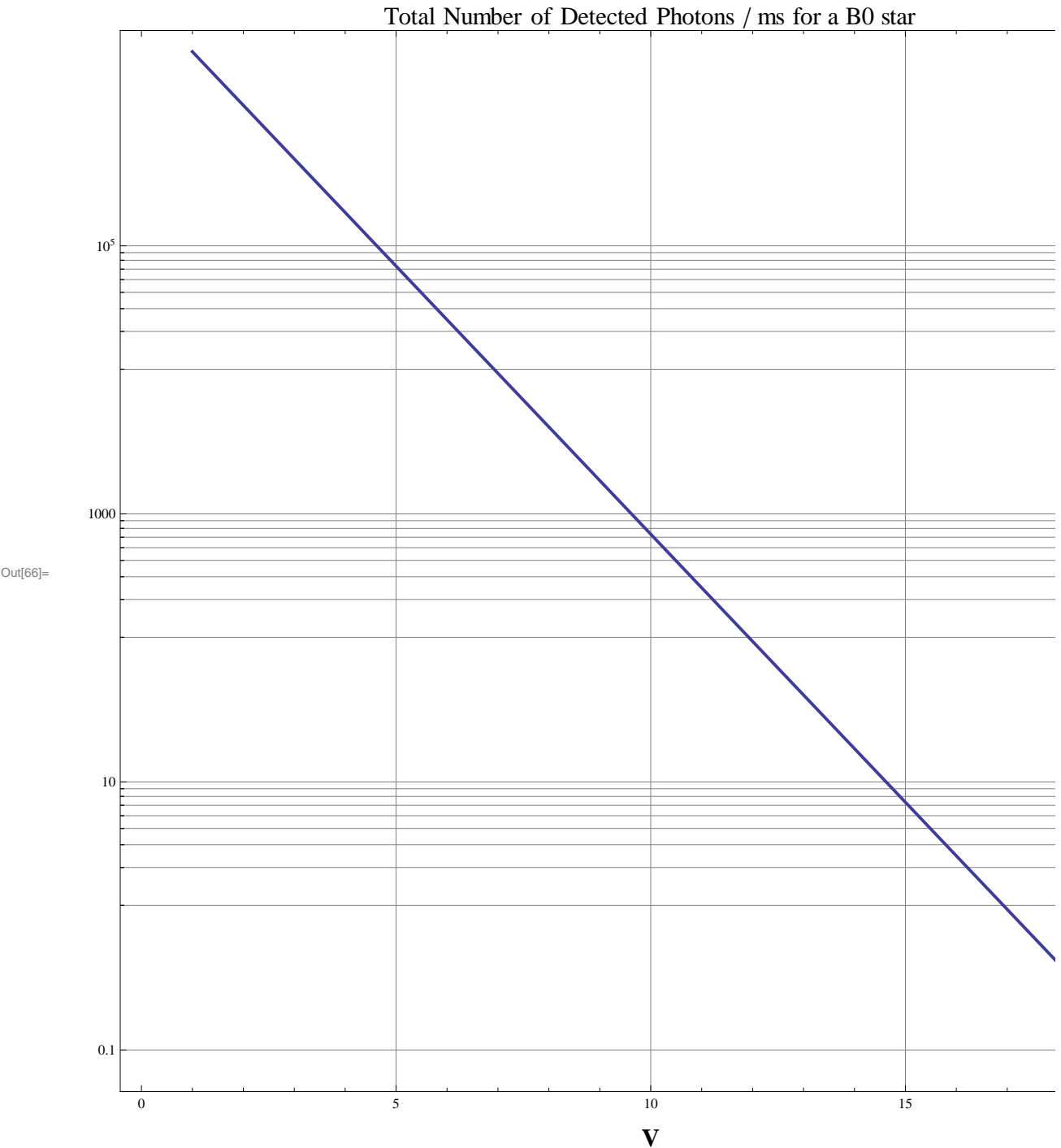
TotDetctdPH = Table[{(i), TotalNumberOfDetectedP[Teff[[1]], i, M1a] / 1000}, {i, 1, 20}]
  (* total # of photons detected from spectral type
  Teff[[n]] / millisecond as a function of V mag 1 to 20*)

Out[61]= {{1, 2.81001 × 106}, {2, 1.11869 × 106}, {3, 445 357.}, {4, 177 300.}, {5, 70 584.4},
  {6, 28 100.1}, {7, 11 186.9}, {8, 4453.57}, {9, 1773.}, {10, 705.844},
  {11, 281.001}, {12, 111.869}, {13, 44.5357}, {14, 17.73}, {15, 7.05844},
  {16, 2.81001}, {17, 1.11869}, {18, 0.445357}, {19, 0.1773}, {20, 0.0705844}}

In[63]:= P1 = ListLogPlot[TotDetctdPH, PlotRange → All, Frame → True, Axes → None,
  GridLines → Automatic, PlotStyle → AbsoluteThickness[2], FrameLabel →
  {Style["V", FontSize → 16, FontWeight → "Bold"], " "}, AspectRatio → 1, Joined → True];

```

```
In[66]:= Show[P1, PlotLabel ->
  Style["Total Number of Detected Photons / ms for a B0 star", {"Times-Bold", 16}]]
```



```
In[67]:= TotDetctdPH = Table[{(i), TotalNumberOfDetectedP[Teff[[7]], i, M1a] / 1000}, {i, 1, 20}]
```

```
Out[67]= {{1, 4.6618 × 106}, {2, 1.8559 × 106}, {3, 738846.}, {4, 294140.}, {5, 117099.},
  {6, 46618.}, {7, 18559.}, {8, 7388.46}, {9, 2941.4}, {10, 1170.99},
  {11, 466.18}, {12, 185.59}, {13, 73.8846}, {14, 29.414}, {15, 11.7099},
  {16, 4.6618}, {17, 1.8559}, {18, 0.738846}, {19, 0.29414}, {20, 0.117099}}
```



```
In[68]:= P2 = ListLogPlot[TotDetctdPH, PlotRange -> All, Frame -> True, Axes -> None,  
GridLines -> Automatic, PlotStyle -> AbsoluteThickness[2], FrameLabel ->  
{Style["V", FontSize -> 16, FontWeight -> "Bold"], " "}, AspectRatio -> 1, Joined -> True];  
In[69]:= Show[P2, PlotLabel ->  
Style["Total Number of Detected Photons / ms for a M0 star", {"Times-Bold", 16}]]
```

