Load all the relevant packages

In [17]:
```
using IntervalArithmetic
```

In [18]:
```
using IntervalRootFinding
```

In [19]:
```
using StaticArrays
```

In [20]:
```
using DifferentialEquations
```

In [21]:
```
Pkg.add("ForwardDifff")
using ForwardDifff
```

```
unknown package ForwardDifff
macro expansion at .\pkg\entry.jl:53 [inlined]
(::Base.Pkg.Entry.##1#3{String,Base.Pkg.Types.VersionSet})() at .\task.jl:335

Stacktrace:
 [1] sync_end() at .\task.jl:287
 [2] macro expansion at .\task.jl:303 [inlined]
 [3] add(::String, ::Base.Pkg.Types.VersionSet) at .\pkg\entry.jl:51
 [4] (::Base.Pkg.Dir.##4#7{Array{Any,1},Base.Pkg.Entry.#add,Tuple{String}})()
at .\pkg\dir.jl:36
 [5] cd(::Base.Pkg.Dir.##4#7{Array{Any,1},Base.Pkg.Entry.#add,Tuple{String}},
::String) at .\file.jl:59
 [6] #cd#1(::Array{Any,1}, ::Function, ::Function, ::String, ::Vararg{String,N
} where N) at .\pkg\dir.jl:36
 [7] add(::String) at .\pkg\pkg.jl:117
```

In [22]:
```
using Plots
```

Define the ODE to be analysed

In [23]:
```
Angeli2(u, p) = SVector(
    p[1]*(100-u[1])-p[2]*u[1]*(p[3]*u[2])^p[4]/(p[5]+(p[3]*u[2])^p[4]),
    p[6]*(100-u[2])-p[7]*u[2]*u[1]^p[8]/(p[9]+u[1]^p[8])
    )
```

Out[23]:
```
Angeli2 (generic function with 1 method)
```

In [24]:
```
# set the parameters
alpha1=1
alpha2=1
beta1=200
beta2=10
gamma1=4
gamma2=4
K1=30
K2=1
v=1

p=[alpha1, beta1, v, gamma1, K1, alpha2, beta2, gamma2, K2];
```

For each variable, create a matrix to put all the solutions (preallocate). Since we don´t know the number of solutions we will get, make the matrix big enough

In [25]:
```
x1_matrix=NaN*ones(5,2001); #create a matrix to put at most 5 solutions of
y1_matrix=NaN*ones(5,2001); #create a matrix to put at most 5 solutions of
```

Let's start!!!

In [26]:
```
counter=1; # initialize the counter

for v in 0:0.005:1 #this is our bifurcation parameter.

    p=[alpha1, beta1, v, gamma1, K1, alpha2, beta2, gamma2, K2]; #update paramet
er vector

    X = IntervalBox(0..100, 2) # create the interval box in the phase plane. in
this case, it is a 2d box.
    # should be as big as state space to make sure we are not missing any soluti
ons

    aa=roots(u->Angeli2(u, p), X) #compute all the roots MAGIC!
    #output of this fantastic code are small boxes (intervals) with contain the
solutions.

    #Since we want to get not an interval, but a real number, we need to take th
e middle value:

    mids = mid.([rt.interval for rt in aa]) #take the middle value for the roots
in the boxes

    count_dif_sols=1
    # now, it is possible that we get several boxes. this can be because (1) we
have several solutions (which we expect,
    # at least for some parameter values), or because the boxes spit out by the
roots function are too small, i.e. thery are finding
    # effectively the same root just with differnt "names" so to say. we shall f
ilter out this second option in the following:
    #and fill our matrices
    for sol in 1:length(mids)

        if (sol==1)
        x1_matrix[count_dif_sols,counter]= mids[sol][1]
        y1_matrix[count_dif_sols,counter]= mids[sol][2]
         count_dif_sols=count_dif_sols+1
        else
            if (abs(mids[sol][1]-mids[sol-1][1])>0.001)
        x1_matrix[count_dif_sols,counter]= mids[sol][1]
        y1_matrix[count_dif_sols,counter]= mids[sol][2]
         count_dif_sols=count_dif_sols+1
            end
        end
    end
    counter=counter+1
end
```

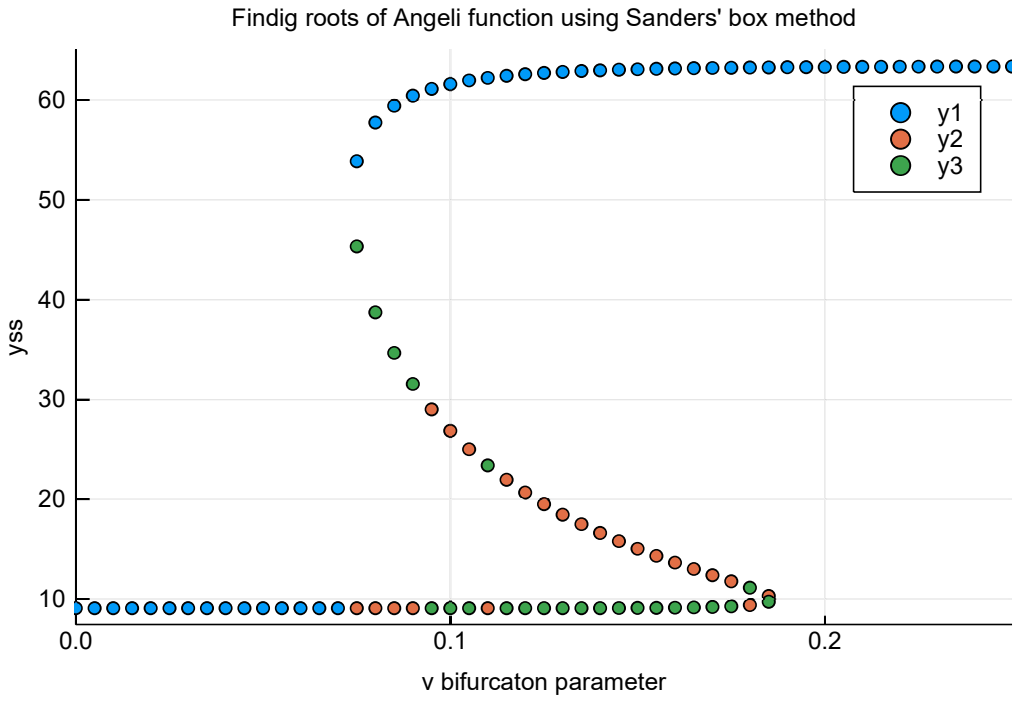
yeii! we are ready. let's plot our results.

In [27]:
```
# first, create a vector with the bifurcation parameter values tested in the pre
vious step
vvect=collect(0:0.005:1);

# we are ready to plot now:
scatter(vvect, y1_matrix[1,:])
scatter!(vvect, y1_matrix[2,:])
scatter!(vvect, y1_matrix[3,:])

#just fixing the labels and stuff
plot!(xlabel="v bifurcaton parameter")
plot!(ylabel="yss")
plot!(title="Findig roots of Angeli function using Sanders' box method")
plot!(xlims=(0,.25),xticks=0:.1:.25)
```

Out[27]:



In [ ]:

In [ ]: