

Precision Focusing with FocusMax

Steve Brady http://focusmax.org



Precision Focusing with FocusMax

CCD Astronomers Hate Focusing!!



I have been chasing focus demons for many years!



My First Telescope Circa: 1964



My Astro-Cameras









1970's





My Astro-Cameras

ST-8 XME



How do you focus this thing ???

1990's



FocusMax was developed by Steve & Larry to address a missing link in observatory automation





FocusMax Goals

- Accuracy equal to or better than manual focusing
- Fast so that valuable observing time is not lost
- Robust so that the user can expect it to arrive at the correct focus even in marginal conditions
- Capable of accommodating a wide range of initial out of focus star diameters
- Operate as an automation client for unattended observing (ACP, CCAP, CCDC,....)



Degree of Focus Metric

Half Flux Diameter (HFD)

The diameter of a circle centered on the unfocused star in which half of the total star flux is inside the circle and half is outside





Degree of Focus Metric

- HFD units are CCD pixels
- Relatively insensitive to variations in seeing
- Accurate over a wide range of unfocused star diameters
- HFD is determined by integrating all of the flux from the unfocused star



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File Set					
Run	Stop				
Vcurve Par	ameters End Poin	•<	Hal Wid	f 💿	
Autofocus	Initial	3446	Center	3596	
Repeat 0	Final	3746	Half Width	150	
Images /position	Step Incr.	10	Steps	30	
Fit Lines =	Left	Right			
Slope	-0.191682	0.19200	08 n	ifference	
Position Intercept	3597.6	3587.2	1	0.38	

A plot of HFD vs. focuser position yields a 'V' shape

The 'wings' of the curve are linear which are dependent on

- optical f/ratio
- CCD pixel size
- focuser gear ratio
- etc.

FocusMax



FocusMax



💆 Vcurve S	equence				
File Set					
Run	Stop				
Vcurve Par	ameters End Point	s 🔘	Half Width (©		
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Images /position 1	Step Incr.	10 9	Steps 30		
Fit Lines =	Left	Right			
Slope	-0.191682	0.192008	Difference		
Position Intercept	3597.6	3587.2	10.38		

FocusMax automatically determines:

FocusMax

- Slope of the Right & Left lines
- Position Intercept
- Position Intercept Difference (PID)



💆 FocusMax Simulator
File Open Wizard Set Help
Profile V Curve Log Scope Jog Mini
Position Temp. 24995 52.08 Pause Stop
Half Flux Diameter = 3.50
Find Expose Focus Select
Acquire Star
Focus Setup Features System

Vertical bin of the sub-framed star

Detected star boundaries



💆 FocusMax Simulator					
File Open Wizard Set Help					
Profile V Log Tele- Scope Jog Mini					
PositionTemp.2499552.08PauseStop					
Half Flux Diameter = 3.50					
Find Expose					
Acquire Star					
Focus Setup Features System					

Location of star on camera chip





Flux integral plot of the star diameter along the x-axis and integrated flux along the y-axis.

HFD is the point marked with a vertical line



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Half Flux Diameter = 3.5	0				
Find Expose Focus Select Acquire Star					
Focus Setup Fea	atures System				

Find button :

- Take a full frame image
- Find brightest star
- Subframe star





Expose button :

 Take a subframe image centered on star from 'Find' star process

Star position on CCD must be known





Focus button:

- Take a full frame image
- Find brightest star in image
- Subframe star
- Move focuser to Start Position
- Move focuser to Near Focus Position
- Take repetitive subframe images
- Measure HFD and calculate Best Focus position





Select button (MaxIm only):

- •Take full frame image
- User clicks on target star with mouseAutofocus is initiated
- •Useful if user does not want to leave present field
- •Blobs (deep sky objects) will confuse FocusMax and report larger HFD values (they appear as out of focus stars)





AcquireStar button:

- Take image and plate solve current telescope position *
- Look up target stars from catalog
- Slew telescope
- Center target star
- Autofocus
- Return slew
- Take image and plate solve telescope position *
- Fine tune pointing to user defined error

•Requires full feature PinPoint (http://www.dc3.com/)



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Near Focus				
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Autofocus Exp. Flux				
Frame 50 Min 0.10 50				
Tgt Star 3 ▼ Max 5.00 500				
Focus Bin 1 - Base Exp				
Focus Start				
Position 24882 📄 🔘 Position				
HFD 20 O HFD				
Prev. Focus 24989 Current Pos.				
Focus Setup Features System				

Near Focus:

- <u>HFD</u> position used to determine focus position
- <u>Exposures</u> the number of subframe images used to determine the final focus position



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Autofocus Exp.	Flux			
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Focus Bin 1 - Base 1.00				
Focus Start				
Position 24882 📄 🔘 Positio	n			
HFD 20 O HFD				
Prev. 24989 Curren	t Pos.			
Focus Setup Features	System			

Move:

- •Set focuser move direction and settle time to prevent image wiggle
- Focuser movement will be toward focus to eliminate backlash
- Move direction is often set to move load against gravity



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Focus	Setup	Feature	s System	

Autofocus:

- Initial subframe width
- Target star binning (1 4)
- Focus binning (1 & 2)
- Min/Max Exposure
- Min/Max Flux
- Base exposure



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Autofocus example:

- Star will be found using 3x3 binning
- Focus Bin will be 1x1
- Initial subframe will be 50 x 50 pixels



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Autofocus example:

 First exposure will be 1.00 sec and may be adjusted up or down to meet the midpoint of the Flux range of 50K – 500K

•Last resort:

- If the star is too dim then it will attempt to target Min Flux
- If the star is too bright it will attempt to target Max Flux setting



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Autofocus exposure calculation:

Target Flux = (500K + 50K)/2 = 275,000

Base Exp. = 1.0 sec

Measured star Total Flux = 536,401

New Exp = $1.0 \times (275 \text{K} / 536 \text{K}) = 0.51 \text{ sec}$



Max Flux Setting (CCD Linearity Test)

- Select moderately faint, isolated star near the zenith
- Focus telescope
- Set Min Flux to 0 on Setup Tab
- Enable CCD Central Region on Features Tab and set to 25% (or smaller)
- Set Base Exp. to 0.1 sec
- Press Find and verify that FocusMax identifies the target star
- Note the Exp., Max Pixel and Total Flux in Log
- Increase Base Exp. to 0.5 press Find
- Increase Base Exp. To 1 sec and repeat in intervals of 2 sec until reach 30 sec (can be automated in MaxIm using Autosave feature)
- Construct a plot of Max Pixel vs. Exp. time



Max Flux Setting





Max Flux Setting





Max Flux Setting





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Focus Start:

- <u>Position</u> move focuser immediately to the listed position (fastest method but position must be current from recent autofocus run)
- <u>HFD</u> requires finding the focuser at HFD setting (medium speed preferred)
- <u>Current Position</u> start at current focuser position and then find HFD position (slowest)



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Focus Setup Features S	ystem					





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Autofocus Exp. File (sec) (10)						
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Tgt Star 3 ▼ Max 5.00 50 Bin	0					
Focus Bin 1 👻 Base 1.00						
Focus Start						
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HFD 20 O HFD						
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Autofocus Exp.	Flux					
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Focus Setup Features	System					


FocusMax Tour Features Tab



Image Calibration:

Help eliminate 'hot pixel' that may cause FocusMax to think a it is a star for focusing

FocusMax

MaxIm

- Create a set of dark frames in the Min/Max exposure range and binning
- Create a set of bias frames
- Save frames to a directory
- Load frames into MaxIm using Set Calibration

CCDSoft

 FocusMax will utilize Image Reduction: AutoDark with each frame taken



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CCD Central Region Enable V Percent 70							
Focus Routine Max Fail Fail							
Return to V 5 3 5 start pos.							
Focus Convergence Steps Samples							
Enable 🗹 2 5							
Focus Setup Features System							

AcquireStar:

Automated target star acquisition, star centering and autofocus



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CCD Central Region						
Enable 👽 Percent 70						
Focus Routine Max Fail Fail						
Return to V 5 3 5						
Focus Convergence Steps Samples						
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Focus Setup Features System						

CCD Central Region:

- Limit the area for target star detection to central region on the CCD
- Reduces impact of curvature of field and coma
- Recommended for wide field / large format cameras



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Focus Convergence								
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Focus Setup Features System								

Focus Routine:

- <u>Return to Start Position</u> triggered by:
 - Autofocus HFD > Max HFD
 - Lost star
 - Clouds
- <u>Max HFD</u> largest allowed HFD
- <u>Fail Attempts</u> number of tries to achieve focus
- <u>Fail Time</u>**r** delay before autofocus routine is attempted again (clouds)

Useful for unattended all night runs



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Return to 5 3 5								
Focus Convergence Steps Samples								
Enable 🗹 2 5								
Focus Setup Features System								

Focus Convergence:

Will determine the best focus position by taking repeated subframe images until the average HFD falls within a user defined tolerance

- <u>Steps</u> the number of focuser steps (units) that the average HFD must fall within
- <u>Samples</u> the number of consecutive measurements that must fall within the above Steps setting before making the final focuser move



Focus Convergence





Accuracy & Precision





Accuracy & Precision



High accuracy Low precision





Focus Repeatability (Precision)

				Deita
Time	Temp	Position	HFD	(steps)
4.50.55	4.5	2571	3.59	
4.52.54	4.5	2574	3.66	-3
4.55.26	4.5	2573	3.66	1
5.04.10	4.5	2573	3.7	0
5.10.09	4.5	2567	3.76	6
5.13.11	4.5	2565	3.77	-2
5.17.25	4.5	2571	3.99	-6
5.19.27	4.5	2569	4.08	2

Precision

(error)

















No significant difference with binning







16" F/4.5 Newtonian Optec focuser

 $1 \text{ step} = 2.18 \mu$

Total error = \pm 15 x 2.18 = \pm 33 µ = \pm .0013"





Is \pm 33µ error good or bad??

16" F/4.5 Newtonian Optec focuser

 $1 \text{ step} = 2.18 \mu$

Total error = \pm 15 x 2.18 = \pm 33 µ = \pm .0013"



Critical Focus Zone and "New" Critical Focus Zone **

 $CFZ = 4.88 * F^2 * \lambda = 49 \mu$

NCFZ = $1.6 * F^2 * \lambda = 16 \mu$

** Get Focused!D. Goldman & B. Megdal Jan, 2010



Critical Focus Zone and "New" Critical Focus Zone **

 $CFZ = 4.88 * F^2 * \lambda = 49 \mu$

NCFZ = $1.6 * F^2 * \lambda = 16 \mu$

My focus precision > CFZ & NCFZ

CFZ & NCFZ does not take into account:

- Seeing
- Telescope aperture



What is the positional error of ± 15 steps as a percent of seeing ?





'<u>New Critical Focus Zone</u>"

Takes into account:

- Seeing
- Telescope aperture
- Telescope focal ratio
- Acceptable focus tolerance

** Dr. Jeff Winter http://www.goldastro.com/goldfocus/ncfz.php



"<u>New Critical Focus Zone</u>"

$NCFZ = 0.00225 \cdot \theta_{FWHM} \cdot \sqrt{\tau \cdot A \cdot f^2}$

NCFZ (microns)

0.00225 - constant (microns per arc-sec/mm)

 θ_{FWHM} - total seeing (arc-sec)

 τ -focus tolerance as a percentage of total seeing (no units)

A - telescope aperture (mm)

f-effective imaging system f/ratio (no units)



"<u>New Critical Focus Zone</u>"

My 16" Newtonian:

$$\theta_{\text{FWHM}} = 3.0" \text{ (my typical seeing)}$$

$$T = ??$$

$$A = 16" \times 25.4 = 406.4 \text{mm}$$

$$f = 4.5$$

$$\text{NCFZ} = 66\mu \text{ total focus repeatability error}$$

$$T = \left(\frac{66\mu}{.00225 \times 3 \times 406.4 \times 4.5^2}\right)^2$$

$$= 1.4\% \text{ focus error in 3" seeing}$$



"<u>New Critical Focus Zone</u>"

3% focus error In 2" seeing

12% focus error in 1" seeing

BUT

I would expect <u>much better</u> focus repeatability (precision) in seeing better then 3 arc-sec!



Focusing System

- Good accuracy (center of CFZ)
- Good precision
 - Focuser step size should not be
 - under sampled to CFZ
 - Under sampled means
 - 1 focuser step >= CFZ



Focusing System

What should be the minimum focuser step resolution relative to the CFZ ??

10:1 rule of thumb used in metrology

- "Measurements should be sensitive enough to detect differences as slight as one-tenth of the total tolerance " (CFZ)
- "Inadequate discrimination will affect both accuracy and precision"

There is also a 4:1 rule but 10:1 has been universally adopted



💆 FocusMax Simulator							
File Open Wizard Set Help							
Profile V Curve Log Tele- Scope Jog Mini							
Focuser							
Simulator							
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In 🕶 10 Steps 💿 CCDSoft							
Profile Position 7.80 Int. Diff. 7.80 Slope L -0.193330 R 0.193179							
System Paths							
Focus Setup Features System							

Focuser:

- Choose ASCOM Focuser
- •Setup focuser
- •Connect / Disconnect focuser
- •Enable native focuser driver temperature compensation



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Profile Position 7. Int. Diff. Slope L -0.193330	.80 R 0.193179							
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Paths								
Focus Setup	Features System							

Backlash Compensation:

- Set focuser backlash direction In/Out
- Number of steps

BL Setting may be available in focuser documentation

You can measure the actual backlash with a drop indicator

Older SCT telescopes may required up to 200 steps in cold temperatures



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Focus Setup Features System							

Imaging SW: Select either MaxIm Or CCDSoft



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Simulator								
Focus Setup Features System								

Profile: Current Vcurve parameters (from Profile window)



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Profile Position Int. Diff. 7.90								
Slope L -0.193330 R 0.193179								
System Paths								
Simulator								
Focus Setup Features System								

System:

- The current user selected system.ini file where data will be saved
- Paths button allows you to change the location of the Log files and Images



System Profile

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Sy Sy Si	stem stem	Profile Nator	Left Right	Mean Slope -0.193330 0.193179	e Mean Po Intercept 7.80	sition Total Diff Points 2	Delete Entries
	Use	Date	Time	PLDiff	L Slope	R Slope	Comments
	Y	2012/07/07	15:55:08	9.22	-0.190280	0.190125	Binning=1 Total pts=34 Good pts=25
	Y	2012/07/04	09:33:00	6.37	-0.196381	0.196233	Binning=1 Total pts=34 Good pts=30

Shows the average Left & Right Slopes and PID



System Profile

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	Y	2012/07/07	15:55:08	9.22	-0.190280	0.190125	Binning=1 Total pts=34	Good pts=25
	Y	2012/07/04	09:33:00	6.37	-0.196381	0.196233	Binning=1 Total pts=34	Good pts=30

Vcurve run data

- Enable / Disable row
- Delete a row
- Binning, Total points and number of good points



System Profile

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Sy Si	isten imula	ı Itor	Left	Mean Slope -0.193330	e Mean Po Intercept 7.80	sition Total Diff Points 2		Delete Entries		
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	Use	Date	Time	PI Diff	L Slope	R Slope	Comments	:		
	Υ	2012/07/07	15:55:08	9.22	-0.190280	0.190125	Binning=1	Total pts=34	Good pts=25	
	Y	2012/07/04	09:33:00	6.37	-0.196381	0.196233	Binning=1	Total pts=34	Good pts=30	

Vcurve run data:

- 1. Review Left & Right Slopes and PID
- 2. Delete values that look like fliers
- 3. Want ~ 12 good Vcurve rows in your Profile

💆 Options 🛛 🔂					
- Auto-connect					
✓ Focuser ✓ Camera					
Purge Files (days) Delete Logs on Startup Temp Log 180					
Camera Delay Pre-focus Message Pre-exp. Post-exp 0 0 (sec) Enable 0 (min)					
Focus Enable auto subframe width Final Focus Focus Offset +/- steps Simulator seeing conditions 3					
Focuser Limit end of Travel Position 0 Steps Polling Rate 3 • sec					
General Verify PinPoint Install SendLlog Text to ACP Size 8 Font MS Sans Serif					

Auto-connect:

Connect devices on startup

FocusMax

- Focuser
- Camera
- Telescope

Default is none

💆 Options 🛛 💽					
- Auto-connect					
📝 Focuser 🛛 🔽 Camera 🕅 Telescope					
Purge Files (days) Delete Logs on Startup Camera Delay Camera Delay Camera Delay Camera Delay Camera Delay Camera Delay					
Pre-exp. Post-exp 0 0 (sec)					
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Focuser Limit end of 0 Steps Polling Travel Position 0 Steps Rate 3 ▼ sec					
- General Verify PinPoint Install SendLlog Text to ACP Size 8 Font MS Sans Serif					

Focus:

• Enable Auto Subframe Width use subframe width defined on Setup Tab

FocusMax

- •<u>Offset</u> useful for photometry to defocus an image
- Final Focus Images average the HFD of consecutive images when the focuser moves to the Best Focus position

💆 Options	—				
Auto-connect					
V Focuser V Car	mera 🔲 Telescope				
Purge Files (days) Delete Logs on Startup Camera Delay Pre-exp. Post-exp 0 0 (sec) Focus Enable auto outoframe width	Log 180 Temp Log 180 - Pre-focus Message Enable 0 fimer (min) Final Focus 5				
Focus Offset +/- steps	Simulator seeing 3				
Focuser					
Limit end of Travel Position 0 Steps Polling 3 - sec					
General Verify PinPoint Install SendLlog Text to ACP Size 8 Font MS Sans Serif					

Focuser:

<u>Limit End of Travel Position</u> prevent the focuser from reaching physical hard stop

FocusMax

<u>Polling Rate</u> - set the time (sec) that the focuser is polled for temperature and position information

💆 Options	×				
Auto-connect					
🔽 Focuser 🛛 🔽 Ca	amera 🔲 Telescope				
Purge Files (days) Delete Logs on Startup	Log 180				
Camera Delay Pre-exp. Post-exp 0 0 (sec)	Pre-focus Message				
Focus Enable auto subframe width Focus Offset +/- steps	Final Focus Images 5 Simulator seeing 3 •				
Focuser Limit end of Travel Position 0 Steps Polling Rate 3 vec					
General Verify PinPoint Install SendLlog Text to ACP Size 8 Gr. Font MS Sans Serif	Flush Camera 5 Images 5 aphic Color Red •				

General:

• Flush Camera Images - consecutive O sec exposures at the end of the autofocus run to remove potential ghost image on the next image

FocusMax

- Font and Font Size can be set
- Graphic Colors Red, Green, Blue useful for laptops with red mylar


Focus Plot



Predicted Focus Position for each subframe image – note variation in position from each image due to seeing

Mean Best Focus - the average focus position



💆 First Light Wizard	
This wizard will measure the charact system and automatically set up all o parameters needed by FocusMax.	teristics of your of the critical
Back	t

- Handles limited range focusers FLI Optec
 - focal reducer
- Gracefully handles sins of relative focusers Backlash
 - End of mechanical travel
- Finds lost stars
- Accurately sets up Vcurve range values



₹	First	Light Wi	zard		

This wizard will measure the characteristics of your system and automatically set up all of the critical parameters needed by FocusMax.

Back Next	Cancel

- Manually focus the telescope
- Make mechanical adjustments so that the focus position is mid-way between the In and Out travel of the focuser
- Select a star near the zenith, press the Find button and verify in the Log that the resulting Min/Max Flux falls within the boundary on the Setup tab
- Verify that the star is not saturated



₹	First Light Wizard	

This wizard will measure the characteristics of your system and automatically set up all of the critical parameters needed by FocusMax.

ieters needed by Focusimax.	
Back Next	Cancel

х

- Select the First Light Wizard from the Wizard menu
- The wizard will prompt you at each step of the process



💆 Vcurve Sequence	- • -
File Set	
Run Stop	
Vourve Parameters	d Half
Pol Autofocus 🗸 Initia	nts Width
Repeat 0 Fina	l 25150 Half Width 156
Images 2 Step /position 2 Incr	10 Steps 31
20000	0000
Fit Lines Left Slope Position Intercept	Right Difference

- Wizard will start by moving the focuser away from the focus point to estimate the slope of one side of the 'Vcurve'
- Will continue to move the focuser until it achieves the HFD setting (default = 40)
- If your focuser can not achieve this setting then re-run the First Light Wizard and reduce the HFD value when prompted



💆 Vourve S	equence			• 💌
File Set				
Run	Stop			
Vcurve Par	ameters En Poi	d 💿	Ha Wid	f 💿
Autofocus	📃 Initia	3446	Center	3596
Repeat 0	Fina	3746	Half Width	150
Images /position	Step Incr	10	Steps	30
		A.	5 ⁵	ф ^Ф
Fit Lines -	Left	Rig	ht	
Slope	-0.191682	0.192	2008 D	ifference
Position Intercept	3597.6	3587	.2 1	0.38

- Once the slope has been estimated, the Vcurve is generated
- Vcurve results are saved in system Profile



💆 Vourve S	equence			×
File Set				
Run	Stop			
Vcurve Par	ameters End Poin	ts ©	Half Width	۲
Autofocus	📄 Initial	3446	Center 35	i96
Repeat 0	Final	3746	Half Width 15	10
Images /position	Step Incr.	10	Steps 30	
	A Contraction of the second se	ES D	f f f	Þ
Fit Lines =	Left	Right		
Slope	-0.191682	0.192008	3 Diffe	rence
Position Intercept	3597.6	3587.2	10.3	18

- 1) Focus the telescope
- 2) Adjust focuser to midpoint of focuser travel
- 3) Select 4 6th mag star (fainter for larger apertures) near zenith
 4) Open Vcurve window current focuser position will be entered



💆 Vourve S	equence			
File Set				
Run	Ston			
_Γ Vourve Par	ameters			·
	Point	ts 🔘	Wid	th 🔍
Autofocus	📄 Initial	3446	Center	3596
Repeat C) Final	3746	Half Width	150
Images Aposition	Step Incr.	10	Steps	30
A A A A A A A A A A A A A A A A A A A		A B B B	5 ⁵	F.
Fit Lines -	Left	Right		
Slope	-0.191682	0.19200	⁾⁸ D	ifference
Position Intercept	3597.6	3587.2	1	0.38

- Half Width number steps away from focus
 Fnd Dainta initial and final focusor positions
- End Points initial and final focuser positions
- •<u>Step Increment</u> number of steps the focuser will move
- <u>Steps</u> number of moves that will be made
- <u>Repeat</u> rerun the Vcurve
- •<u>Images/position</u> take multiple images and average the HFD at each move (helps with seeing effects)



💆 Vcurve Sequence 👘	
File Set	
Run Stop	
Vcurve Parameters End Point Autofocus Initial Repeat Final Images 1 Step	S Half 3446 Center 3596 3746 Half 150 Width Steps 30
/position ' Incr.	A CONTRACTOR
Fit Lines	Bight
Slope -0.191682	0.192008 Difference
Position Intercept 3597.6	3587.2 10.38

Method #1 - Half Width:

- 1) Manually focus the telescope
- Press the Jog button and move the focuser In or Out 100 units then press the Find button
- 3) Continue to move the focuser until you achieve an HFD of 20+ (30 40 is better)
- 4) Note the focuser position
 - 5) Bring the focuser back to the focus position and press the Half Width button on the Vcurve window
 - 6) Enter the difference between the focus position and the position achieved when you manually jogged the focuser
 - 7) Press Run



💆 Vourve Se	quence	[• 💌
File Set				
Run Sta	ор			
Autofocus	meters End Poir	nts (3446	Ha Wid Center	lf Jth 3596
Repeat 0 Images 1 /position 1	Final Step Incr.	3746 10	Half Width Steps	150 30
	L.	A Contraction of the second se	f f	5000
Fit Lines	Left 0.191682	Righ 0.1920	t)08 _ C)ifference
Intercept 3	597.6	3587.2	2	10.38

Method #1 Example:

- 1) Focus position is 3,500 and 4,000 was the position to achieve 30 HFD
- 2) Enter the difference of 500 into the Half Width box
- 3) Adjust the Step Increment value until you see 30 40 <u>Steps</u> displayed
- 4) Press Run





Method #2 - End Points:

- 1) Press the End Points button on the Vcurve window
- Press the Jog button and move the focuser
 <u>'Out</u>' 100 units then press the Find button
- 3) Continue to move the focuser until you achieve an HFD of 20+ (30 40 is better)
- 4) Enter the focuser position in the Initial position





Method #2 - End Points:

- 5) Move the focuser 200 units '<u>In</u>' then press the Find button
- 6) Continue to move the focuser until you find the position approximately equal to the HFD from step 3
- 7) Enter the focuser position in the Final position
- 8) Bring the focuser back to the focus position
- 9) Press Run





Method #2 - Example:

- 1) Focus position is 3,596
- 2) Initial position = 3446 (In) to achieve 30 HFD
- 3) Final position = 3746 (Out) to achieve 30 HFD
- 4) Adjust the Step Increment value until you see 30 40 <u>Steps</u> displayed
- 5) Press Run



How are Slopes Determined?

Hyperbola fit to Vcurve

- Line fit is tangent to hyperbola ('wings')
- Gives better fit statistic
 - uses both sides of V Curve for fit
 - rejects deviant points due to seeing
- Rejects flat spots due to
 - focuser backlash
 - focuser mechanical end of travel

Setting Focus Start and Near Focus HFD (Setup Tab)

💆 L	og		-	×
Files	s Se	t		
182 182 182 182 182 182 182 182 182 182	28:59 29:501 29:04 29:07 29:10 29:13 29:16 29:19 29:22 29:25 29:28 29:31 29:34	Temperature = 49.2 Single Exp. HFD: 20.33 @ 24901 × 511 Y: 382 Flux: 57060 Single Exp. HFD: 1706 @ 24907 × 511 Y: 382 Flux: 5757 Single Exp. HFD: 17.86 @ 24913 × 511 Y: 382 Flux: 57070 Single Exp. HFD: 16.71 @ 24913 × 511 Y: 382 Flux: 56876 Single Exp. HFD: 15.50 @ 24925 × 511 Y: 382 Flux: 56649 Single Exp. HFD: 13.34 @ 24937 × 511 Y: 382 Flux: 56649 Single Exp. HFD: 13.34 @ 24937 × 511 Y: 382 Flux: 56649 Single Exp. HFD: 13.34 @ 24937 × 511 Y: 382 Flux: 56875 Single Exp. HFD: 11.03 @ 24949 × 511 Y: 382 Flux: 56875 Single Exp. HFD: 17.82 @ 24965 × 511 Y: 382 Flux: 56875 Single Exp. HFD: 17.82 @ 24965 × 511 Y: 382 Flux: 56681 Single Exp. HFD: 5.66 @ 24967 × 511 Y: 382 Flux: 56681 Single Exp. HFD: 5.66 @ 24973 × 511 Y: 382 Flux: 56740 Single Exp. HFD: 5.66 @ 24973 × 511 Y: 382 Flux: 56743 Single Exp. HFD: 5.66 @ 24967 × 511 Y: 382 Flux: 56881 Single Exp. HFD: 5.66 @ 24967 × 511 Y: 382 Flux: 56881 Single Exp. HFD: 5.66 @ 24967 × 511 Y: 382 Flux: 56881 Single Exp. HFD: 5.66 @ 24967 × 511 Y: 382 Flux: 56893 Single Exp. HFD: 5.56 @ 24967 × 511 Y: 382 Flux: 56893 Single Exp. HFD: 5.56 @ 24967 × 511 Y: 382 Flux: 56893 Single Exp. HFD: 5.56 @ 24967 × 511 Y: 382 Flux: 56740 Single Exp. HFD: 5.56 @ 24967 × 511 Y: 382 Flux: 56740 Single Exp. HFD: 5.56 @ 24967 × 511 Y: 382 Flux: 56784 Single Exp. HFD: 5.56 @ 24967 × 511 Y: 382 Flux: 56784 Single Exp. HFD: 5.56 @ 24967 × 511 Y: 382 Flux: 56784 Single Exp. HFD: 5.56 @ 24967 × 511 Y: 382 Flux: 56784 Single Exp. HFD: 4.06 @ 24937 × 511 Y: 382 Flux: 56784 Single Exp. HFD: 4.06 @ 24937 × 511 Y: 382 Flux: 56784 Single Exp. HFD: 4.06 @ 24937 × 511 Y: 382 Flux: 56784 Single Exp. HFD: 4.06 @ 24937 × 511 Y: 382 Flux: 56784 Single Exp. HFD: 4.06 @ 24937 × 511 Y: 382 Flux: 56786 Single Exp. HFD: 4.06 @ 24937 × 511 Y: 382 Flux: 56786 Single Exp. HFD: 4.06 @ 24937 × 511 Y: 382 Flux: 56776 Single Exp. HFD: 4.06 @ 24937 × 511 Y: 382 Flux: 56776 Single Exp. HFD: 4.06 @ 24937 × 511 Y: 382 Flux: 56776 Single Exp. HFD: 4.06 @ 24997 × 511 Y: 382 Flux: 56776 S		*
182 182 182 183 183 183 183 183 183 183 183 183 183	3035 9955 9958 9001 1004 1004 1004 1004 1004 1004 1004	Single Exp. HFD: 3.87 @ 25003×511 Y: 382 Flux 57171 Single Exp. HFD: 3.87 @ 25003×511 Y: 382 Flux 57058 Single Exp. HFD: 5.25 @ 25021×511 Y: 382 Flux 57058 Single Exp. HFD: 5.25 @ 25021×511 Y: 382 Flux 56787 Single Exp. HFD: 6.27 @ 25027×511 Y: 382 Flux 56751 Single Exp. HFD: 8.35 @ 25033×511 Y: 382 Flux 56751 Single Exp. HFD: 1.8.5 @ 25057×511 Y: 382 Flux 56771 Single Exp. HFD: 10.52 @ 25057×511 Y: 382 Flux 56778 Single Exp. HFD: 11.65 @ 25057×511 Y: 382 Flux 57176 Single Exp. HFD: 11.65 @ 25063×511 Y: 382 Flux 57178 Single Exp. HFD: 11.65 @ 25063×511 Y: 382 Flux 57178 Single Exp. HFD: 11.67 @ 25063×511 Y: 382 Flux 57178 Single Exp. HFD: 15.17 @ 25063×511 Y: 382 Flux 57410 Single Exp. HFD: 15.17 @ 25075×511 Y: 382 Flux 57280 Single Exp. HFD: 15.17 @ 25081×511 Y: 382 Flux 57280 Single Exp. HFD: 18.81 @ 25093×511 Y: 382 Flux 57382 Single Exp. HFD: 18.81 @ 25093×511 Y: 382 Flux 57382 Single Exp. HFD: 18.81 @ 25093×511 Y: 382 Flux 57378 VCurve Sequence Complete LS: -0.188549 RS: 0.188821 FlD: 11.14 Results saved to Profile: Simulator		
•			Þ	

1) Generate a Vcurve

2) From the Log identify the right or left most extreme HFD value (20.33)

FocusMax Focus Start and Near Focus HFD Settings (Setup Tab)

🤝 Vcurve Sequence		X
File Set		
Run Stop		
Vcurve Parameters End Point	ts 🔍 Ha	ilf 💿
Autofocus 📝 Initial	24901 Cente	25001
Repeat 0 Final	25101 Half Widtł	100
Images 1 Step /position I Incr.	6 Steps	33
20.33¶ 11.03¶	AND DO	3BOOK
Fit Lines Left Slope -0.188549 Position Intercept 25004.4	Right 0.188821 24993.2	Difference 11.14

- Examine the Vcurve graph and identify the circle which begins to deviate from a straight line
- 4) Determine HFD value in the Log by counting down to the circle number from step 2

FocusMax Focus Start and Near Focus HFD Settings (Setup Tab)

💆 FocusMax Simulator 🛛 📼 💌
<u>File Open Wizard Set</u> <u>H</u> elp
Profile V Curve Log Tele- Scope Jog Mini
Near Focus Move
(HFD 11) O In O Out
Exposures 5 Settle Time sec 0
Autofocus Exp. Flux (sec) (1000) Width 50 Min 0.10 40
Tgt Star 2 ▼ Max 5.00 500 Bin 1 ▼ Base Focus Bin 1 ▼ Exp 0.50
Focus Start
Position 4920
HFD 16 O HFD
Focus 4996 Current Pos.
Focus Setup Features System

- 5) Round off the HFD value and enter the value in the Near Focus (11)
- 6) Enter the Focus Start HFD some5 units higher than the NearFocus HFD (16)







💆 AcquireStar 🛛 💽
File Set
Setup Rtn slew C Center Star Zenith Meridian cross PinPoint Bright 2 Sep. 0.75 Exclusion Settle 5 Settle 5 Settle 5 Settle 5 Settle 5 Settle 5 Sec Min 45 Min 45 Min 0 deg No. 2 Stars Dim 120 Sep. (arc sec)
Auto-center Final Spiral Max arc pointing Search Error 1 min Sync Exp 5 Attempts 3
Setup PinPoint

Setup:

- Return Slew after autofocus run
- Zenith select stars from catalog starting at zenith
- Meridian Cross- do not check for most German Equatorial mounts



💆 AcquireStar 🛛 🗾 📈
File Set
Setup Rtn slew V Zenith Auto Auto Alt. Meridian PinPoint Alt. Target Star Selection Bright Target Min Max 11
Sep. 0.75 Exclusion 120 (arc sec)
- Auto-center
Final Spiral Max arc pointing Search Error 1 min Sync Exp 5 Attempts 3
Setup PinPoint

Setup:

- Settle Time after slew
- Min Altitude allowed for star
- Min Slew set to 0 to use potential star in current FOV
- Number of Stars to select from catalog



💆 AcquireStar 🛛 🔤	
File Set	
Setup Rtn slew Center Star Zenith Auto Heridian cross PinPoint Min Slew 0 deg No. 2 Stars Target Star Selection Bright -2 Sep. 0.75 Exclusion Settle 5 sec Min Att. Min 0 deg Dim 11 120 Sep. (arc sec)	
Auto-center Final Spiral Max 1 arc pointing search Error 1 min Sync Exp 5 Attempts 3	
Setup PinPoint	J

Setup:

Center Star

- None blind slew to target star
- Auto center star using calibrated telescope moves (see Telescope window to calibrate)
- **PinPoint** center star with plate solved images with PinPoint



💆 AcquireStar 🛛 💽
File Set
Setup Rtn slew V Zenith Auto Auto Auto Auto rross PinPoint Auto deg Settle 5 sec Min 45 deg Min 0 deg slew
Target Star Selection Bright -2 Sep. 1 (deg) 0.75 Exclusion
Auto-center Final Spiral Max 1 arc pointing search Error 1 min Sync Exp 5 Attempts 3
PinPoint

Target Star Selection:

- Target Min/Max target star magnitude range to select from star catalog
- Bright / Sep (deg) reject bright stars that are within 0.75 deg of potential target star.
- Dim / Sep (arc sec) reject dim stars down to 11th mag that are within 120 arc-sec of a potential target star



💆 AcquireStar	— ×
File Set	
Setup Center St Rtn slew ✓ Zenith △ Meridian ○ rarget Star Selection ○ Target Star Selection ○ Bright Target -2 ○ (deg) 0.75 Exclust Auto-center Final ○ pointing ✓ Sync ○ Sync ○	ar Settle 5 sec Min 45 deg Alt. 45 deg Min 0 deg No. 2 Stars Dim 120 Sep. (arc sec) Max 1 arc Error 1 min Attempts 3
Setup	PinPoint

Auto-center:

- Final Pointing fine tune telescope pointing after slew
- Sync telescope after successful plate solve with PinPoint
- Spiral Search to determine telescope pointing – useful if target is not on chip



💆 AcquireStar	X
File Set	
Setup Rtn slew Zenith Meridian cross Center Star – None Auto PinPoint PinPoint Target Star Selection Target Star Selection Target Star Selection Bright -2 Sep. (deg) 0.75 Exclusion Auto-center Final pointing Sync Exp Sec Sync Exp Sec Sec Sync Sec Sec Sec Sec Sec Sec Sec Se	Settle 5 sec Min 45 deg Alt. 45 deg Min 0 deg No. 2 Stars Dim 11 Sep. 120 Sep. (arc sec) Max 1 arc Error 1 min tempts 3
Setup	PinPoint

Auto-center:

- **Exposure** time for plate solving telescope pointing
- Max Error allowed on telescope slews. Will allow for < 1 arc-sec positioning if mount is able to make small accurate adjustments
- Attempts the number of centering failures before declaring failure and telescope moves to next target star



Z AcquireStar
File Set
Star Detection Plate Parameters Min size (pixels) 2 Min Brightness 200 Sigma Above Mean 4 Solve time (sec) 60
Catalaog Expansion (%) 30
Use stars from -2.00 to 20.00
Catalog GSC-ACT 🗸
Path E:\Catalogs
Test Path Expose & Solve
Setup PinPoint

Plate Parameters:

- Binning for plate solves (1 4 allowed)
- X & Y pixel scale (at 1x1 binning)

Catalog:

- Select catalog and catalog path
- Test Path button will determine if PinPoint can read selected catalog at RA 00:00:00 Dec 00:00:00
- Expose and Solve button take an actual image and plate solve



- •Maybe 'black magic'
- •May not work with all optical systems
- •Some users report non-linear response (APO)
- •Focuser should have a remote temperature probe
- Probe should be coupled to telescope preferably near primary optics
- •Avoid taking measurements until telescope has acclimated to ambient temp
- Most telescopes will require moving focuser out as temp drops (tube shrinkage)



My 16" f/4.5 Newtonian

- Optec focuser with external probe
- Drilled hole in side of tube and positioned probe next to mirror face
- Measured Temperature vs. Position over multiple nights with Temp Comp Wizard



My 16" f/4.5 Newtonian

- Focus Convergence set to 1 Step, 10 Samples to assure adequate sampling
- Enabled AcquireStar with: Zenith enabled Return slew disabled Meridian Cross disabled PinPoint to center target star
- Binning = 1x1 (1.02 arc-sec/pixel)
- Seeing ~3 arc-sec FWHM



Temperature vs. Position

(Scatter Plot)





Temperature vs. Position

(Scatter Plot)





Averaged temperature coefficients (slopes) over several nights

Result

Able to extend time between autofocus from 60 minutes to 120 minutes

Jeff Dickerman - Optec

FocusMax 👤





Temperature Compensation Wizard

7	Collect	Temp.	Comp.	Data	
---	---------	-------	-------	------	--

File

This wizard will collect the necassary temperature & focus position data which can be used to setup the focuser for automated temperature compensation.

It is recommended that you begin this wizard soon after sunset in order to maximize the temperature range and resulting positional measurements.

It is highly recommended that the Focus Convergence method be used!

[Back	Next	Stop]

- Collect temp & position data by performing repetitive focus runs
- Use AcquireStar to identify star at zenith throughout the night
- Use Focus Convergence to reduce focus errors
- Set time between autofocus runs
- Will park the telescope at end of session





There is a lot more work to do!

- Not all focusers are created equal for temperature sensing
- How to handle non-linear responses
- •Where to place probe for closed tube telescopes



FocusMax V4:

- New autofocus routine that uses both sides of Vcurve
- Several different TC methods
- Will perform TC least square analysis on data
- Plot TC data
- Built in scripting capabilities
- Plot Profile data
- •New focus plot graphics



Precision Focusing With FocusMax

CCD Astronomers using FocusMax Love Focusing!

Steve Brady http://focusmax.org http://tech.groups.yahoo.com/group/FMaxUG