Planetary Imaging

AISIG Meeting June 6, 2018 Sam Saeed

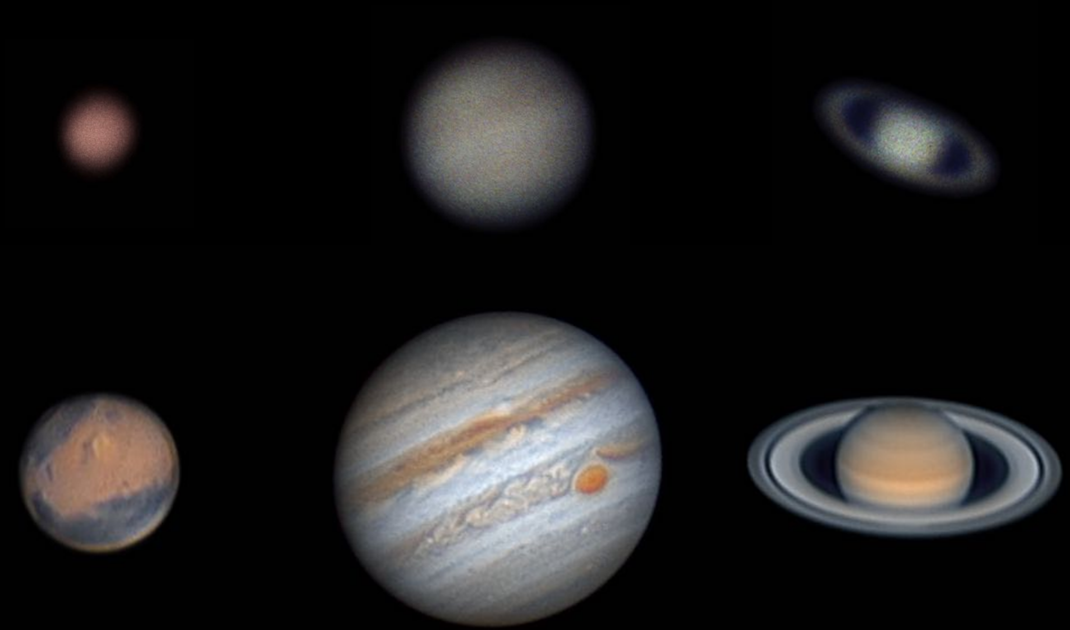
then ...

1986

then and now

1986

2016



the battle for the planets…

Preparation…*the strategy*

1. When: planet is at closest approach for the season and at highest altitude for the night.
2. Where: at a site where it is dark, dry, good and steady seeing.
3. How: by using tracking mount, telescope, barlow and camera.

Capturing…*the battle*

1. Locating the planet in the FOV.
2. Focusing.
3. Capturing video images at highest frame rate possible with a decent histogram and gain setting.

Processing…*the aftermath*

1. Sorting through the video files to find if it’s worthy of spending any more time.
2. Rating the video and trimming it down to the acceptable frames.
3. Derotating the video frame to compensate for planet rotation during capture.
4. Stacking the derotated good frames to create a master image.
5. Improving the master image appearance using photo editing software.

Preparation…*the strategy*

1. When: best when planet is at closest approach for the season and at highest altitude for the night. You can find this data using a planetarium software or search the Internet.

Date		Constellation	Apparent Magnitude	Apparent Diameter (arcsecs)	Tilt	View from Earth (0h UT) (North up)	Distance (AU)*		Solar Elongation	Illuminated Phase	Central Meridian Longitude (0h UT)
							from Earth	from Sun			
2018	Feb 17	Oph	+0.9	6".1	+4°.0		1.5177	1.5852	75°W	90%	133°
	Feb 27	Oph	+0.8	6".6	+1°.5		1.4212	1.5737	79°W	89%	37°
	Mar 9	Oph	+0.7	7".0	-0°.9		1.3251	1.5616	83°W	88%	300°
	Mar 19	Sgr	+0.5	7".6	-3°.3		1.2297	1.5492	87°W	88%	204°
	Mar 29	Sgr	+0.3	8".2	-5°.6		1.1360	1.5365	91°W	88%	108°
	Apr 8	Sgr	+0.1	8".9	-7°.8		1.0445	1.5236	96°W	87%	12°
	Apr 18	Sgr	-0.1	9".8	-9°.7		0.9555	1.5105	100°W	87%	276°
	Apr 28	Sgr	-0.3	10".7	-11°.4		0.8700	1.4975	105°W	88%	181°
	May 8	Sgr	-0.5	11".8	-12°.9		0.7833	1.4845	110°W	88%	85°
	May 18	Cap	-0.8	13".1	-13°.9		0.7111	1.4718	116°W	89%	350°
	May 28	Cap	-1.1	14".6	-14°.7		0.6393	1.4595	122°W	90%	256°
	Jun 7	Cap	-1.4	16".3	-15°.0		0.5736	1.4476	129°W	91%	162°
	Jun 17	Cap	-1.7	18".1	-14°.9		0.5152	1.4364	137°W	93%	69°
	Jun 27	Cap	-2.0	20".1	-14°.4		0.4656	1.4259	145°W	95%	337°
	Jul 7	Cap	-2.3	21".9	-13°.5		0.4264	1.4162	155°W	97%	247°
	Jul 17	Cap	-2.6	23".4	-12°.3		0.3994	1.4076	166°W	99%	157°
	Jul 27	Cap	-2.7	24".2	-11°.1		0.3862	1.4000	173°W	100%	69°
	Aug 6	Cap	-2.7	24".1	-10°.1		0.3872	1.3936	166°E	99%	340°
	Aug 16	Cap	-2.5	23".3	-9°.5		0.4017	1.3885	155°E	97%	251°
	Aug 26	Sgr	-2.2	21".8	-9°.6		0.4282	1.3847	145°E	95%	161°
	Sep 5	Cap	-1.9	20".1	-10°.2		0.4644	1.3824	136°E	93%	69°
	Sep 15	Cap	-1.7	18".4	-11°.4		0.5087	1.3814	128°E	91%	337°
	Sep 25	Cap	-1.4	16".7	-13°.0		0.5594	1.3819	121°E	89%	243°
	Oct 5	Cap	-1.2	15".2	-14°.9		0.6154	1.3838	115°E	87%	148°
	Oct 15	Cap	-1.0	13".8	-16°.8		0.6760	1.3872	110°E	86%	53°
	Oct 25	Cap	-0.7	12".6	-18°.8		0.7406	1.3919	105°E	86%	317°
	Nov 4	Cap	-0.5	11".5	-20°.7		0.8088	1.3979	101°E	85%	220°
	Nov 14	Aqr	-0.3	10".6	-22°.4		0.8805	1.4051	97°E	85%	122°
	Nov 24	Aqr	-0.1	9".8	-23°.9		0.9550	1.4135	93°E	85%	25°
	Dec 4	Aqr	+0.0	9".0	-25°.0		1.0324	1.4229	89°E	86%	286°
	Dec 14	Aqr	+0.2	8".4	-25°.8		1.1122	1.4331	86°E	86%	188°
	Dec 24	Psc	+0.3	7".8	-26°.2		1.1941	1.4441	82°E	86%	89°

* 1 AU (Astronomical Unit) = 149,597,870 kms (92,955,806 statute miles)

Mars

Date	Constellation	Apparent Magnitude	Apparent Diameter (arcsecs)	Tilt	View from Earth (0h UT) (North up)	Distance (AU)*		Solar Elongation	Illuminated Phase	Central Meridian Longitude (0h UT)
						from Earth	from Sun			
Jul 7	Cap	-2.3	21".9	-13°.5		0.4264	1.4162	155°W	97%	247°
Jul 17	Cap	-2.6	23".4	-12°.3		0.3994	1.4076	166°W	99%	157°
Jul 27	Cap	-2.7	24".2	-11°.1		0.3862	1.4000	173°W	100%	69°
Aug 6	Cap	-2.7	24".1	-10°.1		0.3872	1.3936	166°E	99%	340°
Aug 16	Cap	-2.5	23".3	-9°.5		0.4017	1.3885	155°E	97%	251°
Aug 26	Sgr	-2.2	21".8	-9°.6		0.4282	1.3847	145°E	95%	161°

Preparation...*the strategy*

1. When: best when planet is at closest approach for the season and at highest altitude for the night. You can find this data using a planetarium software or search the Internet.

Saturn

Apparition Period	Opposition Circumstances											Superior Conjunction
	Opposition Date	Constellation		Declination	Apparent Magnitude	Diameter (arcsecs)		Ring Tilt	View from Earth (North up)	Distance (AU)*		
						Globe	Ring			from Earth	from Sun	
2013/14	2014 May 10		Lib	-15°.3	+0.2	18".6	42".3	+21°.7		8.8997	9.9084	2014 Nov 18
2014/15	2015 May 23		Lib	-18°.3	+0.1	18".5	41".9	+24°.4		8.9667	9.9784	2015 Nov 29
2015/16	2016 Jun 3		Oph	-20°.5	+0.1	18".4	41".7	+26°.0		9.0149	10.0288	2016 Dec 10
2016/17	2017 Jun 15		Oph	-21°.9	+0.0	18".4	41".6	+26°.6		9.0427	10.0581	2017 Dec 21
2017/19	2018 Jun 27		Sgr	-22°.4	+0.0	18".3	41".6	+26°.0		9.0488	10.0652	2019 Jan 2
2019/20	2019 Jul 9		Sgr	-22°.0	+0.0	18".4	41".7	+24°.3		9.0329	10.0495	2020 Jan 13
2020/21	2020 Jul 20		Sgr	-20°.6	+0.1	18".5	41".8	+21°.6		8.9948	10.0109	2021 Jan 24
2021/22	2021 Aug 2		Cap	-18°.4	+0.1	18".6	42".1	+18°.1		8.9353	9.9500	2022 Feb 4
2022/23	2022 Aug 14		Cap	-15°.4	+0.2	18".7	42".5	+13°.9		8.8569	9.8697	2023 Feb 16

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Preparation...*the strategy*

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Jupiter

Apparition Period	Opposition Circumstances											Superior Conjunction
	Opposition Date	Constellation		Declination	Apparent Magnitude	Diameter (arcsecs)		Tilt	View from Earth (North up)	Distance (AU)*		
						Equatorial	Polar			from Earth	from Sun	
2014/15	2015 Feb 6		Cnc	+16°.5	-2.4	45".3	42".4	-0°.2		4.3462	5.3319	2015 Aug 26
2015/16	2016 Mar 8		Leo	+5°.9	-2.3	44".4	41".6	-1°.8		4.4354	5.4277	2016 Sep 26
2016/17	2017 Apr 7		Vir	-5°.7	-2.3	44".2	41".4	-3°.0		4.4554	5.4559	2017 Oct 26
2017/18	2018 May 9		Lib	-16°.0	-2.3	44".8	41".9	-3°.3		4.4001	5.4093	2018 Nov 26

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Preparation...*the strategy*

2. Where: at a site where it is dark, dry, good and steady seeing.

• Dedicated Seeing Monitor Hardware Solution:
http://www.alcor-system.com/new/SeeingMon/DIMM_Complete.html
https://airylab.com/night-seeing-monitor/

• Visual Method:
http://weather.gc.ca/astro/seeing_e.html

V	< 0.4"	Perfect motionless diffraction pattern
IV	~ 0.4-0.9”	Light undulations across diffraction rings
III	~ 1.0-2.0”	Central disc deformations. Broken diffraction rings
II	~ 3.0-4.”	Important eddy streams in the central disc
		Missing or partly missing diffraction rings
I	> 4"	Boiling image without any sign of diffraction pattern

• Software and Hardware you may already have:

MaxIm DL, Telescope, Camera – measure FWHM at reasonable resolution (up to 2 ArcSec/Pixel)

Preparation…*the strategy*

3. How: tracking mount, telescope, barlow and camera
   - solid, sturdy equatorial mount
   - sampling, magnification and pixel size
   - sampling and focal ratio consideration

Planetary Resolution: Telescope vs Camera

Under-sampled **Within range** **If conditions allow** **Over-sampled**

- Pixel Size for commonly used cameras from ZWO. Current for summer of 2016.
- Frame Rate is the maximum allowed by ZWO camera model, based on 640 x 480 ROI.
- Resolution is in arc-sec/pixel • Dawes Limit = 116/aperture in mm

Telescope	f Ratio	Focal Length	Z174 5.86μ 11.3x7.1mm Diag=13.4 309 fps f30 best f41 max Resolution	Z224 3.75μ 4.8x3.6mm Diag=6.09 127 fps f19 best f26 max Resolution	Z290 2.9μ 5.6x3.2mm Diag=6.45 184 fps f15 best f20 max Resolution	Z183 2.4μ 13.2x2.8mm Diag=15.9 149 fps f12 best f17 max Resolution	Daws Limit in ArcSec
Refractor 6" 1.0x	f8	1215	1.00	0.64	0.49	0.41	
Refractor 6" 1.6x	f12.8	1944	0.63	0.40	0.31	0.26	1 = 0.76 1/2 = 0.38 1/3 = 0.25
Refractor 6" 2.0X	f16	2430	0.50	0.32	0.25	0.21	
Refractor 6" 2.5x	f20	3000	0.40	0.26	0.20	0.16	
Refractor 6" 3.0x	f24	3645	0.33	0.21	0.16	0.14	
Mak 6" 1.0x	f12	1800	0.67	0.43	0.33	0.28	
Mak 6" 1.6x	f19	2880	0.42	0.27	0.21	0.17	1 = 0.76 1/2 = 0.38 1/3 = 0.25
Mak 6" 2.0X	f24	3600	0.33	0.22	0.17	0.14	
Mak 6" 2.5x	f30	4500	0.27	0.17	0.13	0.11	
Mak 6" 3.0x	f36	5400	0.22	0.14	0.11	0.09	
SC 8" 1.0x	f10	2000	0.60	0.39	0.30	0.25	
SC 8" 1.6x	f16	3200	0.38	0.24	0.19	0.15	1 = 0.58 1/2 = 0.29 1/3 = 0.19
SC 8" 2.0X	f20	4000	0.30	0.19	0.15	0.12	
SC 8" 2.5x	f25	5000	0.24	0.16	0.12	0.10	
SC 8" 3.0x	f30	6000	0.20	0.13	0.10	0.08	

Telescope	f Ratio	Focal Length	Z174 5.86μ 11.3x7.1mm Diag=13.4 309 fps f30 best f41 max Resolution	Z224 3.75μ 4.8x3.6mm Diag=6.09 127 fps f19 best f26 max Resolution	Z290 2.9μ 5.6x3.2mm Diag=6.45 184 fps f15 best f20 max Resolution	Z183 2.4μ 13.2x2.8mm Diag=15.9 149 fps f12 best f17 max Resolution	Daws Limit in ArcSec
SC 10" 1.0x	f10	2600	0.47	0.30	0.23	0.19	
SC 10" 1.6x	f16	4200	0.29	0.19	0.14	0.12	1 = 0.46 1/2 = 0.23 1/3 = 0.15
SC 10" 2.0X	f20	5200	0.24	0.15	0.12	0.10	
SC 10" 2.5x	f25	6500	0.19	0.12	0.09	0.08	
SC 10" 3.0x	f30	7800	0.16	0.10	0.08	0.06	
SC 11" 1.0x	f10	2800	0.43	0.28	0.21	0.18	
SC 11" 1.6x	f16	3200	0.27	0.18	0.13	0.11	1 = 0.42 1/2 = 0.21 1/3 = 0.14
SC 11" 2.0X	f20	4000	0.22	0.14	0.11	0.09	
SC 11" 2.5x	f25	5000	0.17	0.11	0.08	0.07	
SC 11" 3.0x	f30	6000	0.14	0.09	0.07	0.06	
SC 14" 1.0x	f11	3900	0.31	0.20	0.15	0.13	
SC 14" 1.6x	f18	6240	0.19	0.12	0.10	0.08	1 = 0.32 1/2 = 0.16 1/3 = 0.11
SC 14" 2.0X	f22	7800	0.16	0.10	0.08	0.07	
SC 14" 2.5x	f28	9750	0.12	0.08	0.06	0.05	
SC 14" 3.0x	f33	11700	0.10	0.07	0.05	0.04	
RC 10" 1.0x	f8	2000	0.60	0.39	0.30	0.25	
RC 10" 1.6x	f12.8	3200	0.38	0.24	0.19	0.15	1 = 0.46 1/2 = 0.23 1/3 = 0.15
RC 10" 2.0X	f16	4000	0.30	0.19	0.15	0.12	
RC 10" 2.5x	f20	5000	0.24	0.16	0.12	0.10	
RC 10" 3.0x	f24	6000	0.20	0.13	0.10	0.08	
RC 12" 1.0x	f8	2440	0.50	0.32	0.25	0.20	
RC 12" 1.6x	f12.8	3900	0.31	0.20	0.15	0.13	
RC 12" 2.0X	f16	4900	0.25	0.16	0.13	0.10	1 = 0.38 1/2 = 0.19 1/3 = 0.13
RC 12" 2.5x	f20	6100	0.20	0.13	0.10	0.08	
RC 12" 3.0x	f24	7300	0.17	0.11	0.08	0.07	

Capturing…*the battle*

1. Locating the planet in the FOV

- Flip-Mirror Diagonal with a centering eye-piece on top, barlow and camera at rear end.
- Guide Scope aligned to main scope with 3-point adjustment screws, take an image with the guide scope, solve the plate, then GoTo planet.
- 2 cameras, first one with a large sensor without a barlow, focus, take an image, solve the plate, GoTo planet. Then replace with barlow and imaging camera, refocus.




Capturing…*the battle*

2. Focusing

- Software assisted focusing (such as the one in FireCapture software); focus directly on the planet.
- Use a focus mask visually or with focus assisted software (such as GoldFocus); focus on a nearby star.

$NCFZ = 0.00225 * \theta_{FWHM} * \sqrt{\tau} * A * f^2$ (New CFZ in microns)

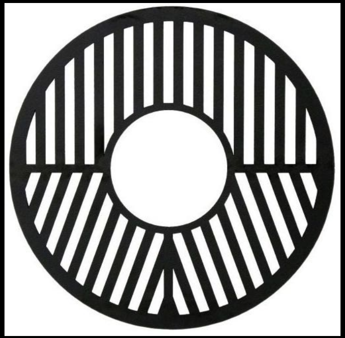
θ_{FWHM} - total seeing (arc seconds)

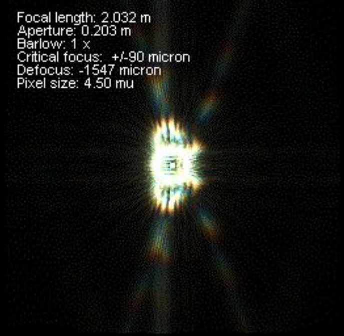
τ - focus tolerance as a % of total seeing (15%)

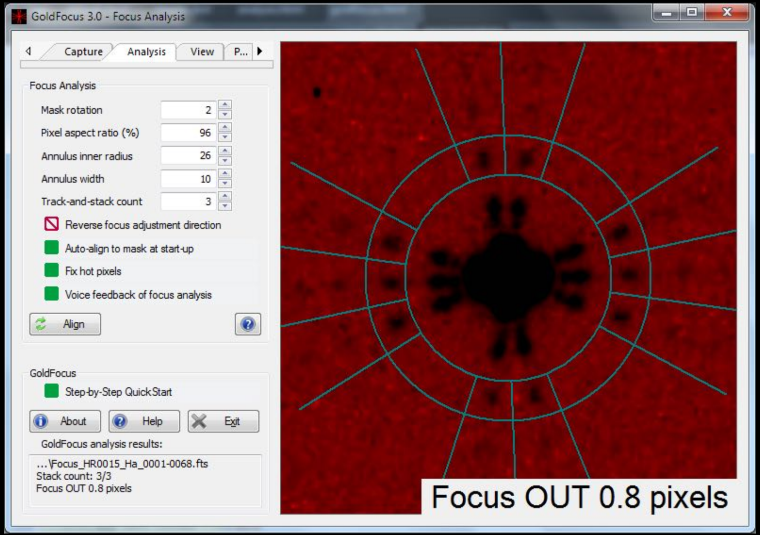
A - telescope aperture (millimeters)

f - telescope focal ratio

0.00225 - constant







$CFZ = 4.88 * \lambda * f^2$ (Traditional CFZ in microns)

λ – wave length (microns)

f – telescope focal ratio

4.88 – constant

F/# $\lambda = 550$ nm	F/3	F/6	F/8	F/10
Focus error $\lambda/10$	+/- 4 μm	+/- 16 μm	+/- 28 μm	+/- 44 μm
CFZ error $\lambda/3$	+/- 12 μm	+/- 48 μm	+/- 86 μm	+/- 134 μm

Capturing…*the battle*

3. Capturing video images at highest frame rate possible

FireCapture software is what I use exclusively.

The goal is to achieve the highest frame rate. This is done through a careful adjustment of Gain & Exposure time while maintaining the desired Histogram level.

• Gain Setting:

Jupiter and Mars: I use about 50% of the possible Camera Gain to maintain a Histogram of 30% to 40%

Saturn: I use about 75% of the possible Camera Gain to maintain a Histogram of 30% to 40%

• Bit Depth:

When using a monochrome camera: you may consider using 8-bit capture if seeing does not allow for SNR under 2.

Let’s visit FireCapture Software

Processing...*the aftermath*

1. Autostakkart: Sort through the video files to find if they are worthy of spending any more time.

I check the video files in AutoStakkart and create a quick stack of about 10% of the frames to decide whether it is a good capture or not. If bad, I toss it and move on. If good, I proceed to the next step.

2. PIPP: Rate the video and trim it down to the acceptable frames.

I open the videos in PIPP software to join them together, center the planet, debayer the color, rotate the images (if I chose to), add WinJupos naming convention, and reject the bad frames. I don't rearrange the frames based on quality yet because I need them in time order for WinJupos.

3. WinJupos: Derotate the new PIPP video frames based on mid-capture time and save a new derotated video file.

4. Autostakkart: Sort and stack the frames using the derotated WinJupos video to produce the master image.

5. PixInsight / Photoshop: Improve the master image appearance using photo editing software.

Let's visit the Software

References

The Handbook of Astronomical Image Processing, by Richard Berry & James Burnell.

Planetary Tables, http://www.nakedeyeplanets.com

DIMM Seeing Monitor (hardware and software), by Alcor Systems

AiryLab Seeing Monitor (hardware and software), by AiryLab SARL

Weather Canada, Seeing Forecast for Astronomical Purposes

Innovations Foresight, Critical Focus Zone

Gold Astro: GoldFocus, Focus Masks & New Critical Focus Zone

Torsten Edelmann: FireCapture software

Emil Kraaikamp: Autostakkart software

Planetary Image Preprocessing: PIPP software

Grischa Hahn: WinJupos software

Jupiter, Saturn & Mars images were captured and processed by Sam Saeed.