High Performance PIAACMC-type Coronagraph designs for centrally obscured and segmented Apertures

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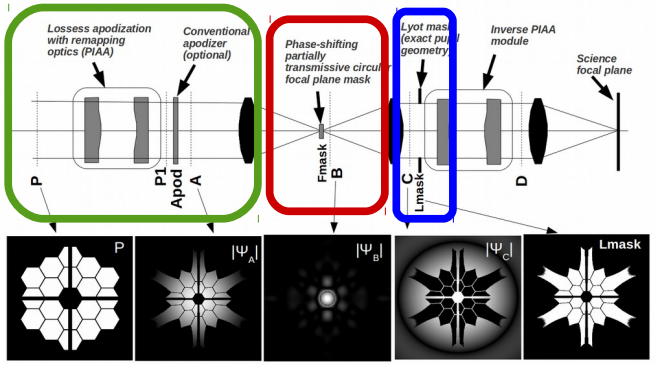
How does PIAACMC work ?

Phase Induced Amplitude Apodized Complex Mask Coronagraph (PIAACMC)

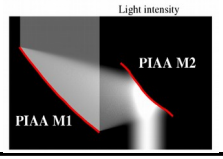


Achieves starlight suppression by combining:

Lossless apodization with aspheric optics (lenses or mirrors)
Creates PSF with weak Airy rings

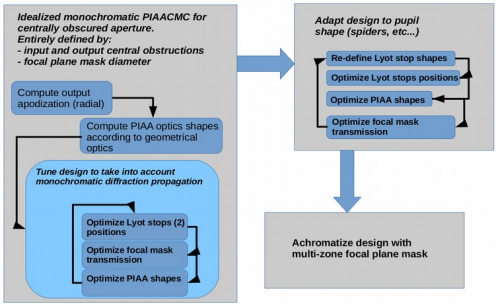
Focal plane mask
complex amplitude -1<t<0
Induces destructive interference inside downstream pupil

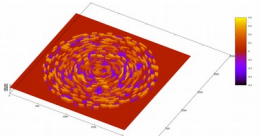
Lyot Stop
Blocks starlight



Multi-zone focal plane mask designed to simultaneously optimize broadband contrast and sensitivity to stellar angular size

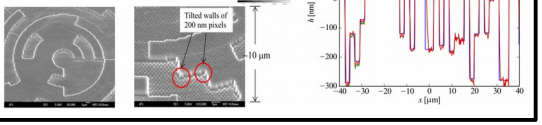
PIAACMC design process





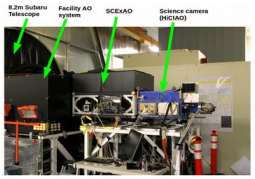
Focal plane mask for WFIRST
1e-9 raw contrast, 1.3 l/D IWA
optimized for broadband light
and 1 mas stellar angular size/jitter
Sag within -/+ 0.3 um
35 rings, 154.7 um diameter
(2.2 um wide rings)

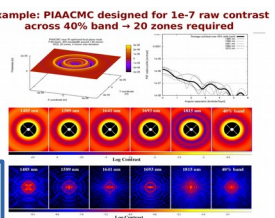
Focal plane mask manufactured at JPL's MDL
Meets performance requirements
(WFIRST PIAACMC Milestone report)



Subaru Telescope

PIAACMC's small IWA enables direct imaging of giant planets around nearby stars in reflected light

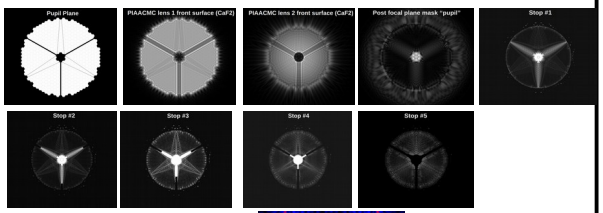




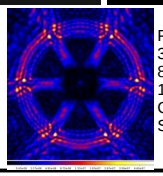
The Subaru Coronagraphic Extreme AO (SCExAO) instrument includes a PIAACMC with a 1 l/D IWA. Aspheric optics are CaF2 lenses

Thirty Meter Telescope

PIAACMC's small IWA enables direct imaging of rocky planets in the habitable zones of nearby M-type stars



The SCExAO instrument will be made compatible with TMT as a visitor instrument. The TMT-pupil optimized PIAA optics will replace the current optics.

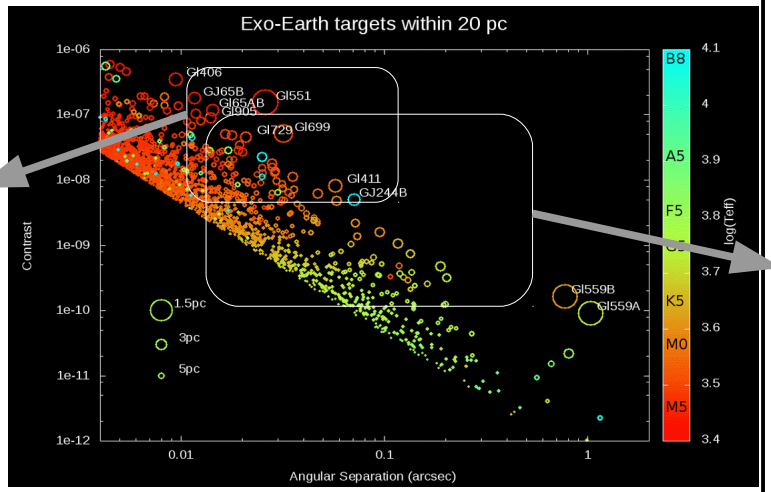


PSF at 1600nm
3e-9 contrast in 1.2-8 l/D
80% off-axis throughput
1.2 l/D IWA
CaF2 lenses
SiO2 mask

Scientific merit for exoplanet imaging

PIAACMC is fully compatible with segmented and centrally obscured apertures: its performance is unaffected by pupil shape

PIAACMC simultaneously offers:
- high throughout (>50%)
- small IWA (1 to 2 l/D, depending on stellar angular size)
- high contrast (theoretically ~1e-10, limited by wavefront aberrations, stellar angular size and chromaticity)



Contrast and Separation of hypothetical Earth-like planets for each star within 20pc.
Size of circle indicate distance to Earth (large = nearby star), while color encodes star spectral type.

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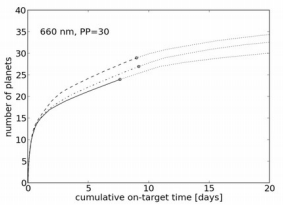
WFIRST

PIAACMC's high efficiency and small IWA enables direct imaging of known giant planets with significantly greater sensitivity than WFIRST's baseline OMC coronagraph.
Small IWA greatly enhnaces WFIRST coronagraph science:
- spectroscopy at longer wavelength
- access to lower mass planets, including rocky planets in hab zones
- higher efficiency → better data quality, more targets



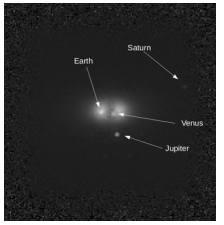
Case	Output channel	wavelength (nm)	band (%)	# pixels	# RV characterizations in less than 1 day each (min, max) HLC	SPC	PIAA
1	imager	465	10	4.9	15	11	76
2	imager	565	10	4.9	15	11	87
3	imager	835	10	4.9	7	5	42
4	imager	670	18	4.9	16	13	85
5	imager	770	18	4.9	10	7	61
6	imager	890	18	4.9	5	5	36
7	IFS	670	1.4	4.9	4	2	39
8	IFS	770	1.4	4.9	2	1	30
9	IFS	890	1.4	4.9	0	0	14

Single polarization for each case, 0.4 mas jitter, post-processing gain = 1/30
Assumes planet location is known

PIAACMC is the backup architecture for WFIRST's coronagraph. Testbed development and laboratory validation of the PIAACMC design for WFIRST is ongoing.

12m segmented High Definition Space Telescope

PIAACMC's high efficiency and small IWA enables high SNR spectroscopy of habitable planets from visible to near-IR



12m aperture
1.63 um central lambda, 20% wide band
50% throughput from coatings + detector QE
70% throughput in coronagraph (Lyot stops)
2 day exposure
In "simple" model (monochromatic, no manufacturing error, point source, Fourier transforms), PIAACMC yields better than 1e-10 raw contrast.

Stellar angular size is taken into account.(this is the limiting contrast contribution)