Broadband Near-infrared Spectroscopy for Core-collapse Supernova Nucleosynthesis

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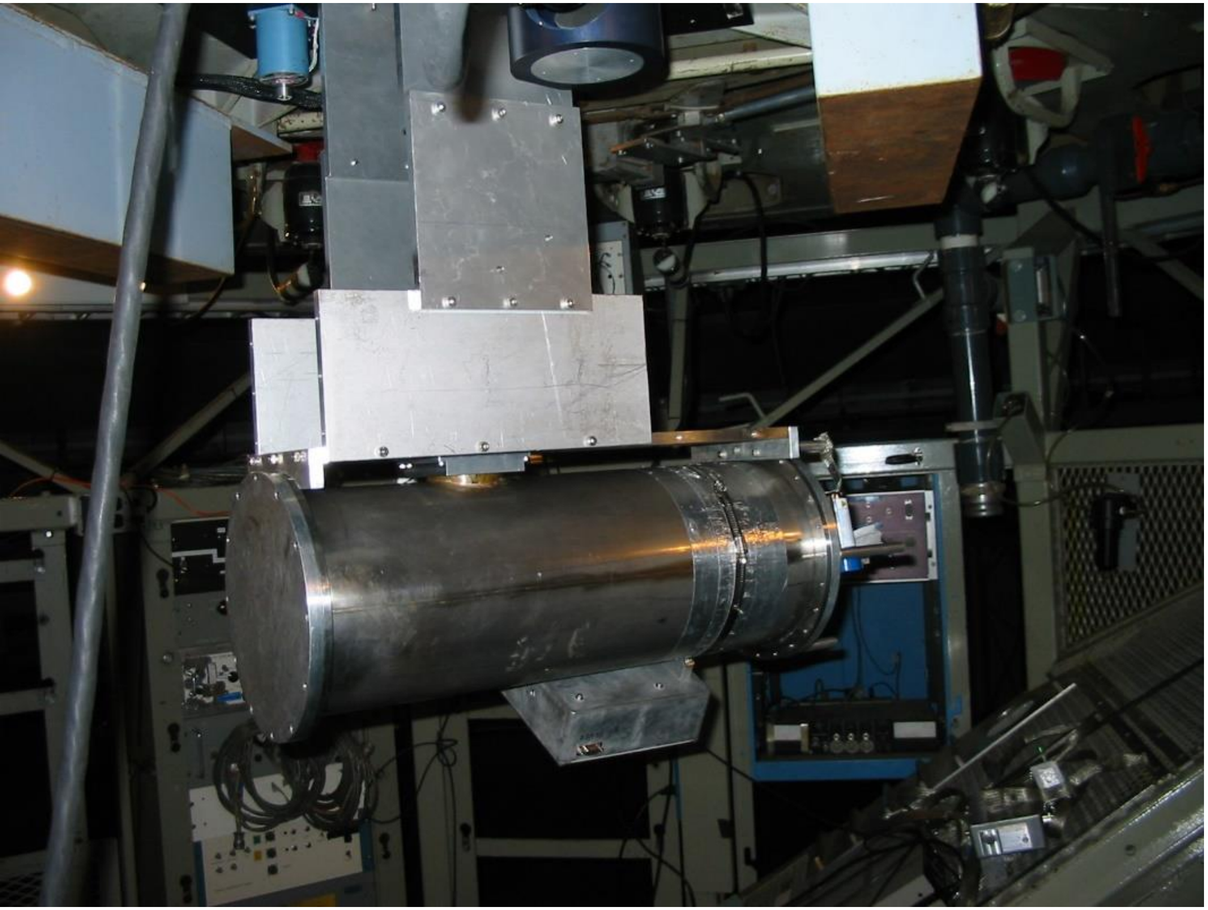
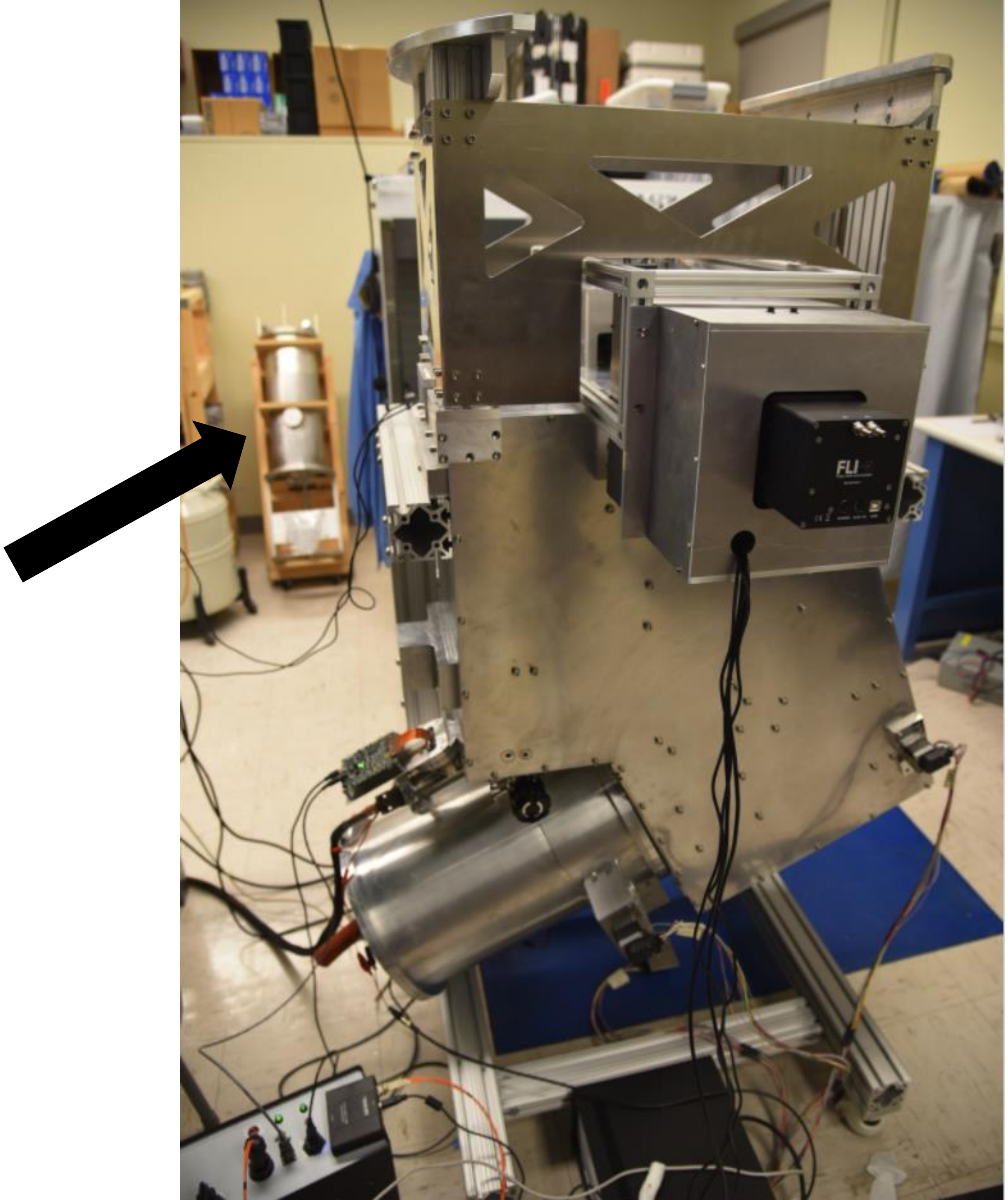
University of Toronto

DSC_7624.JPG 2003/09/29 11:58:57.9

Photo Credit: George Gull




FLI

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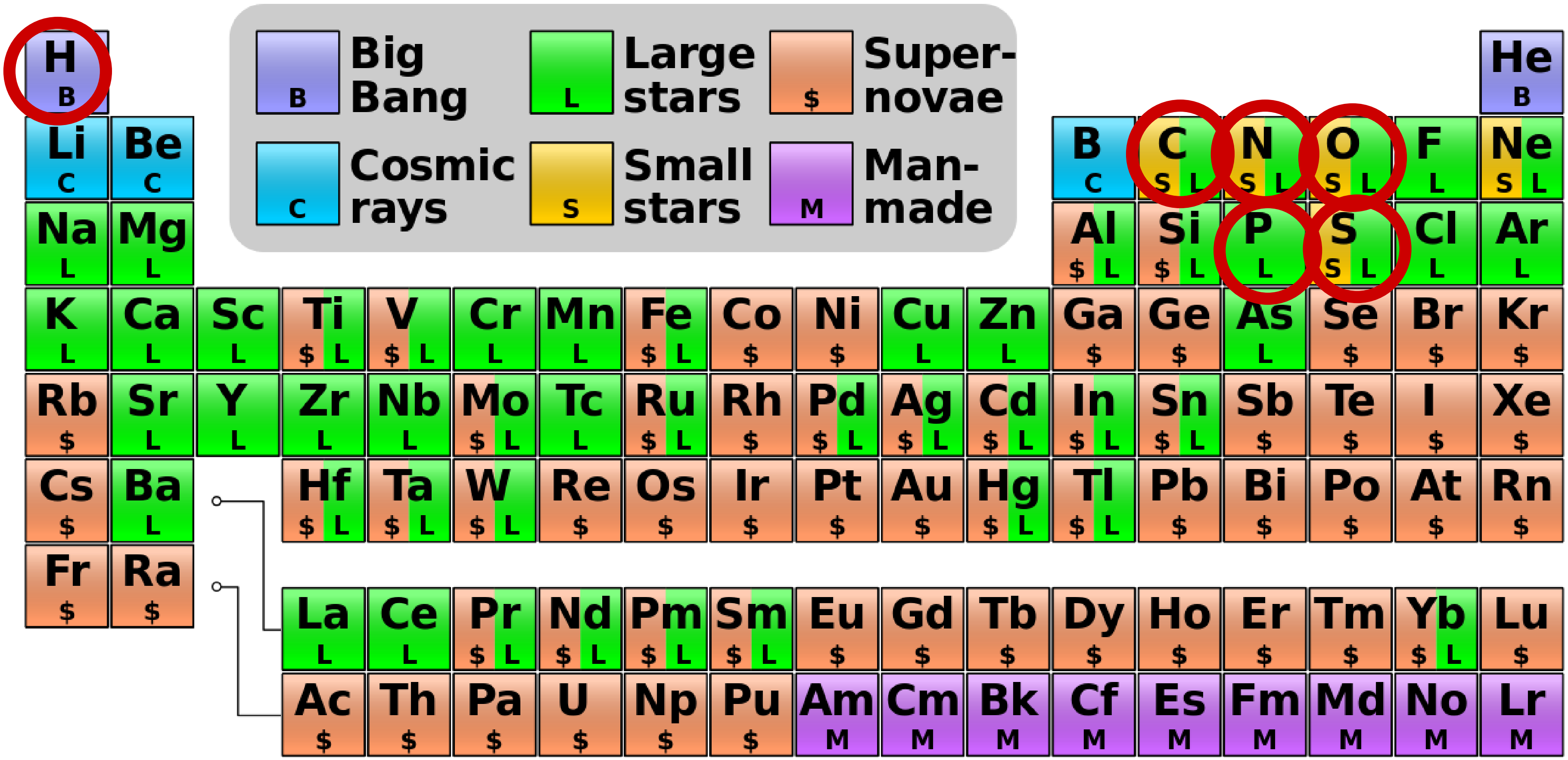
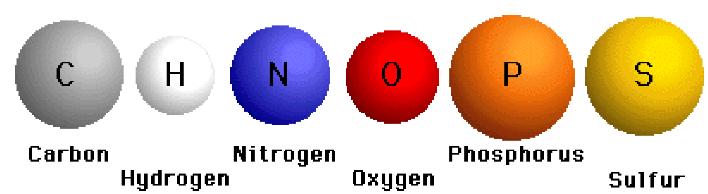
Triplespec 2007 Jan at Cornell

(The most complete Triplespec photo that I personally own.)

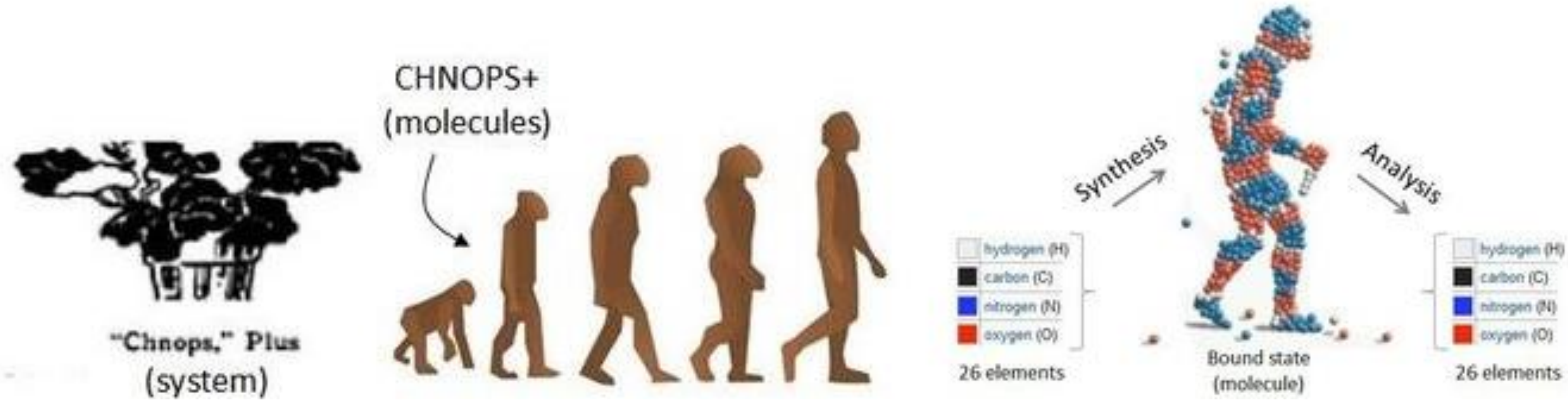
NIRES (= Keck version of Triplespec) in 2017 March.
Now at Keck II.

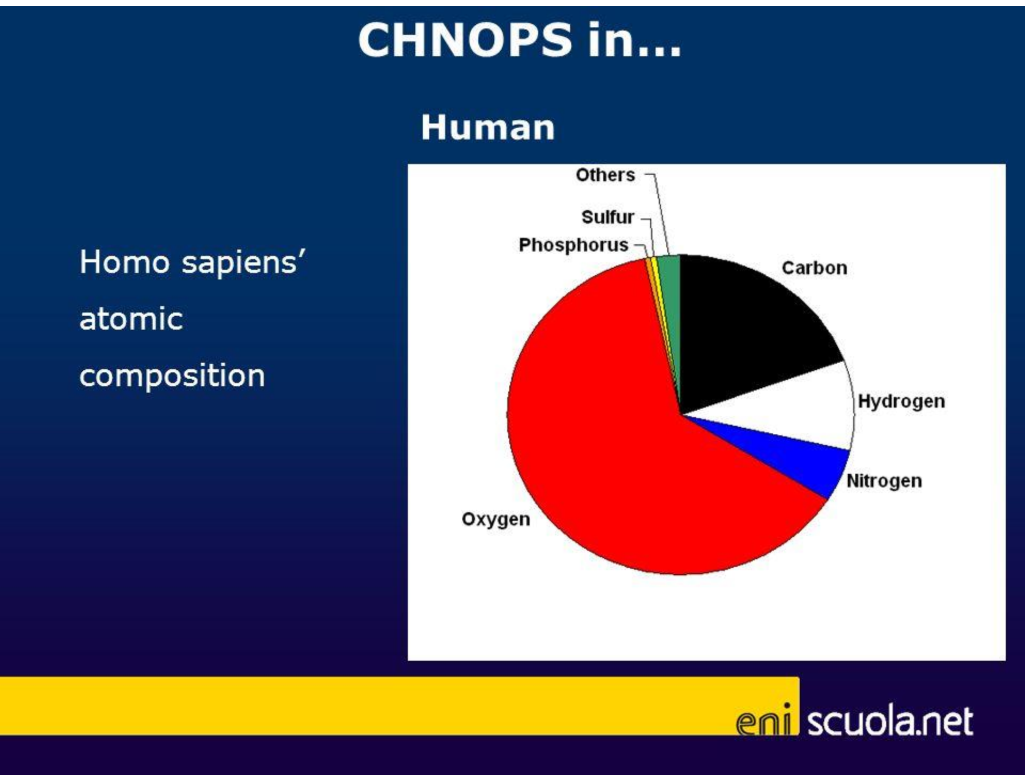
Six indispensable elements for human body

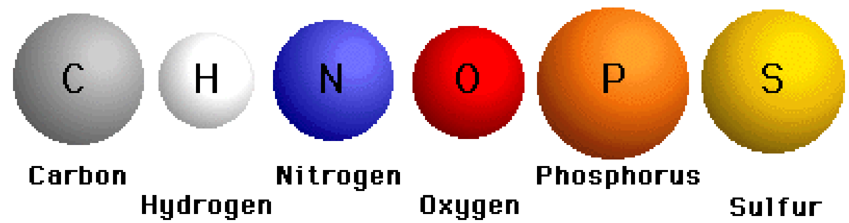




Six indispensable elements for human body

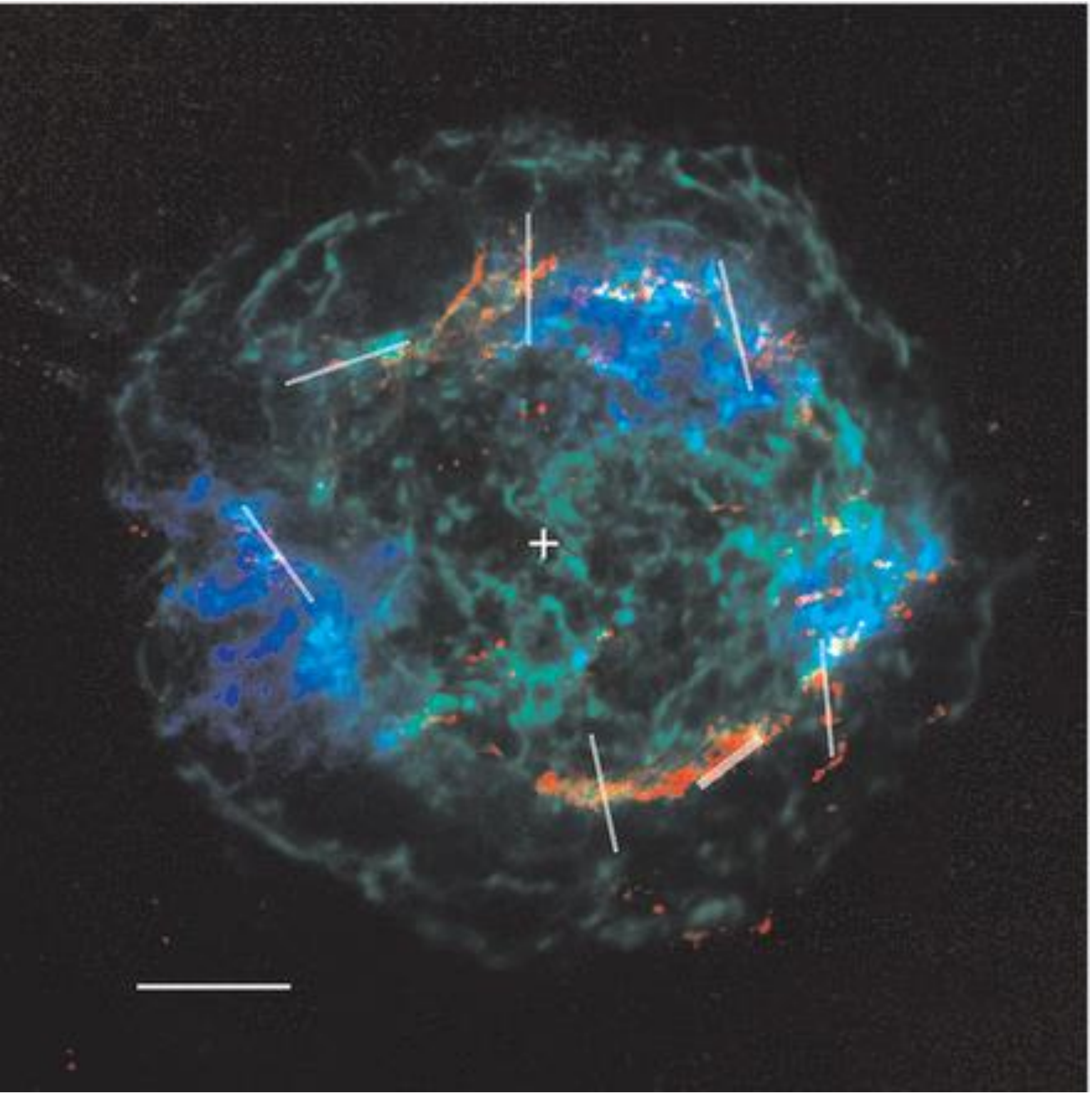






Production rate of P (Phosphorus) has not been measured in supernova explosions.

Triplespec Spectroscopy of Cassiopeia A



P, S, O, He, Fe, H .... have transitions in J band around 1 micron

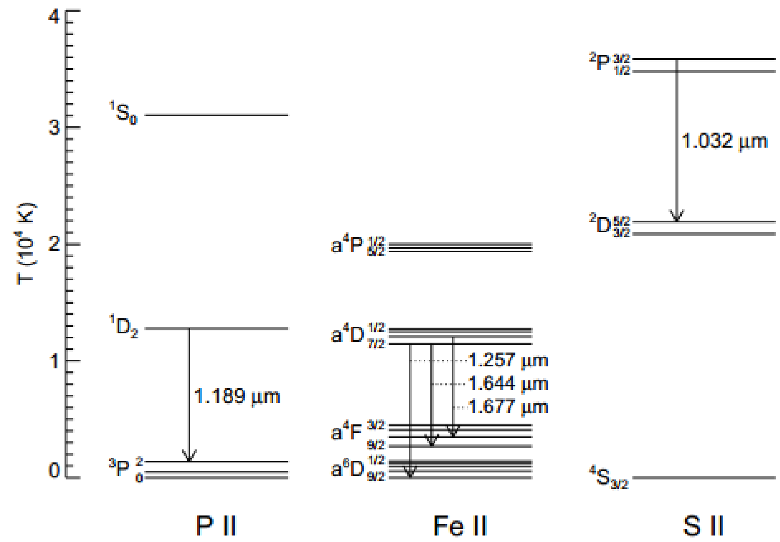
6 slit positions along its [Fe II] shell

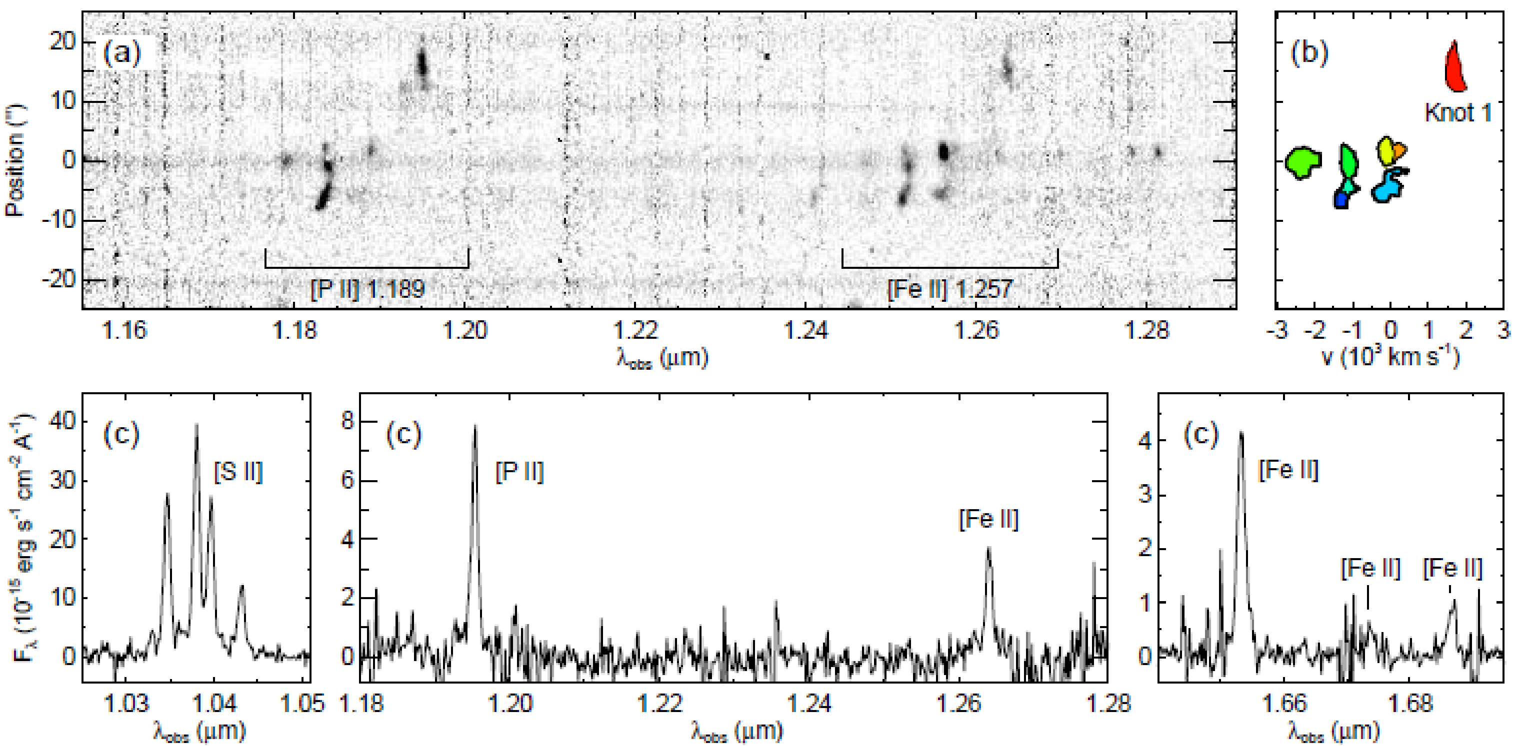
(≈ 30 minute exposure time in total)

Cassiopeia A (~330 yrs old, Type IIb core-collapse supernova)

"Detection of Phosphorus"

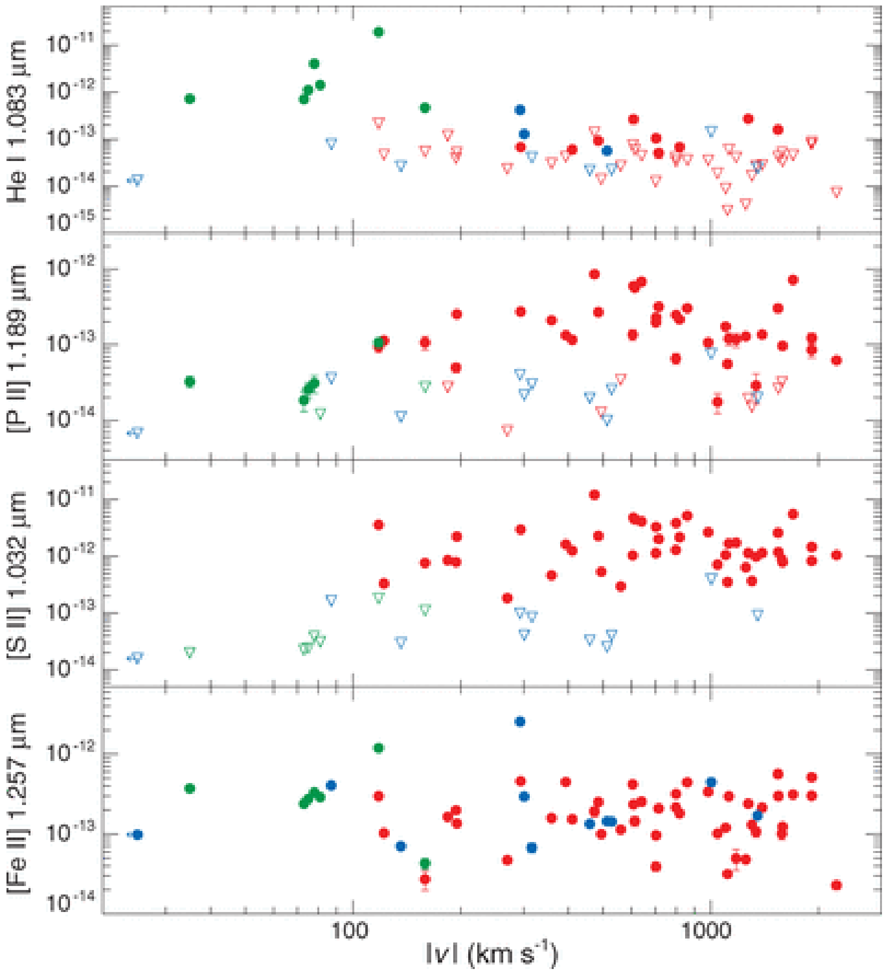
P (Phosphorus): neutron capture on Si in hydrostatic Ne-burning shells in the pre-SN stage and also in explosive C and Ne burning layers.

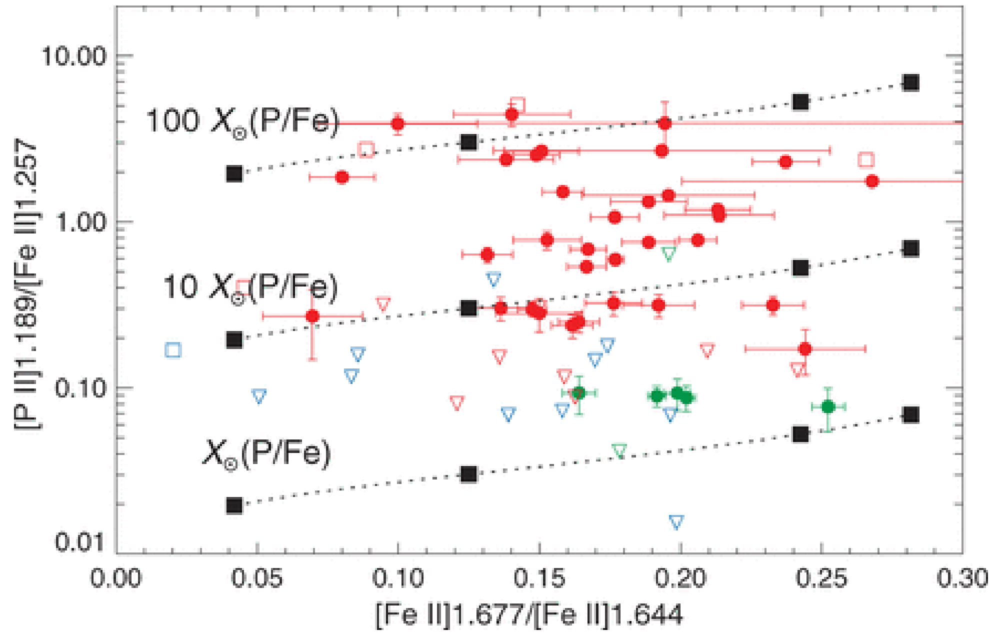




(Koo, Lee, Moon et al. 2013, Science)

“Detection of Phosphorus”





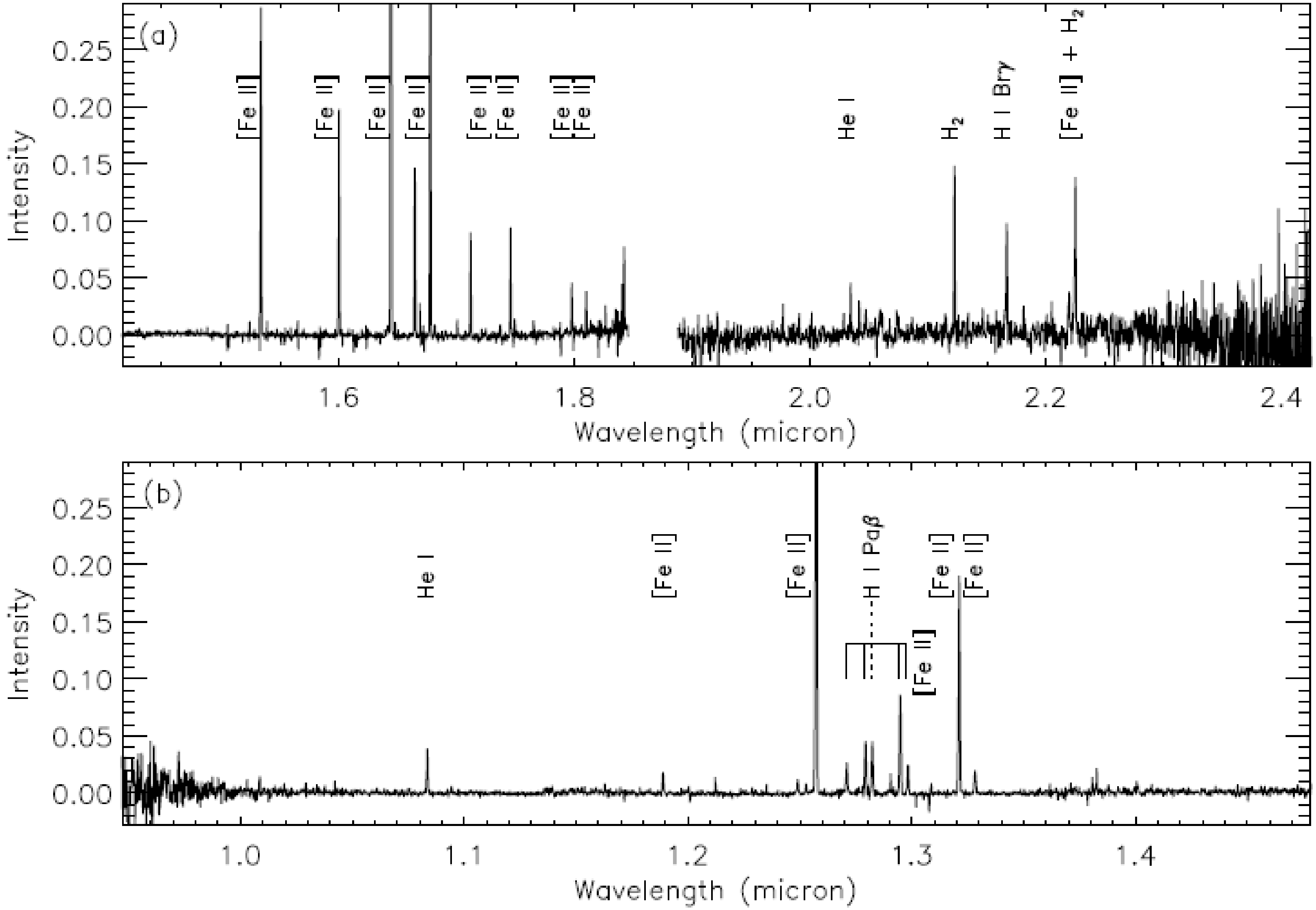
P/Fe abundance ratio is 10–100 times higher than the cosmic value

→ In situ production of P in SNe.

Good correlation between high-velocity S and P.

$$\frac{F_{[\mathrm{PII}]1.189}}{F_{[\mathrm{FeII}]1.257}} = 2.87 \frac{f_{^1\mathrm{D}_2,\mathrm{PII}}}{f_{\mathrm{a}^4\mathrm{D}_{7/2},\mathrm{FeII}}} \frac{f_{\mathrm{PII}}}{f_{\mathrm{FeII}}} X(\mathrm{P/Fe}),$$

Triplespec Spectrum of Young Core-collapse Supernova Remnant



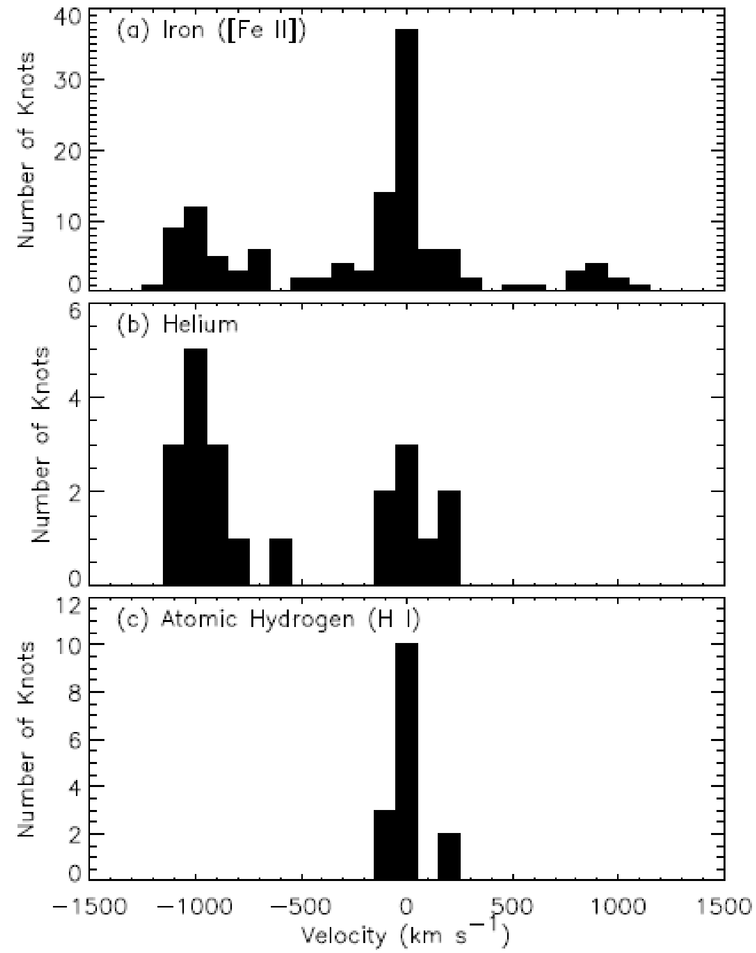
Only Fe, He and H, nothing else (Moon et al. 2017)

Triplespec Spectrum of Young Core-collapse Supernova Remnant: Highly Blue-shifted Ejecta of Fe & He

Si burning in explosive supernova nucleosynthesis

$^{28}Si + ^{4}He \leftrightarrow ^{32}S + \gamma$;
$^{32}S + ^{4}He \leftrightarrow ^{36}Ar + \gamma$;
$^{36}Ar + ^{4}He \leftrightarrow ^{40}Ca + \gamma$;
$^{40}Ca + ^{4}He \leftrightarrow ^{44}Ti + \gamma$;
$^{44}Ti + ^{4}He \leftrightarrow ^{48}Cr + \gamma$;
$^{48}Cr + ^{4}He \leftrightarrow ^{52}Fe + \gamma$;
$^{52}Fe + ^{4}He \leftrightarrow ^{56}Ni + \gamma$;
$^{56}Ni + ^{4}He \leftrightarrow ^{60}Zn + \gamma$

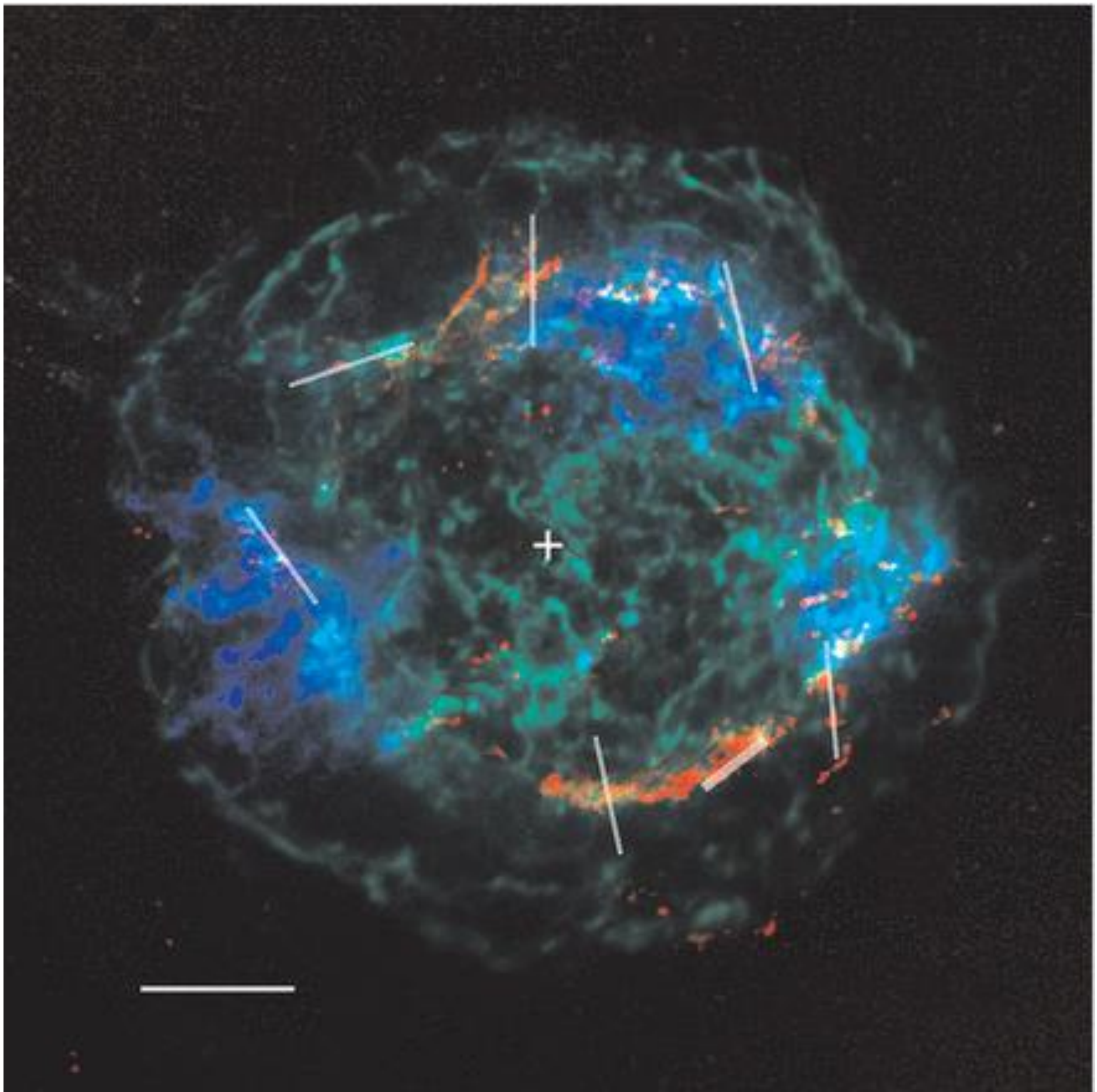
Mediated by α particles



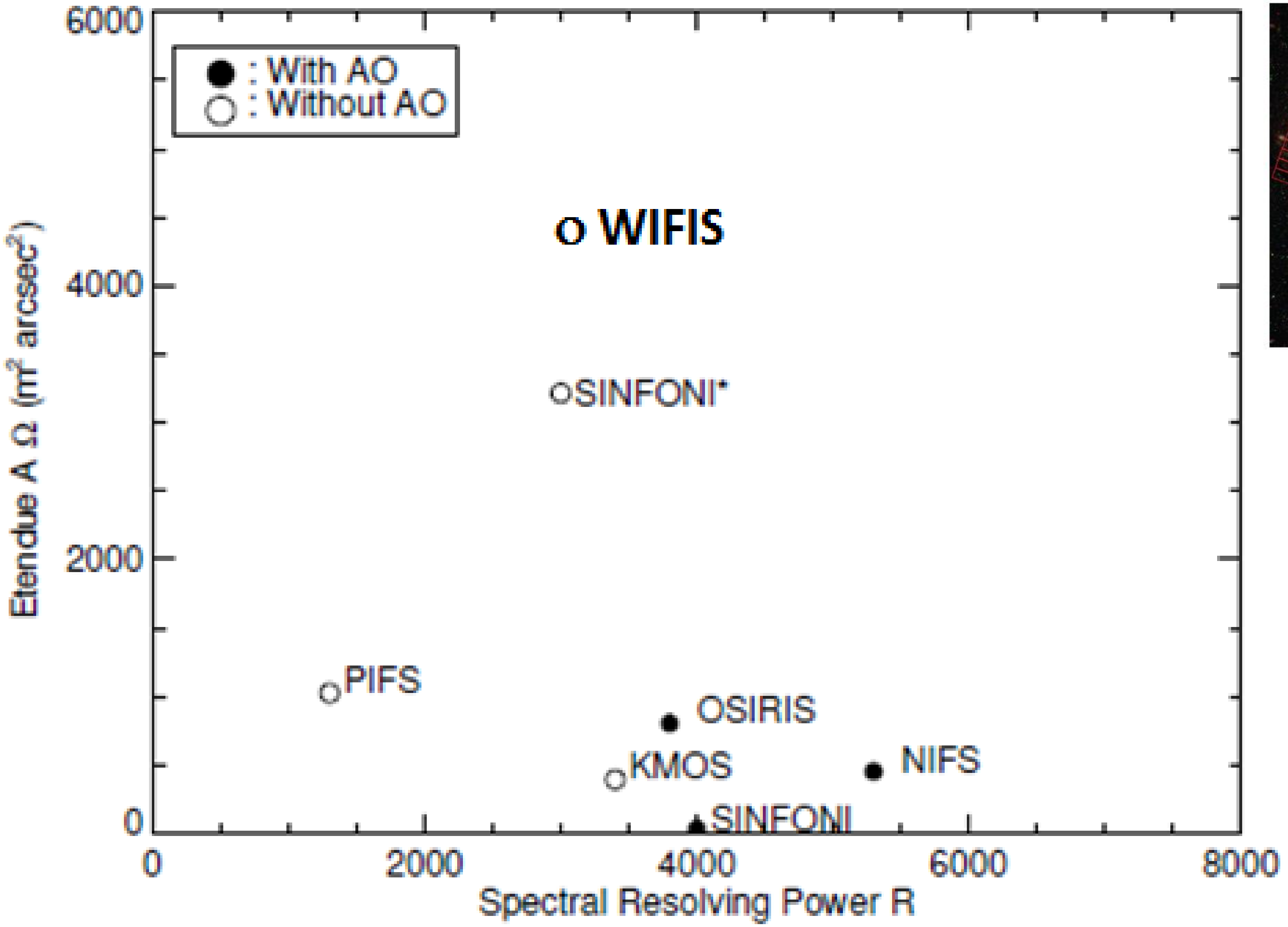
"α-rich freezeout": Incomplete Si burning gives "freezeout" leftover α particles.

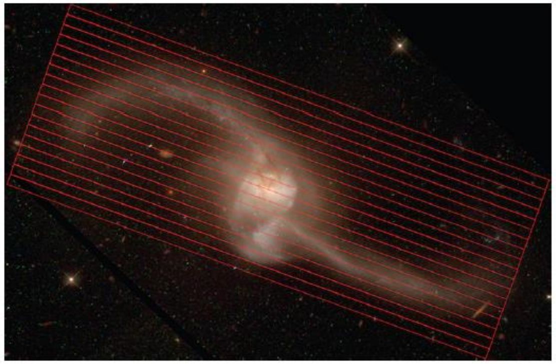
(Moon et al. 2017)

We need an integral-field near-infrared spectrometer with a large FoV for spectral mapping of extended objects.



Development & Commissioning of
Wide Integral Field Infrared Spectrograph (WIFIS)





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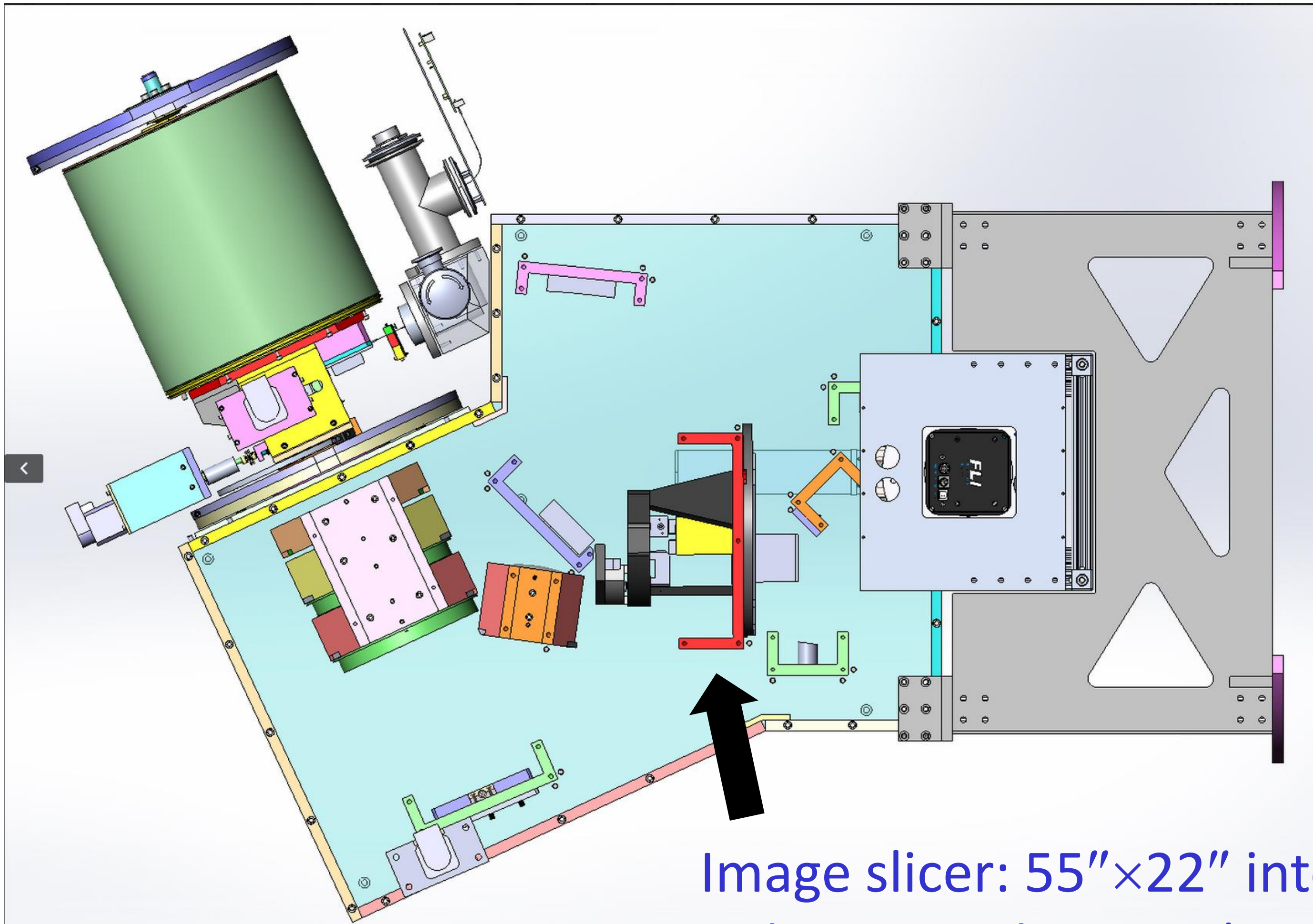
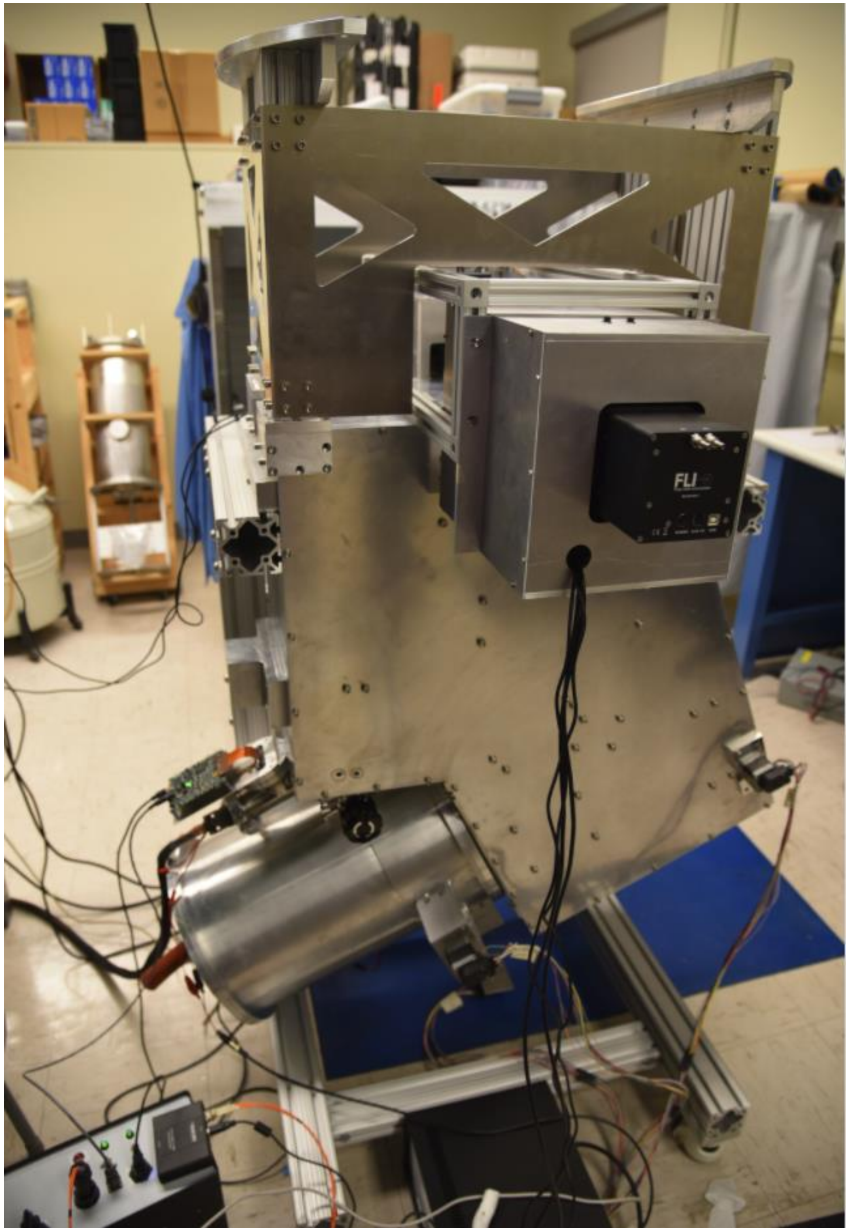


Image slicer: 55″×22″ integral field on
Bok 2.3-m telescope (or 12″×5″ on GTC)



WIFIS at U.Toronto Lab

WIFIS Commissioned (2017 May)

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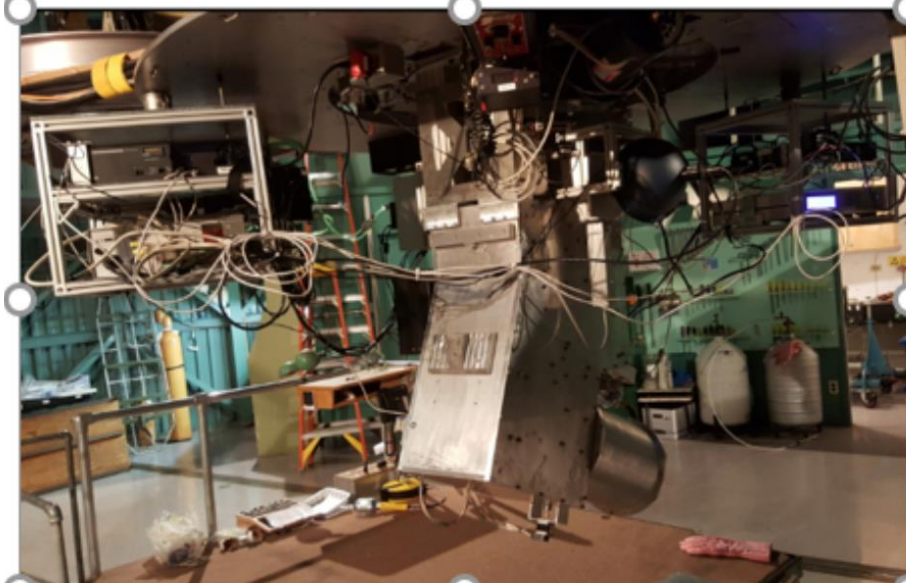
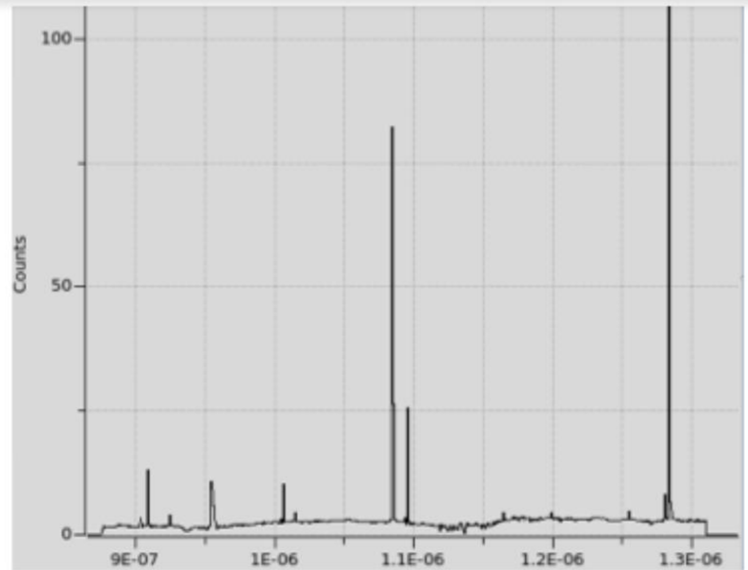
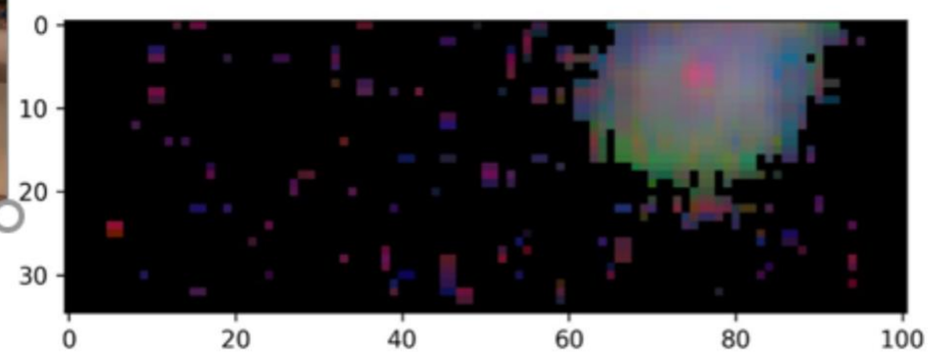
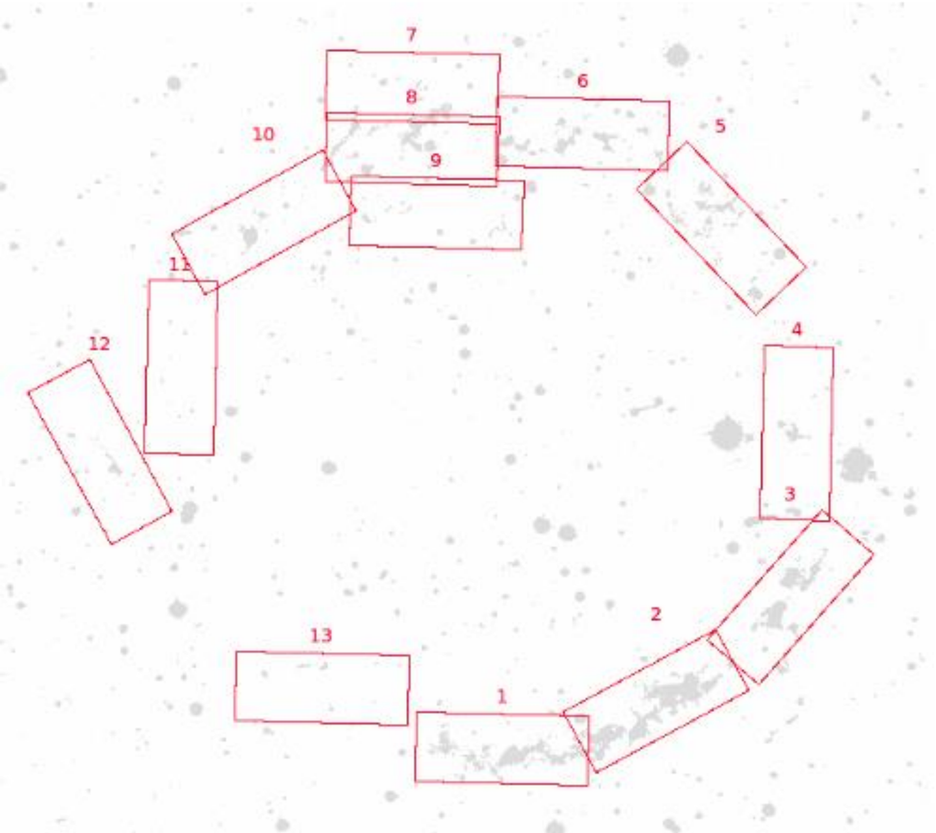


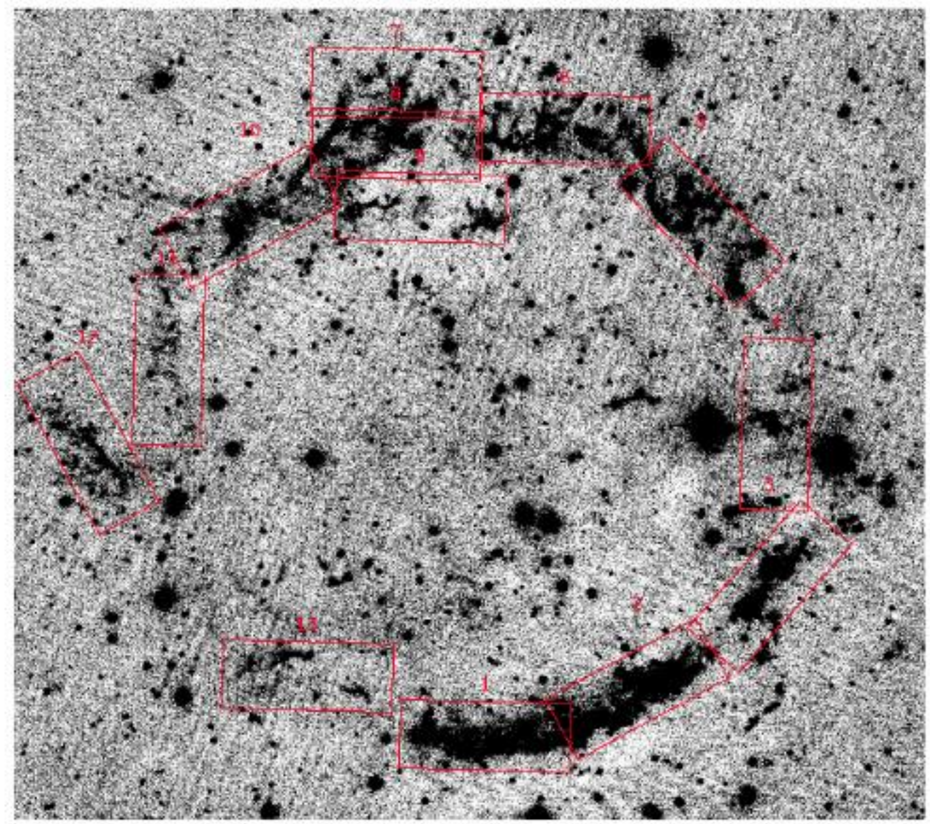




WIFIS commissioning sample data of a planetary nebula.

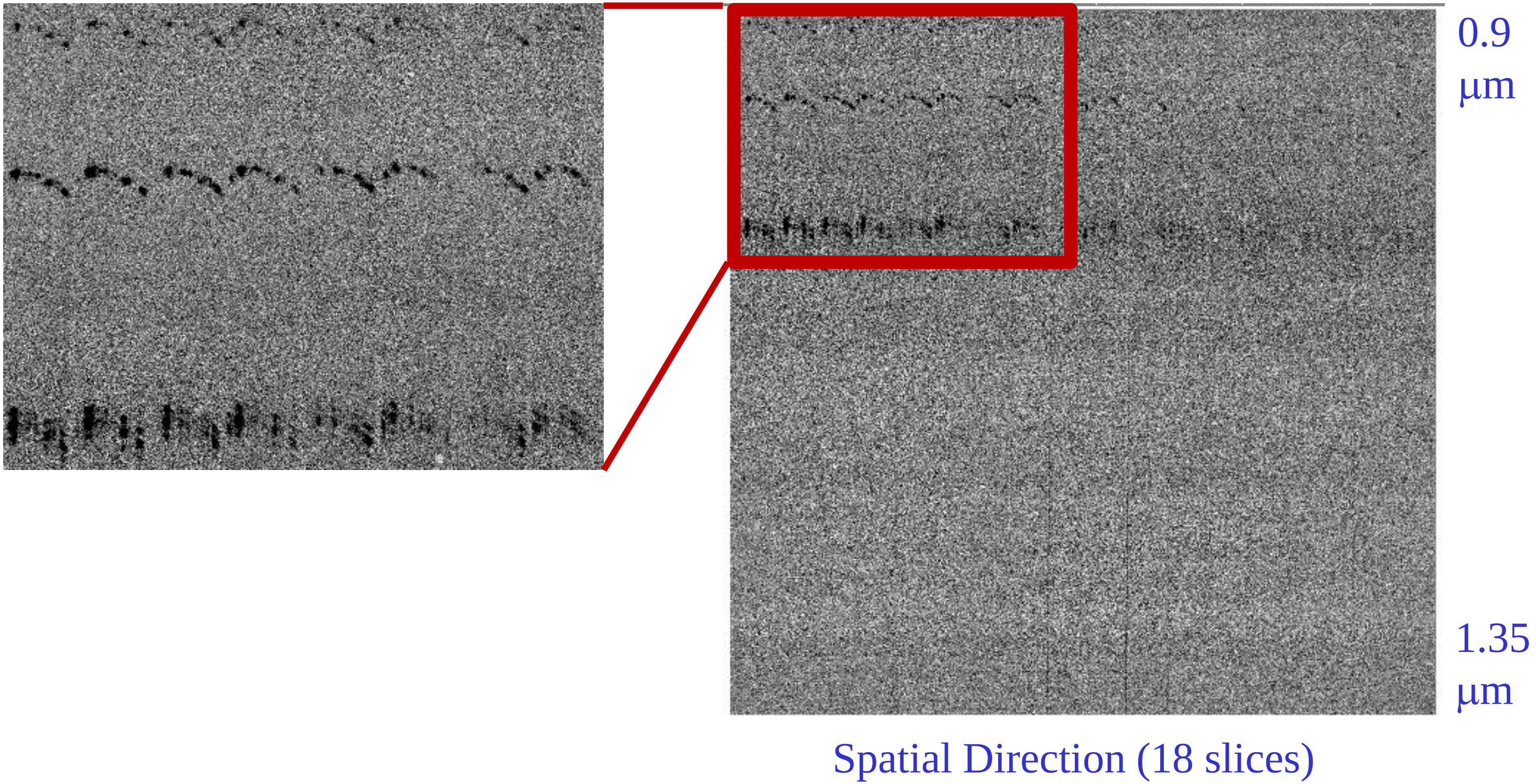
WIFIS Near-Infrared Spectral Mapping of the Entire Shell of Cassiopeia A





Completed in 2017 June with 13 WIFIS pointings and data are being analyzed.

Sky-subtracted Sample Raw Data of WIFIS Cassiopeia A Observations



Broadband and Wide Integral Field Infrared Spectroscopy (especially zJ band) is an excellent tool for studying nucleosynthesis of core-collapse supernovae.

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More importantly, it's great to see you all here!