Astrophysics v. Airships

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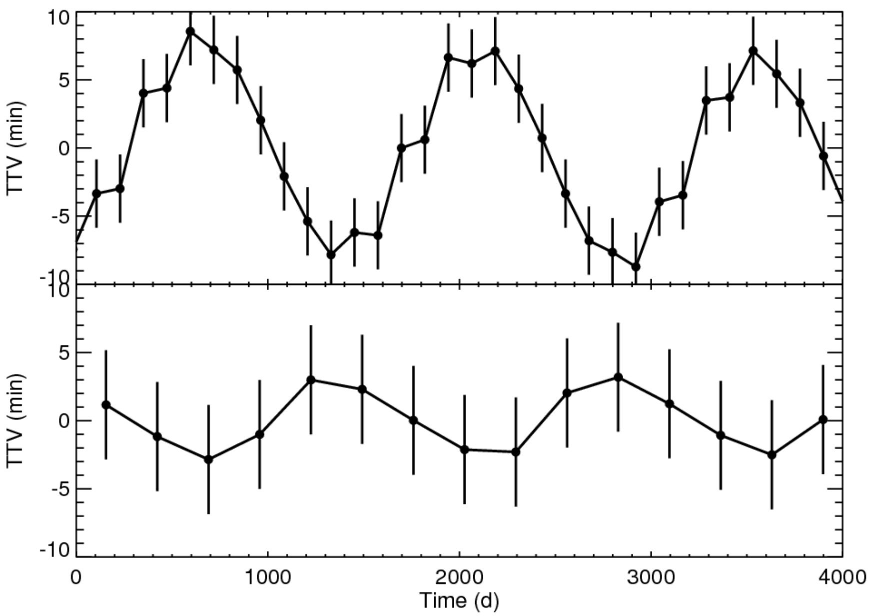
Ground rules

- Confine discussion to ~0.3-to-5um
- No attempt or pretense to be comprehensive
- Some science examples from my own experience

Exoplanets I – Transit Timing

- Kepler suggests that many exoplanets are in multiple systems – frequently transits of several planets are seen
- The gravitational interactions between the planets lead to systematic variations in the occurrence of transits
- This is the best way of determining planetary masses if the parent star is too faint for RV confirmation

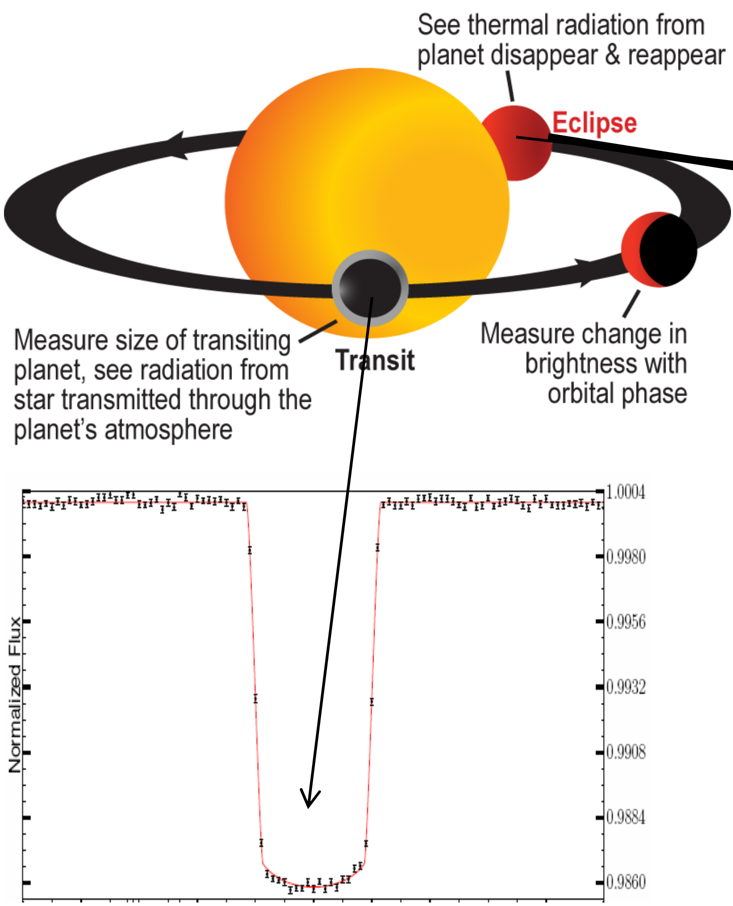


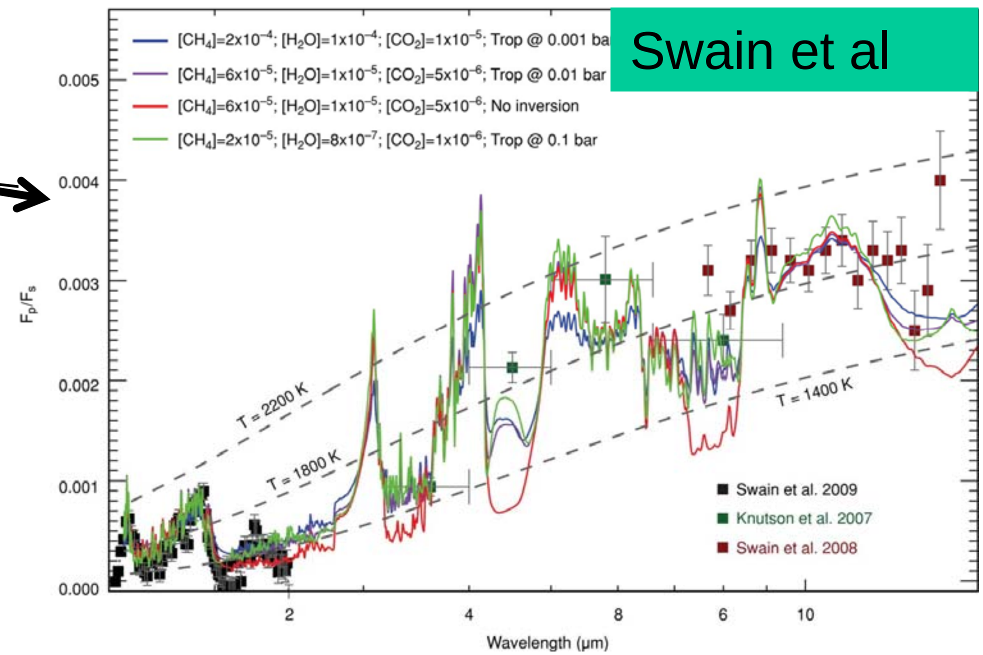
Simulation by Eric Agol of timing variations in transits for Kepler 62e and 62f, recently announced planets in the habitable zone of a low mass solar type star, using 2.4m telescope. 5 earth masses is the assumed mass of each.

Spitzer Space Telescope

Exoplanets II – Diagnostic Spectroscopy

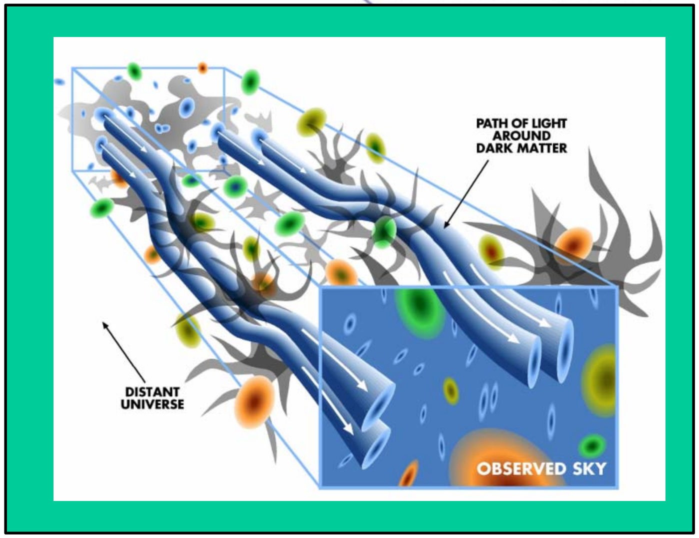
- Spectroscopic studies of transiting exoplanets – in emission and absorption – probe the composition, structure, and dynamics of their atmospheres by studying water, CO, CO_2, CH_4, etc.





Need 1->3um [prefer >5um], ~1m class telescope, good pointing, high precision

Weak Lensing [WL]



•WL is a subtle distortion of the shapes of galaxies due to intervening dark [+luminous] matter along the line of sight
• It is an important cosmological probe of dark matter, dark energy, galaxy clusters, and the growth of structure
• Major missions – Euclid and WFIRST – devoted to WL will launch in 2020+
• Ground based projects – LSST and HyperSuprimeCam – are studying WL
• Study organizer Jason Rhodes is leading WL expert

- An ABT could have an important niche in WL studies, particularly if launched before Euclid, or, at least, WFIRST, e.g. by going deeper in limited areas or around particularly interesting clusters than did Euclid.
- This would require a wide field of view in addition to excellent, stable images and moderate aperture

Spitzer Space Telescope

Debris Disk Imaging

• Planetary debris disks – analogous to the zodiacal and Kuiper dust clouds in the Solar System – are found around many solar-type stars via infrared photometry

• *Their lifetimes are short compared with the stellar lifetimes; comets, asteroids, etc. must be present and active to refill the circumstellar environment*

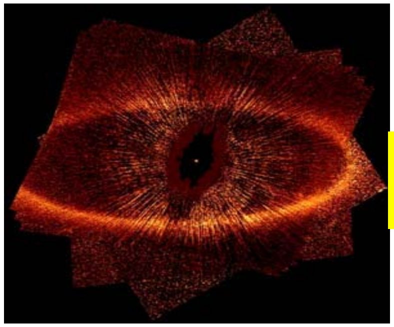
• They are markers of planetary system formation and evolution

• *Scattered light imaging will reveal their structures – perhaps influenced by co-orbiting planets – and similarities to the Solar System*.

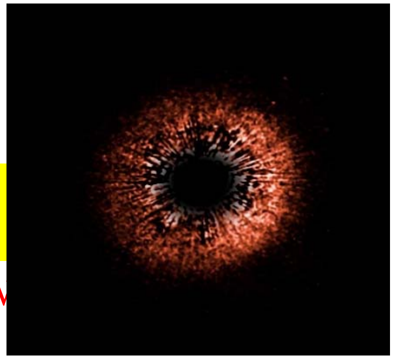
• This imaging requires coronagraphic instrumentation to cancel the light from the parent star.

• This places constraints on the image quality and stability of the system

• Objective is contrast $<10^{-7}$ at visible wavelengths



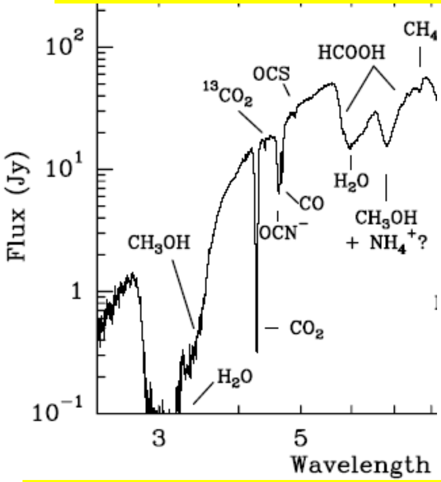
HST scattered light images of debris disks



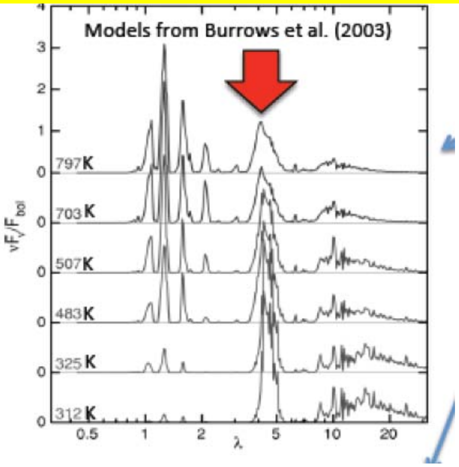
MW

1-5um Spectroscopy – Stellar, Circumstellar, and Interstellar

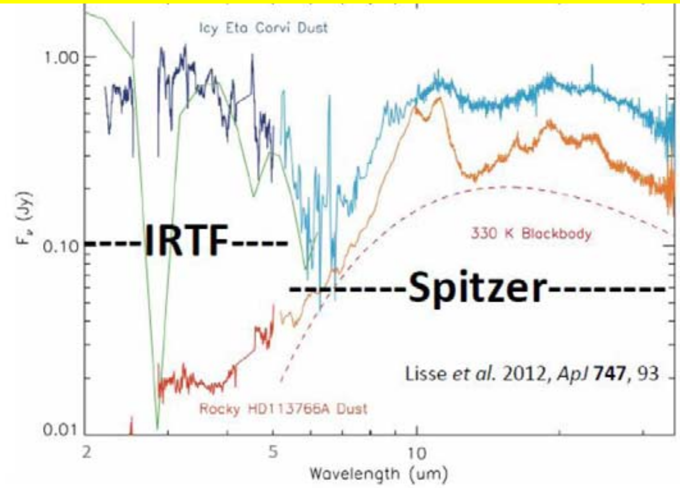
Circumstellar Ices



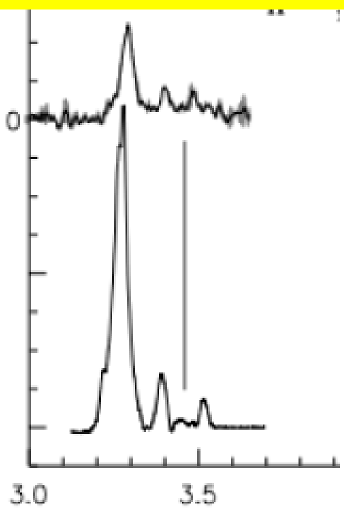
Brown Dwarfs



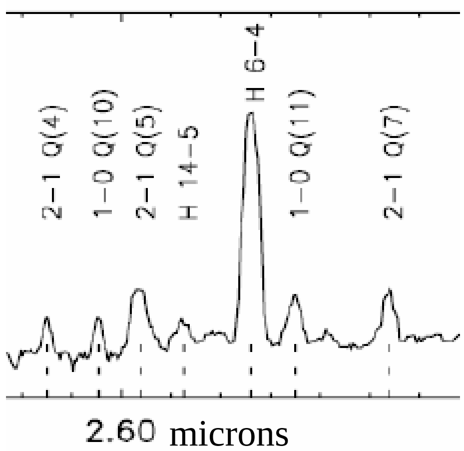
Warm Debris Disk



Interstellar Hydrocarbons



Gas Phase Emission Lines



- •1-5um region very rich in spectral features and diagnostics.
- •Spitzer had no spectroscopic capability below 5um
- • A modest telescope in survey or pointed mode could do great stuff, "site survey" permitting
- •Extend to ~10um if detector technology permits

Capabilities Summary*

Science Case	Wavelength	Aperture	End/End Pointing	Comments
Transit Timing	Vis or NIR	2m+ [for Kepler field]	~few arcsec	Timing to less than one minute; long time baseline
Exoplanet Spectroscopy	1->3um ->5um better	1m+	Subarcsec to keep source on slit	Precision better than 1 part per thousand . Timing to minutes. Cool detector.
Debris Disk Coronagraphy	Visible	1 m class telescope & coronagraph	<0.05 arcsec stability	Angular resolution better than 0.5" Contrast 3x10^{-8} or better. ~2-m class, higher contrast for exoplanets
Weak Lensing	Visible	2-m class	Image close to diffraction limit and stable to <0.05 arcsec. ~1 degree FOV.	
1-5um Spectroscopy	1-5um	>0.5 m	Few arcsec	Match pixel size to desired resolving power, etc. Scan or survey capability desired

* There is much to be done. Of these science cases, only weak lensing is specifically addressed by a dedicated mission at present, although all would merit one -

Other Considerations

- Things omitted;
  - *Interferometry – have to compete with LBTI, two 8.4 m telescopes with ~22m greatest spacing*
  - *Astrometry – have to compete with GAIA*
  - *Wavelengths >5um – may depend on detector/cooler technology. Have to compete with JWST/SOFIA*
  - *Purposeful large area surveys – might supplement Euclid/WFIRST*
  - *Transient observatory*
- Suggestions for future work
  - *Consider Arecibo/HET type geometry with fixed primary and moveable feed containing instruments*
  - *Badly need a site survey for the infrared…what is sky background, likely telescope temperature without active cooling, and the like. This will determine competitiveness with ground facilities. Might a 2m ABT equal an 8.4m in sensitivity at ~4um, say? How close to space are we?*
  - *Need to match detector and instrument temperature needs to actual sky background as well as spatial, spectral resolution*

Impact of Thermal Background

- An important question for the sky survey will be the instrumental background in the infrared.
- Spitzer, a cold telescope with 85 cm aperture in space is ~ 50 (300) x more sensitive than 8m Gemini on the ground at 3.6 (4.5) um.
- Compared to our airship:

$(S/N)_{AS} = (1/50) \times (D_{AS}/8)^2 \times (SkyBR_{GR}/SkyBR_{AS})^{0.5} \times (S/N)_{SPITZ}$

- Therefore, the airship will not be competitive in raw sensitivity with Spitzer – or with a similar small, perhaps radiatively cooled, telescope, unless the sky brightness is more than ten thousand times lower than on the ground.

Compared to the ground,

$(S/N)_{AS} = (D_{AS}/8)^2 \times (SkyBR_{GR}/SkyBR_{AS})^{0.5} \times (S/N)_{GEM}$

- Here, a reasonable sized telescope could achieve comparable sensitivity to the ground if the brightness reduction is merely a factor of 100.
- Note that the sensitivity achieved by the WISE survey is about equal to that achievable in ~ 1 hr by Gemini
- Conclusion: It appears that the comparative advantage of the airship telescope in the thermal IR does not lie in its ability to do surveys

Conclusions

- Numerous optical/infrared projects in the balloon/small Explorer class might be usefully implemented on an airship.
- Telescope apertures >1m and wavelengths out to 5um provide the most attractive range of options. Pointing performance and image quality will be drivers for many – but not all - applications.
- A “sky-survey” of background and thermal considerations for infrared payloads would be very helpful
- A [scientifically] targeted mission seems [to me, at least] a more sensible option than a general purpose observatory
- If the price is right, a fleet of airship-based observatories could be an interesting alternative to suborbital or even SMEX missions within the NASA portfolio