Venus features at 300 to 3000 nm wavelength

A systematic survey of known spectral »windows« in which Venus is *more*

than a clean white disk with phase and absolute darkness beyond the terminator and which are in the NUV to NIR range and thus accessible - in principle - from the ground, as a motivation for observation attempts by amateurs during the mission of Venus Express

wavelength (nm)	day- or nightside?	from where?	processes involved?	references
350-370	day	cloud deck	reflected sunlight, locally absorbed -> high contrast	Ross 1928; Scott & Reese 1972; Caldwell 1972; Murray & al. 1974; Travis & al. 1979
400-650 (several lines, esp. between 450 und 560)	night	upper atmosphere	Herzberg II O_2 airglow	Lawrence & al. 1977; Slanger & Black 1978; Bougher & Borucki 1994
TBD (range of the human eye)	night; sporadic; controversial	probably upper atmosphere	TBD (»Ashen Light«)	Phillips & Russell 1988; Phillips & Russell 1992; Cruikshank 1992; Fischer 2001b
418	day	upper clouds	sunlight reflected at 60 to 70 km, locally absorbed	Belton & al. 1991
558	night	upper atmosphere	emission from atomic oxygen	Slanger & al. 2001; Crisp 2001
850 + 900	night	surface	weak thermal emission	Baines & al. 2000
986	day	upper clouds	sunlight reflected at 60 to 70 km, locally absorbed	Belton & al. 1991
1010	night	surface	thermal emission	Carlson 1991; Lecacheux & al. 1993; Meadows & Crisp 1996; Baines & al. 2000; Pellier 2004; Shiga 2004
1100	night	surface	thermal emission, modulated by topography; low-contrast absorption by higher clouds	Crisp & al. 1991a; Meadows & Crisp 1996
1180	night	surface	thermal emission, modulated by the highest mountains; medium-contrast (up to factor 2) absorption by higher clouds	Crisp & al. 1991a; Carlson & al. 1991; Anon. 1991; Meadows & Crisp 1996
1269	night (airglow also: day)	upper atmosphere (95 km) *plus* very deep clouds	airglow from molecular oxygen, added to thermal emission from the deep, with low-contrast (factor 0.3) absorption by higher clouds	Connes & al. 1979; Allen 1987; Crisp & al. 1991a; Anon. 1991; Allen & al. 1992; Bougher & Borucki 1994; Crisp & al. 1996
1310	night	very deep clouds	thermal emission; low-contrast absorption by higher clouds	Crisp & al. 1991a
1740	night	deep clouds	thermal emission by clouds at roughly 25	Allen & Crawford 1984; Allen 1987;

			bar (17 km) with high-contrast (up to factor 5) absorption by higher clouds	Crisp & al. 1989; Crisp & al. 1991b; Carlson & al. 1991
2300 (esp. 2210 and 2320)	night	deep clouds	thermal emission by clouds at 8 bar (32 km) with high- contrast (factor 5 to 20) absorption by higher clouds	Allen & Crawford 1984; Allen 1987; Crisp & al. 1989; Bézard & al. 1990; Bell & al. 1991; Crisp & al. 1991b; Carlson & al. 1991

Summary (draft! to be extended)

Looked at through a telescope in visible light the planet Venus is a dazzling but totally bland white disk with the phase and some limb darkening the only effects detected reliably. Whether dark features on the disk seen by some visual observers are real at all is a matter of debate; CCD imaging - which has hugely advanced amateur studies of e.g. Mars and Jupiter in the past decades - does not verify these sightings conclusively yet.

Discoveries with large ground-based telescopes and spacecraft, however, have in the last decades revealed a much more interesting planet. There are *three* basic phenomena of Venus that cause contrast phenomena on either the day or night side which are accessible to ground-based telescopes, and some of these are - or may well be - accessible to amateur instruments as well:

- On the dayside at certain wavelenghts **structure in the upper cloud deck** can be imaged, both in the Near UV and Near IR, as demonstrated by several NASA spacecraft, the HST and esp. the camera of the Galileo spacecraft during the 1990 swingby (Belton & al. 1991); amateurs are monitoring Venus' clouds in the UV without great problems and have captured the (difficult) cloud detail at the Galileo NIR wavelength as well.
- On the nightside **airglow emission** from both molecular oxygen at 550-555 nm and other visible wavelenghths (Slanger & Black 1978) as well as 1.27 µm (Allen & al. 1992) and from atomic oxygen at 558 nm (Slanger & al. 2001) has been detected. Whether the - still controversial - »Ashen Light« often claimed to be detected by amateurs (Cruikshank 1992; Phillips & Russell 1992; Fischer 2001b) is a related phenomenon is TBD.
- In nine narrow windows in the NIR between 850 nm and 2.32 µm **thermal emission from deep clouds** and even the surface is evident (Allen 1987; Crisp & al. 1991a; Baines & al. 2000), with higher clouds visible in absorption: the longer the wavelength the higher the emitting region of the atmosphere and the higher the cloud contrast.

Amateur astronomers with CCDs could try - and have sometimes already succeeded - to detect and track the cloud streaks on the dayside with suitable filters and high-pass spatial filtering. And they could go for the shortest-wavelength window in which thermal emission escapes - as has been done soon after its discovery with a 1-m telescope (Lecacheux & al. 1993) and recently even with a much small amateur instrument and a regular CCD camera (Pellier 2004).

Thus the worldwide amateur community - with 21st-century instrumentation - could well support and extend (at least in the time and perhaps also the spectral but surely not the spatial domain) the work of the VMC and VIRTIS instruments on Venus Express, and a joint observing campaign should be worthwile! In particular it would be helpful if the active periods of these instruments would be publicly known, as a motivation for observing runs - and if the VEX community would share some of its data readily with advanced amateur astronomers who would do so vice versa.

References

Allen & Crawford 1984: Cloud structure on the dark side of Venus, *Nature* **307** [1984 Jan. 19] 222-4 - discovery paper of the NIR emission windows.

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Allen & al. 1992: Variable oxygen airglow on Venus as a probe of atmospheric dynamics, *Nature* **359** [1992 Oct. 8] 516-9 (with a summary on p. 481) - emission over the nightside at 1.27 µm.

Anon. 1991: The dark side of Venus at three wavelengths, *AAO Newsletter* # 59 [1991 Oct.] 1 - images at 2.3 and 1.18 µm and in the light of the O_2 airglow.

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Bougher & Borucki 1994: Venus O_2 visible and IR nightglow, *JGR* **99** [1994] 3759-76 - thermosphere dynamics & chemistry derived from the Herzberg and 1.27 µm lines.

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Carlson & al. 1991, Galileo Infrared Imaging Spectroscopy Measurements at Venus, *Science* **253** [1991 Sep. 27] 1541-8 - provides a telling NIMS spectrum and quantitative contrast data for the various NIR windows.

Connes & al. 1979: O_2 Emission in the Day and Night Airglow of Venus, *Astrophys. J.* **233** [1979 Oct. 1] L29-32 - at 1.27 µm it's 1000 times stronger than the visible one.

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Fischer 2001a: Gibt es das »Aschgraue Licht« wirklich? *Skyweek* **17** # 3 [2001 Jan. 25] 2-3 - German; reviews the key literature on the Ashen Light phenomenon.

Fischer 2001b: Venus & das Ashen Light: Was Experten sagen, *Skyweek* **17** # 5 [2001 Feb. 20] 6-7 - German; collected assessments of the nature of the Ashen Light from Slanger, Russell, Crisp and Cruikshank.

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Pellier 2004: Thermal Emission on the Venusian Nightside, www.astrosurf.org/pellier/venusthermal - website with his own observations from May 2004; more details on the ALPO Japan site of 2004 May 19, 18, 17, 16 and 12.

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Russell & Phillips 1990, The Ashen Light, *Adv. Space Res.* **10** # 5 [1990] 137-41 - the Ashen Light campaign of 1988 and the leading explanations before it.

Scott & Reese 1972: Venus: Atmosphere Rotation, *Icarus* **17** [1972] 589-601 - image sequences at 370 nm.

Shiga 2004: Amateur Images Venus' Surface, skyandtelescope.com/news/article_1266_1.asp (2004 June 2) - describes Pellier's breakthrough in imaging the night side in the 1 µm window on May 12, 2004

Slanger & Black 1978: The O_2 Bands in the Nightglow Spectrum of Venus, *Geophys. Res. Lett.* **5** [1978] 947-8 - nightglow from 400 to 700 nm, as discovered by Venera 9 and 10.

Slanger & al. 2001: Discovery of the Atomic Oxygen Green Line in the Venus Night Airglow, *Science* **291** [2001 Jan. 19] 463-5 - green line emission at 558 nm.

Travis & al. 1979: Orbiter Cloud Photopolarimeter Investigation, *Science* **203** [1979 Feb. 23] 781-5 - PVO observations at 365 nm.

Other relevant websites

VAOP, ESA's Venus Amateur Observing Project (related BAA announcement)!

Venus Watch by Hans G Lindberg

Lots of amateur pictures of Venus (ALPO Japan collection)

Amateur pictures of Venus since 2001 (ALPO collection)

Galileo's images of Venus from the 1990 flyby (alt. collection)

Mariner 10 images of Venus (and more)

VIRTIS on Venus Express (DLR page on the instrument)

Die Augen des Venus Express (German; Interview with U. Keller on the VMC)

Venus Express' instruments (short descriptions and links to homepages)

Venus Science Planning (PDF)

Europa erkundet den Nachbarplaneten der Erde (German; DLR Press Release on Venus Express, describing among others VMC and VIRTIS)

Venus in K band with the NOT

BAA Venus section's, J. Sussenbach's (!), M. Weigand's J. Warell's and D. Niechoy's Venus and homepages

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